

IRONWORKS AND IRON MONUMENTS FORGES ET MONUMENTS EN FER





IRONWORKS AND IRON MONUMENTS study, conservation and adaptive use

étude, conservation et réutilisation de FORGES ET MONUMENTS EN FER

> Symposium Ironbridge, 23–25 • X •1984



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INTRODUCTION

The symposium, "Ironworks and Iron Monuments: Study, Conservation and Adaptive Use", was held at the Institute of Industrial Archaeology in Coalbrookdale (Shropshire, England) on 23-25 October 1984.

The meeting was organized by ICCROM in collaboration with the Ironbridge Gorge Museum Trust and with the co-sponsorship of TICCIH (The International Committee for the Conservation of the Industrial Heritage).

Until recently, ICCROM's interest in the preservation of the industrial heritage could not materialize into promotion of actual programmes because of limited resources in funds and staff. Only in 1980 did the availability of a few E.E.C. research fellowships allow implementation of a field research programme (study and preservation of two blast furnaces in Central Italy), which permitted us to establish a first contact with problems existing in this comparatively new domain of conservation of cultural property.

In particular it soon became apparent that, in this field, there is a relative scarcity of information on conservation techniques and conservation ethics; several ideas that are familiar to the community of specialists devoted to the conservation of more traditional types of cultural property (art, architecture, etc.), are not at all evident to those who study the preservation of industrial heritage, and it is not clear whether they can be transplanted into the new field without modification, in view of some objective differences (size of buildings, necessity of adaptive use to ensure preservation and justify costs, significance of the monument to the public, etc.) at both the conceptual and practical level.

It must be considered, for instance, that an important role in the drive for the preservation of the industrial heritage was played (and still is played) by the historian's interest in reconstructing the technology of the past and the public's desire to see it in action. Whereas such attitudes have a deep influence on industrial conservation, they have a marginal one in the conservation of art and architecture.

The ICCROM research group therefore reached the conclusion that the implementation of some programme allowing an exchange of ideas between "conservationists" and "industrial archaeologists" (each category actually having a multidisciplinary composition: historians, archaeologists, architects, chemists, engineers, etc.) would be very much in keeping with the statutory aims of the organization.

As the ICCROM competence was, for the moment, limited to ironworks, this topic was chosen for a symposium, but it was also decided to enlarge its scope and include the structures and monuments that were built with the metal the ironworks

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produced, following in this the example set by the main activities of the Ironbridge Gorge Museum.

The second section of the programme was meant to stimulate greater interest among architects and engineers and to yield more information on actual conservation projects.

The idea of the symposium was gradually refined and brought to the planning stage through a series of informal discussions with Neil Cossons (Director of the Ironbridge Gorge Museum at the time), Barrie Trinder (Deputy Director at Ironbridge) and David Crossley (of Sheffield University) when they came to Italy to help the ICCROM research team set up a plan of studies of the local ironworks. (This plan, incidentally, should be implemented starting in 1985 and constitute the second phase of ICCROM's involvement in the conservation of industrial heritage.)

As TICCIH also provided guidance in identifying possible speakers and participants for the meeting, ICCROM could not have enjoyed better support for finding access to a new domain.

Notwithstanding these favourable conditions, the outcome of the project only in part corresponds to the aspirations of the organizers, but this is rather logical for a first attempt.

In a majority of the written reports, the industrial heritage is considered mainly under the viewpoint of technological history, while the actual problems of conservation of the buildings themselves were less represented; this is also due to the fact that several of the conservation/rehabilitation cases discussed are still at the study level and have not yet reached the stage of design and execution.

Further action to improve contacts and increase attention to the actual conservation problems appears therefore to be required; this might take the form of interdisciplinary work on a conservation project or of another meeting dedicated to the discussion of several conservation/adaptive-use programmes.

In particular, the problem of conservation ethics (i.e. the allowable extent and modes of restoration and reconstruction, compatibility of modern use with the integrity of the monument, etc.), which is seldom faced from the standpoint of the instrinsic historic or aesthetic value of the object itself (which is, instead, the typical angle of the "conservationist" approach), should be more strongly emphasised in the future.

Fortunately, at the Coalbrookdale meeting some of these shortcomings were offset by the visits planned by Barrie Trinder, as well as the evidence provided at all levels by the Ironbridge Gorge Museum itself, with its brilliant examples of accurate archaeological investigation and rigorous presentation and protection of the uncovered ruins (e.g. the Coalbrookdale and the Blists Hill furnaces) and of faithful conservation of monumental structures (the Iron Bridge), near which some reconstructions of the techniques are made available to the public on a reduced scale (museum) or even at full size (the new wrought iron plant). These provided an extremely good basis for informal discussion and confrontation of the attitudes of the specialists from various branches.

Unfortunately, such discussions did not find their way into the published proceedings of the meeting, because a strenuous schedule of presentations and visits fully occupied all the official time available in the three days.

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INTRODUCTION

Le Symposium "Forges et monuments en fer; étude, conservation et réutilisation" s'est déroulé à l'Institut d'Archéologie Industrielle à Coalbrookdale (Shropshire, Angleterre) les 23, 24, et 25 octobre 1984.

La réunion a été organisée par l'ICCROM en collaboration avec l'Ironbridge Gorge Museum Trust et sous le patronage du TICCIH (le Comité International pour la Conservation du Patrimoine Industriel).

L'intérêt de l'ICCROM pour la préservation du patrimoine industriel n'a pu se concrétiser que très récemment en raison de l'insuffisance des moyens financiers et du personnel.

En 1980, seulement, la disponibilité de quelques bourses d'étude octroyées par la C.E.E. a permis d'établir un progràmme de travail sur le terrain (l'étude et la conservation de deux hauts fourneaux dans l'Italie centrale) ce qui a consenti à l'organisation d'aborder les problèmes existants dans ce domaine relativement nouveau de la conservation des biens culturels.

Cette expérience a montré en particulier qu'il existe dans cette discipline un manque d'information vis-à-vis des techniques et de la théorie de la conservation; certaines idées qui sont désormais familières à la communauté des specialistes de la conservation des types plus traditionels de biens culturels (art, architecture) ne semblent pas être évidentes pour ceux qui s'occupent de la préservation du patrimoine industriel. De plus il n'est pas sûr que ces idées puissent être appliquées sans modification dans le nouveau domaine, en raison de quelques différences objectives qui existent soit au niveau pratique qu'au niveau conceptuel (dimension des bâtiments, nécessité d'une utilisation nouvelle pour assurer la conservation et justifier le coût de l'entreprise, signification du monument pour le public, etc.).

Il faut noter en particulier, que dans la création d'un mouvement d'opinion pour la préservation du patrimoine industriel un rôle important a été joué (et est joué encore) par des historiens soucieux de reconstruire les techniques industrielles plus anciennes et un public désireux de pouvoir les voir appliquées. Ces attitudes qui ont, au contraire, un moindre importance dans la conservation de l'art et de l'architecture, influencent profondément la conservation industrielle.

Le groupe de recherche de l'ICCROM est arrivé alors à la conclusion qu'il rentrerait dans les buts statutaires de l'organisation de réaliser une confrontation entre les "experts de la conservation" et les "archéologues industriels", tout en gardant à l'esprit le fait que chacune de ces deux définitions, assez imprécise, englobe en soi une varieté de spécialistes provenants de disciplines diverses (historiens, archéologues, architectes, chimistes, ingénieurs, etc.).

Du fait que la compétence de l'ICCROM était à l'époque limitée aux forges, cet argument fut choisi comme le sujet d'un symposium tout en y ajoutant une deuxième section consacrée à la conservation des structures et des monuments bâtis avec le metal produit par les forges anciennes.

Le but de l'introduction de cette section était celui d'attirer l'attention des ingénieurs et des architectes et de stimuler la présentation de communications concernants des programmes de conservation et restauration. L'idée d'un symposium prit plus de consistance grâce à quelques rencontres informelles avec M. Neil Cossons (qui était alors le directeur de l'Ironbridge Gorge Museum), M. Barrie Trinder (Vicedirecteur du Musée) et M. David Crossley (de l'Université de Sheffield) qui vinrent aider le groupe de recherche à preparer un plan d'études archéologiques des forges italiennes.

Le fait que le TICCIH fournit également une aide pour l'identification de rapporteurs et des participants possible, mis l'ICCROM dans les meilleures conditions pour ses débuts dans un domaine nouveau.

Mais, comme il se passe toujours lors d'un premier essai, le résultat de la réunion ne réalise pas entièrement les espoirs des organisateurs, en dépit de toutes ces conditions favorables.

Dans les communications presentées au symposium le point de vue le plus fréquent est celui de l'histoire de la technologie, tandis que les problèmes de conservation des bâtiments eux-mêmes sont moins représentés. Cela pourrait dépendre aussi du fait que plusieurs projets de conservation et réutilisation qui ont été presentés sont au stade de l'étude et pas encore à celui de la réalisation.

Il semble ainsi qu'une action ultérieure visant à améliorer les contacts et à porter plus d'attention à la phase de réalilisation pratique serait souhaitable; cela pourrait consister en un travail interdisciplinaire sur des projets de conservation/réutilisation ou en une deuxième réunion dediée surtout à la présentation de projets de ce type.

Ainsi les problèmes liés à la théorie de la conservation (c'est à dire, type et extension des restaurations ou reconstructions permissibles, compatibilité de la nouvelle utilisation avec l'intégrité du monument etc.) qui, jusqu'à present, n'ont presque jamais fait l'objet d'une étude du point de vue de la valeur intrinsèque, historique ou esthétique, de l'objet lui même (qui est le point de vue typique du "conservateur") devraient être bien plus clairement mis en évidence dans le futur. A la réunion de Coalbrookdale, certaines de ces faiblesses furent heureusement compensées par le programme de visites preparé par Barrie Trinder qui occupa tous le jours une partie de l'après-midi. L'Ironbridge Gorge Museum fournit, à tous les niveaux, des exemples qui se prêtent bien à la démonstration et à la discussion des problèmes mentionnés ci-dessus: la fouille archéologique suivie d'une présentation rigoureuse des restes découverts (les hauts fourneaux de Coalbrookdale et Blists Hills), la conservation fidèle des structures en fer (le pont de Ironbridge) mais aussi, à côté, la reconstruction pour le public de la technologie sur petite échelle (au musée) ou même sur grande échelle (la nouvelle forge).

Malheureusement les discussions entre les spécialistes qui ont participé au symposium n'ont pas pu trouver de place dans les actes imprimés; pour la plupart elles se déroulèrent hors de la salle de réunion où un programme très serré de presentations occupa tout le temps disponible.

Les exposés sont reproduits ici tels que présentés par les auteurs, sans correction, la rapidité de diffusion et un coût modeste étant des priorités habituelles pour l'ICCROM. En conséquence les auteurs eux mêmes sont responsables du choix et de la présentation des faits contenus dans leurs articles et les opinions exprimées ne reflètent pas nécessairement celles de l'ICCROM.

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THE CONSERVATION OF MONUMENTS CONNECTED WITH THE IRON AND STEEL INDUSTRY IN THE SHEFFIELD REGION

DAVID CROSSLEY*

SUMMARY

The Sheffield Trades Historical Society has pioneered the conservation of sites connected with iron, steel and related industries. Its first venture, in 1933, was the preservation of Shepherd Wheel, a water-powered cutlery grinding works dating from the 16th century. There followed a 30-year campaign to save Abbeydale scythe works, with its crucible-steel melting shop. Both were eventually restored and incorporated into Sheffield City Museums. In the 1950's the Society purchased Rockley blast furnace (1652), which has since been subject to archaeological excavation and consolidation, and also Wortley Top Forge, a wrought iron works where buildings date from 1713. A new project is to restore Bower Spring cementation steel furnace, in Sheffield.

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JULY 1984

THE CONSERVATION OF MONUMENTS CONNECTED WITH THE IRON AND STEEL INDUSTRY IN THE SHEFFIELD REGION

Introduction

The history and reputation of the Sheffield area as a producer of high-quality steel and of a wide range of metal goods is based on a combination of resources. Iron has been smelted in the locality since the Middle Ages, but what has distinguished South Yorkshire from so many other ore-bearing regions has been the abundance not only of water power. wood and coal, but of refractory clays and stone, abrasive stone for grinding and, of great importance, communities whose upland agriculture was particularly suited to the pursuit of industrial by-employments (Hey, 1972). Surviving sites and structures are to be found over the Don basin within and beyond Sheffield itself and cover a range of occupations. from iron-ore mining through iron smelting and steel conversion to the water-powered forging and grinding operations of the secondary metal trades. For over 50 years there has been an active local interest in the conservation of buildings and plant within this group of industries. Although much remains to be done, it is now possible to display an important range of buildings, monuments to this width of activity.

The sites relevant to this survey are the pumping-engine house for the 19th-century ore mine at Rockley, the 17th and 18th-century charcoal blast furnace at Rockley, the wrought-iron forge at Wortley, the cementation steel furnace at Bower Spring, Sheffield, the scythe forge with crucible-steel shop at Abbeydale and the grinding shop, Shepherd Wheel, both on streams on the outskirts of Sheffield. This group of sites, rescued, restored and maintained over the last 50 years illustrates many problems of general application. They concern changing attitudes, among local government bodies and at large, as well as questions of organising and safeguarding restoration projects. The sites will be discussed in the order in which restoration has been carried out.

First of all some explanation must be attempted for the lengthy history of interest in Sheffield in the conservation of industrial buildings. Long before the term 'Industrial Archaeology' was coined, and before the study of industrial buildings became widespread, there was a vocal group in the city which was prepared to alert public opinion to the disappearance of its industrial heritage and to raise financial and practical help towards the maintenance of representative structures and skills.

This latter point, the recording of methods in the skilled trades, is the key to the early emergence of interest among the public, and for an explanation we have to go back to the years immediately following the first world war. In the 1920's there was much local interest in training in the skills which made up the traditional Sheffield metal trades. One manifestation was the foundation of the Sheffield Trades Technical Societies (STTS), which were formed with the support of management in industry and of the trades unions, and with encouragement from the Applied Science departments of the University. A wide range of topics and speakers appeared on the societies' early programmes, and these did much to place the skills of contemporary industry in their historic context. It was clear that some traditional trades would soon only be memories, and a movement emerged which pressed the need to record and practice old skills and to preserve the equipment used with them.

The early activity is best illustrated by interest in Shepherd Wheel, a water-powered grinding shop in the Porter Valley, Sheffield whose history is recorded from the 16th century. As with many traditional buildings, the requirements of legislation under the Factory Acts made uneconomic modifications necessary, and in 1925 individuals connected with STTS secured agreement from the Home Office to exempt Shepherd Wheel during the working lives of the existing elderly tenants. This was a crucial move in preventing the abandon ment and probable demolition of the building. The most prominent figure in this incident was David Flather. who in 1926 became Master of the Cutlers' Company of Sheffield. Although this position is largely formal and traditional it was, and indeed is, not without influence and helped Flather, owner of a local steel company, to put over his view that due regard should be paid to the preservation of the skills and equipment which had earned the products of Sheffield their reputation.

This is the background to the formation, in 1933, of the 'Society for the Preservation of Old Sheffield Tools and Equipment', later re-named the Sheffield Trades Historical Society (STHS). The tradition of an integrated approach to industrial preservation, not only of buildings but of equipment and methods, has characterised the Society and, latterly, the industrial museums which the City of Sheffield has taken over or created since 1970. Valuation of working methods as much as plant is not always found in industrial conservation movements, not least because of the practical problems which arise when old skills die out. But in the 1930's the approach was apt, and attracted the wider public in a way that the preservation of an unused building might not have done.

In 1933, when the Society was formed, attention was still concentrated upon Shepherd Wheel. The building and dam lay within City parkland, and the group of STTS members who had formed the new Society had for some time been refurbishing the Wheel after the departure of its last tenants. When repairs were complete and incongruous equipment had been removed, there began a series of demonstration days, held at summer weekends. These were manned by grinders who still worked in the industry, and they finished blades on the water-powered stones. These events took place until 1941 and attracted large attendances. It was originally intended also to restore the next works downstream, Ibbotson Wheel, It was originally another small grinding shop. The plan was to transfer hand-forgers' hearths and equipment from elsewhere in Sheffield, so that visitors could see the complete sequence of forging and grinding. Unfortunately Ibbotson Wheel was found to be too dilapidated for the Society or the City to repair, and the buildings were eventually demolished.

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The demonstrations of blade-grinding were of significance in attracting a body of interest and support which was important in overcoming difficulties which were to be encountered elsewhere. With this background, the individual conservation projects undertaken in the area will be considered in the order in which they have been carried out.

The Abbeydale Works

This water-powered scythe works lies five miles south west of Sheffield on the river Sheaf, in wooded surroundings which have changed relatively little during the residential development of the area in the present century. Although its origins as a scythe-grinding works date back to the beginning of the 18th century, the present complex of buildings was erected in the period 1770-1830. It comprises a tilt-force and a grinding-hull, both water powered, a Huntsman crucible steel-melting shop, hand-forges, a warehouse block, manager's house and cottages. Abbeydale was used for scythe manufacture until late in the 19th century when its tenants, Tyzacks, gradually transferred their activities to Little London Works, downstream. The firm retained Abbeydale until 1935, when it was purchased by a charitable trust for presentation to the City. It was clear to the founder members of the Society that Abbevdale would be well suited to use as an industrial museum, and a campaign was started to prevent demolition of the buildings and transformation of the site into Between 1936 and 1938 the opposing proposals were discussed with a park. a good deal of heat, and when in 1938 the Society offered the City Council £300 towards renovation of the buildings, the response was a request for £1250, to be raised within six months with demolition as the alternative. Indeed by the end of the year the City's estimate of repair costs had risen to £1600. Undaunted, the Society launched an appeal for the 'Proposed Sheffield Industrial Museum and Benjamin Huntsman Memorial', which raised £1500. Even when most of this sum had been transferred to the City to allow work to start, the Society's minutes suggest that the Parks Comittee were still discussing demolition.

In fact, restoration did begin, and it is of interest that the task continued despite the outbreak of war. Volunteer work went on during 1940 and 1941, and the City Architect proceeded with renovation whenever labour could be spared from the building of air-raid shelters. By the end of 1940 the crucible shop was ready for equipment promised by Sheffield steel firms, and in 1941 work was in progress on the tilt forge. The cottages were in good enough repair to accomodate bombed-out families, and in 1942 a Sheffield firm, Wardlows, began to make crucible steel at Abbeydale, after war damage to their own furnaces.

At the end of the war the Society had high hopes of seeing a successful conclusion to their efforts, but this was not to be quickly achieved. The Parks Department was reluctant to give up the storage space in the Abbeydale buildings, but was also allowing the structures to deteriorate, a process hastened by the severe winter of 1946/7. The Society campaigned for a decision, supported by the Inspectorate of Ancient Monuments of the then Ministry of Works. The upshot was that the City handed back the money raised by the Society in 1938 and requested the



removal of objects collected as exhibits for the proposed museum. The latter included the massive set of tilt hammers brought from the works of William Jessop Ltd., which were far beyond the Society's resources to transport, even if there had been anywhere to take them. The attitude of the City Council attracted much unfavourable attention, not least in the local and specialist press, and generated a good deal of sympathy for the aims of the Society, which could rightly claim that much of its voluntary effort had gone for nothing. There was indeed a gradual change of attitude, and although Abbeydale continued to deteriorate during the 1950's, the buildings were never demolished. By 1963 the position had changed to the point where the City leased Abbeydale to the Council for the Conservation of Sheffield Antiquities (CCSA), for restoration and eventual return as part of the Museum. The CCSA was an organisation set up in 1954 by a group of bodies among which STHS was prominent, and had already proved itself by the restoration of Shepherd Wheel.

The CCSA faced a daunting task. Abbeydale had seen little repair for twenty years, and the work of 1938/41 lay in virtual ruin. Roofs had to be replaced, major restoration was required to the masonry, and the water system was in decay. In particular, the water wheels had to be completely rebuilt and the dam emptied, dredged and the sealing of puddled clay restored. This part of the work highlighted the often-forgotten costs of water power.

By 1970 the restoration reached the point where Abbeydale could be handed over to the City Museum, for opening to the public. It has since become a major attraction among English museums and it has been possible to complete the restoration while the public have had access. If there have been disappointments these have lain in the limited extent to which it has been possible to demonstrate traditional trades in the way that the founders of Sheffield's industrial preservation movement hoped for. It has not been possible to melt steel except on a few private occasions for filming, due to the dangers inherent in the restricted space in the Although the water wheels are regularly operated, it is crucible shop. inadvisable to work the tilt-hammers at present, due to the effect of vibration on the forge building and the need for further work on the main camshaft of the hammers. It has been possible to man the hand forges on certain summer 'working days', but the hope that craftsmen displaced from city-centre premises might use Abbeydale has not been fulfilled. This problem has now been solved by the erection of replica workshops within the new industrial museum at Kelham Island, where a satisfactory system of demonstration by craftsmen working on a commercial basis has now been arranged.

This is necessarily a brief view of a long and often tortuous story, pieced together from Society minute books, the local press, and from correspondence. Even so summary a treatment illustrates the problems which early conservation bodies could face when fostering the cause of industrial preservation, and provides an example of a change in attitudes which, in Sheffield at least, has ensured the preservation of a sample of sites and a fitting place for industrial history in the museum structure.

Shepherd Wheel

As noted above, Shepherd Wheel was the scene of pioneer attempts at preservation. It was rather overshadowed by the Abbeydale campaign, and ceased in 1941, the buildings after demonstrations of grinding deteriorated. In 1948 much of the roof fell in, and by this time the dam was failing to hold water, the penstock timbers had rotted and the water-wheel was in poor order although, being largely built of iron it had not yet suffered the degree of collapse seen at Abbeydale, where two of the wheels have wooden spokes. Alerted by its experiences at Abbevdale. the Society engaged in protracted discussions with the City Parks Department, but failed to secure agreement on a scheme for renovation: indeed the latter was apparently seen in Council circles as an unnecessary expense, and in 1954 it was learned that £500 had been set aside to cover the cost of demolition. The CCSA was formed at this time, and requested the Council to delay the plan for demolition while an attempt was made to raise money to restore the water wheel, which by then had collapsed, and to removate the interior. It was further requested that if the CCSA appeal succeeded, the £500 voted for demolition should be put towards the reinstatement of the roof. The appeal was successful and repairs were completed in 1959, allowing the resumption of the pre-war custom of running demonstrations at holiday weekends. The success of these led to Shepherd Wheel being taken into the City Museum's care in 1970, since when it has been open to the public.

Rockley Furnace and Engine House

Believed to be the oldest surviving blast-furnace stack in Britain, Rockley stands 12 miles north of Sheffield in wooded country on the outcrop of the Tankersley iron-stones (Crossley,1980). It was built in 1652 and was operated at the end of the 17th century by the Spencer partnerships (Raistrick and Allen,1939), probably going out of use by 1740. Recent archaeological excavations have shown a further period, probably about 1800, when coke was used and when the furnace was equipped for making large castings. So far no documentary evidence has been found for this.

The engine house lies 200m from the furnace, but topographical evidence suggests that it was unlikely to have been built before the latter went out of use. The engine house bears a date-stone of 1813, by which time a tramway appears to have been built over the filled-in overflow of the furnace pond. A Newcomen atmospheric engine occupied the building until about 1880, draining workings in the ironstone and coal seams: the mine, nearby, would have sent its output to the Worsbrough basin of the Dove and Dearne Navigation by way of the tramway.

The land on which these buildings stand was purchased by STHS in 1957. The purchase was made not only to secure the preservation of these monuments, but also because of the close connection between Rockley furnace and Wortley Forge (below): under the Spencer partnerships pig iron from the furnace went to Wortley for conversion into bar iron.



When purchased, the furnace was overgrown, with trees established on the top of the structure. Most of the ashlar facing had been robbed away, some during the present century, and the rubble core-work had deteriorated due to weathering and root action. Renovation of a structure of this kind presents great difficulties: replacement of ashlar is undesirable, for the original form is not known. Consolidation of the rubble is made difficult where stones have been dislodged, exposing the soft filling between the leaves of the wall. This is at present the problem at Rockley, and replacement of the eroding rubble presents a major The position has been somewhat improved by the capping of the task. furnace wall, with concrete laid on mesh covering the loose fill, so reducing waterlogging and frost damage. Similarly, the drying of the structure will it is hoped reduce the rate at which the cast iron lintels over the blowing and casting arches are being corroded away.

The excavations carried out around the furnace have shown the layout and detail of the associated structures. It has not, however, been possible to display the bellows and casting areas, due to the risk of weathering of the friable sandstone foundations and also because of the danger presented to visitors by open excavations at an un-manned site. This would have been a particular risk in the case of the casting pit associated with the final use of the furnace. Accordingly, it was decided to backfill the excavations, but in the future it may be possible to indicate the major features such as the wheelpit, casting pit and bellows house by means of concrete kerbing, in association with an annotated perspective reconstruction drawing on an etched metal display plate to be set up close to the furnace.

By comparison, the engine house at Rockley presents fewer problems. When it was acquired it was in poor condition, and the vestiges of the tile roof were a particular danger. Due to lack of resources the roof was removed rather than rebuilt in 1967, a decision which is now regretted. In 1972 major structural work was financed by the Department of the Environment, preventing the disintegration of the chimney corner of the building; had this not been done, the engine house would have collapsed. The structure is now in good condition, requiring little maintenance and presenting few opportunities for vandal damage.

Wortley Forge

Wortley Top Forge lies on the River Don 12 miles upstream from Sheffield. The earliest buildings in the existing complex date from the beginning of the 18th century, bearing a date of 1713. The site is known to have been that of a bloomery early in the 17th century, evolving before 1700 into one of the finery forges of the Spencer partnership (Mott, 1971). The forge gradually changed into a producer of wrought-iron goods, and in the 19th century it had a considerable reputation for railway axles (Andrews, 1956). The changes of the century after 1750 can easily be seen, with the addition of buildings and the conversion of plant: particularly striking is the piecemeal replacement of wood by cast iron in the older of the two tilt-hammers. The 19th-century prosperity of the works is marked by enlargements dated to 1850, when a good deal of



equipment was brought in, some new, as the blower wheel penstock, some archaic, as the second tilt hammer, which may well have been a redundant piece from a works re-equipping with steam hammers.

Top Forge was purchased by STHS in 1955, having been disused since about 1910, though still essentially complete apart from the loss of the re-heating furnaces and their water-powered blower. The Society had a passing involvement at Wortley in the mid-1930's: equipment, notably a rolling mill from the Lower Forge at Wortley had come into the collection stored during the war at Abbeydale, and there had been some tentative discussion about buying the Top Forge site. Acquisition in the 1950's arose from fears for the future of the forge when it came on the market, and funds were raised by appeal for the purchase of the properties at Wortley and Rockley.

The complex of buildings is a large one, comprising the force itself. an arcaded structure with one end forming the dam wall and the other contiguous with a pair of cottages. There is a detached wing, known as the blacksmiths shop and foundry. There are three water wheels and two tilt hammers. One pond is within the property, while another is in outside ownership, upstream towards the head-race weir on the Don. The scale of the buildings has made restoration a hard task for the volunteer group which has been at work over the last 30 years. A trust was formed in 1970 to launch appeals and to manage funds received from national and local government and from industry and other donors. Early work concentrated on making walls and roofs sound, and ensuring that the dam a considerable problem, entailing This was was water-tight. reinstatement of the core of the bank, which carries the entrance road into the forge: a task of which the visitor sees no sign. The current programme involves restoration of the tilt-hammers and the water-wheels. The later hammer is now finished, after the repair of its cast-iron stands, the formation of a new base and the re-alignment of the helve. Its wheel is in process of re-erection after the turning of shaft bearings in situ. The older hammer and wheel remain to be restored, while the blower-wheel and its penstock require full renovation after earlier first-aid treatment.

Wortley Top Forge illustrates particular problems faced by amateur bodies in restoring and maintaining a site of some complexity. The first difficulty is that the time-scale is undefined. Restoration takes place over a lengthy period, and after a time deterioration sets in, before other areas are complete or even started. Maintenance and restoration can thus compete for resources. In the case of Abbeydale, the voluntary fund-raisers of the CCSA and their paid and unpaid workers could look forward to the restored works being taken over and maintained by the local authority museum service, but at Wortley there is no such end in view. A related difficulty is that a volunteer body cannot man its property continuously, forfeiting potential revenue from week-day visitors. Above all, levels of income cannot be forecast: donations from industry reflect fluctuations in the wider economy: local and national government aid follows changes in levels of public spending. At Wortley the managing trust has been fortunate in its industrial connections, but an increasing proportion of the funds for the restoration have recently had to come from

open days manned by those who would otherwise be working on the restoration. Of particular importance at Wortley are 'steam weekends' held twice or three times a year. These have proved a major attraction to the public, and net takings of £2000 for a weekend have been achieved. They are based on a collection of stationary steam engines built up by the Society and by individual members, but other owners of old machinery bring items to run and display. The income is welcome; indeed without it little could be done, but preparation and organisation of these events curtails restoration time, and the diversion of effort from the essential centre of the monument, the forge, inevitably causes concern. This is the true cost of such methods of fund raising; it is made even more serious when the time available to the volunteer force for actual restoration work recedes to the point where the income from open days has to be used in the employment of professional builders, whose charges soon make away with the funds raised. Wortley is not alone in facing such problems, but Top Forge provides an apt illustration of their complexity.

Bower Spring Furnace: the current concern of the Sheffield Trades Historical Society

One particularly significant type of structure is absent from the preceding sections. For two hundred years, from the early years of the 18th century, much of the steel used for Sheffield tools and cutlery was made by the cementation process, whereby high-quality bar iron, normally from Sweden, was converted into 'blister' steel by heating in contact with charcoal in sealed chests. One complete example of a cementation furnace remains in Sheffield, rebuilt to an incorrect profile after war damage. and used until 1951 by Daniel Doncaster Ltd. This furnace, although safeguarded under the Ancient Monuments Acts, is difficult of access. Another example was sought for preservation and display, and an opportunity for action arose when a fragment of such a furnace was discovered during the demolition of buildings which had hidden it since the early years of this century. Because the furnace is incomplete its internal structure can be seen, to an extent which is impossible with the intact example. The furnace, at Bower Spring, a street close to the centre of the city and near the new Kelham Island industrial museum, was built by Thomas Turton in 1828 and later worked by Moss and Gamble, who gave it up soon after 1900 (Barraclough, 1976).

Since exposure, the furnace has been consolidated on two occasions, but as the bricks used in construction are of poor quality and particularly liable to frost damage, maintenance will be a regular commitment. The difficulty is that the furnace, although now scheduled under the Ancient Monuments Acts, is still in private ownership, and the Society is anxious for some arrangement to be made whereby it can be brought into the care of Sheffield City Museums, and it continues to use its good offices to this end. For the Museum's part, the furnace would be a significant addition to the tour of the early-19th-century industrial area to which visitors to Kelham Island are directed.

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THE No.1 SMITHERY, CHATHAM DOCKYARD, 1805 - 1984: 'LET YOUR EYE BE YOUR GUIDE AND YOUR MONEY THE LAST THING YOU PART WITH'

ANGUS PETRIE*

A description and history of the Smithery and associated Foundry are given. An opportunity for development is identified, and problems of management, conservation and interpretation are explored.

The views expressed in this paper are those of the author and not necessarily those of any public body with which he has been associated.

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INTRODUCTION

At sunset on Friday 30th September 1983 the Flag of Rear-Admiral W A Higgins, CBE, The Flag Officer, Medway, and Port Admiral, Chatham, was hauled down to the sound of a Gun Salute. A little earlier in the short ceremony to mark this occasion Vice Admiral Sir James Kennon, KCB, CBE, representing the Admiralty Board, thanked the officers and workforce of the Dockyard, and the communities of the Medway towns, past and present, for their service and contribution to the Royal Navy and national security for more than four hundred and thirty years. In a brief speech he brought to mind the many famous ships, glorious victories, sad defeats, lives spent in dedicated service to the Crown, and the tens of thousands of men who had left Chatham to die at sea or in foreign lands. After a short religious service the Band of Her Majesty's Royal Marines beat the retreat. The ceremony took place beside the river and in the gathering gloom a small coastal vessel slipped by lowering its Ensign to half mast; on the grass beside the band, some small children with less sense of history, 'bopped' to the music.

Chatham Dockyard is situated on the south bank of the River Medway in the south-east of England about thirty two miles from the centre of London. Economically the position of the Dockyard was of particular significance as the river, flowing through the low hills of the North Downs, gives access to the rich hinterland of the Weald which in past times supplied timber and iron for the construction and maintenance of ships. The site offers shelter from winds in most quarters and a soft bottom for careening vessels. Strategically the site has been important from ancient times: the road from Dover and Richborough runs along the chalk ridge to a crossing point over the River Medway nearby, providing a link from the heart of England to the ports with the shortest distance to the continent. The Romans built a bridge and a walled town at the river crossing, now the site of the City of Rochester. In the third and fourth centuries AD the area was probably used by the Classis Brittanica, the Roman fleet used for the protection of Britain.

During the last five centuries the Dockyard has played an important role in the protection of England from her foes, the River Medway giving easy access to the North Sea, the eastern Channel, the Baltic, and the northern European countries. For much of that time the Dockyard was one of the largest industrial enterprises in Britain, officers, craftsmen and labourers combining to serve the needs of a changing Navy. In a very special way the Dockyard has played a part in technological progress, and the spread across the world of European peoples, their power and influence.

This year the Chatham Historic Dockyard Trust took over control of the older part of the Naval Base. The remaining buildings in this area essentially comprise an eighteenth and early nineteenth century dockyard created to build, maintain and service the wooden warships of a sailing navy. Some of the buildings are superb; others are of less distinction. Together they form a whole which in many ways is unique.

One of these buildings, the No.l Smithery has been much altered and is in a sadly dilapidated condition; but in itself, it represents the great change from craft skills to more modern technology; offers a special viewpoint on social and national history, and was an important element in the development of shipbuilding.

THE NO.1 SMITHERY

Research

This paper is based on research which began in 1979 when the Dockyard was still under naval control, and whilst handover to heritage interests was foreseen but was still a distant prospect. The work has included study of the Dockyard buildings and their environs, study of the associated equipment, and research into archives held in public depositories and in the Dockyard.

The archival sources for the Royal Navy are particularly rich including many sorts of documentation ranging from the policy papers of governments to the minutes of dockyard officers. In the case of the No.l Smithery most of the original plans for the building and alterations still exist, as well as building contracts. During the run down of the Naval Base, the closure of which was announced in June 1981, these archives have been supplemented by collecting the more mundane records of everyday life within the Smitheries. A particular success has been the recovery of three pay books and two orders of seniority giving details of smiths, hammermen, and labourers who served between circa 1850 and 1924. Many of the Dockyard workers have helped, and eighteen interviews have been recorded with people who either worked in or were closely connected with the Smitheries.

Origins

A forge was built for the navy at Chatham in 1571. In 1585, George Johnson and sundry blacksmiths were paid for making a 'Great Chain' that was to protect the anchorage from the Spanish Armada. In those days smiths work for the navy included, anchors, chains, ships fittings, nails, locks, and tools. Before the eighteenth century ironwork was supplied by outside contractors who had their forges in the Yard.

On 27th August 1666, John Ruffhead, Anchorsmith, complained to Samuel Pepys, Secretary to the Navy Board, that he had delivered ironwork to the value of £6000 during the previous year and had only received £800.

Drawings and watercolours exist from 1698 that show, a view of the Yard from across the river, a plan of the Yard, as well as detailed plans and side views of the buildings, including, a small smiths' shop for locks, etc., with one fire, an anchor shop with three fires and a capstan crane nearby, and a 'Great Smiths Shope' with eight forges, a tool store and offices for the foreman and clerk.

The first Master Smith was appointed by the Navy Board in 1723. A new smiths' shop was built in 1735 on the site of the 'Great Smiths Shope'. The new building had sixteen fires, and in 1740 the officers requested that another four be added.

The Smithery

On 4th May 1805 the Yard officers petitioned the Navy Board for a new Smithery. They explained that the existing building '.... was in a general defective state....' and '.... a Building originally badly planned'; and further that a new building '.... is of such consequence from the great introduction of iron work in Building and repair of Ships.'.

The design chosen was that of Edward Holl, an architect who later became Survyor of Buildings for the Navy, and who was at that time woking for the office of the Inspector General, the celebrated Samuel Bentham. At Chatham six of the major buildings that are now Scheduled Ancient Monuments were built under Holl's direction. In the Royal Dockyards in this country and abroad his designs add beauty and grandeur, something he is on record as having striven to achieve. The alterations to the No.l Smithery have, however, not been very sympathetic to his building.

The Officers of the Yard met Mr. Goodrich, the engineer representing the Inspector General, and Mr. Holl, to choose the most suitable site, where the the Officers noted '.... a Shop may be built with great propriety and also be convenient to the Dock, and destroy no Building at present occupied, excepting a few saw pits,'. A warrant for the erection of the building was issued on 24th March 1806.

Essentially, the building comprised three ranges and two small houses or cabins enclosing a yard, the whole making a rectangular block measuring 180 x 150 feet. (See Fig.1). The internal width of each range is 53 feet and it is worth noting that in the original roof the 20 tie beams were each $62\frac{1}{2}$ feet long.

On the original plan the yard is Jarked as'for the immediate reception of New and Old Work'. To the south of the gate is the 'Masters Cabin', to the north the 'Weighing place and Foreman's Cabin'. In the corners of the yard the privy and beer cellar are marked, the latter representing a well established practice - the 'Smiths' Porter' usually being supplied by the Tapster of the Yard. A small room above the beer cellar with access to the eastern range may have been a tool store. In the northern range by a small door is marked 'Space for repairing ships' hearths.'

The layout of the forges is perhaps of greatest interest. These numbered forty in all and each had access to a brick chimney of which there were originally twenty eight. The great width of the ranges was necessary to house bellows, which extended up to twelve feet from each hearth. In 1808 when the building must have been substantially complete, the question of using a steam-engine to blow the fires was raised. The Navy Board asked John Rennie, the civil engineer, his opinion, and the Secretary's notes, made whilst he gave his evidence to the board survive. He raised the problem of the large number of smiths who might lose their employment, but considered that '... if to a blowing machine to the hearths was added a steam engine with forge and tilt hammers, etc., with proper furnaces for heating the metal the advantages arising from such a construction would be very considerable.'. The Smithery was to wait another twenty-four years before the introduction of such a scheme. For the time being bellows were used.

An Engine House was added to the north-eastern corner of the Smithery in 1841. Stylistically this closely resembled the original Smithery building. The roof is still of slate on timber and a double window survives in the party wall. A 16hp Boulton and Watt engine was installed and used to drive lift and tilt hammers, as well as a fan for blowing the fires.

The following year another engine supplied by the same company was installed alongside the first. This engine was 8hp and was housed in its own engine house. The engines were joined by a new flywheel shaft and main bearing. (See Figs. 2 and 3).

During 1843, the Admiralty seem to have been particularly concerned with improvements to the Smitheries, commissioning a report on this subject, and receiving reports on the use of high pressure steam for land engines, and the the use of Whitworth machine tools.

Naysmith steam hammers were introduced at Chatham and other major yards in 1844. Problems arose immediately over the adequacy of foundations for the anvils and weaknesses in boiler construction.

During the 1840s, '50s and '60s, demand for the products of the Smithery rose steadily. The equipment used by the smiths improved rapidly in quality and quantity. New furnaces and forges were introduced. The system of blowing air was improved to feed all the fires in the Smithery. Power was supplied to hammers and machines by shafts and belts, steam pipes and donkey engines.

A plan, signed by the Clerk of Works in 1859, was amended to show improvements in the Smithery and associated buildings up to circa 1870. In the Smithery seven steam hammers are shown, five chimney furnaces, three other furnaces, a lathe, and drilling, nut, and bolt machines. (See Fig. 4).

The Foundry

A building associated with the Smithery, and which was later to become incorporated into the No.l Smithery, began in a humble way. It seems likely that by 1809 the Smithery was working at full capacity for in that year, the Navy Board issued a warrant for the erection of a 'Shop for the fitting and repairing of 'Ships' Hearths'. The estimates were approved by Edward Holl who may have designed the building. The shop measured 52 x 24 feet externally and the long western side was aligned with the main facade of the Smithery. It survives today in a much altered state. (See Fig. 5). It seems likely that this shop was used to cast grates, and that by the late 1840s it was being used as a foundry. For in 1847 the Metal Mills had been constructed on the site in front of the Smithery, and were producing at the rate of 700 tons of sheet copper, 400 tons of bolt copper, and 800 tons of re-manufactured iron per year.

The original hearth shop was reconstructed in 1855 to form a new Iron Foundry. This new building consisted of two shops measuring 20 x 50 feet with a drying closet measuring 20 x 25 feet to the north. Three cupola furnaces were positioned at the north end of the western shop.

A Brass Foundry was built to the north of the Iron Foundry, probably during 1857. The original plans have not been located, and this part of the No.1 Smithery was destroyed by enemy bombing during World War II, leaving only a few structural clues.

Iron Warships

The Achilles, the first iron battleship to be built in a Royal Dockyard, was laid down in the No.2 Dock at Chatham in 1861. The construction of this new type of ship meant that the Dockyard workshops had to be rapidly adapted. The Smithery and Iron Foundry were both enlarged and their machinery improved.

A 'Rivet Making Shop' was added to the north-eastern corner of the Smithery abutting the 1842 Engine House. Charles Dickens visited the Yard whilst the Achilles was being built and in 'The Uncommercial Traveller' gives his impressions of the ironworking facilities at Chatham. Of this shop he says "The making of the rivets is merely a pretty round game, played by a man and a boy, who put red hot barley-sugar in a Pope Joan board, and immediately rivets fall out of window (sic); but the tone of the great machines is the tone of the great Yard and the great country: "We don't particularly want to do it; but if it must be done ---- !"".

Such was the demand for ironwork that a new Smithery had to be built attached to the Metal Mills, and a temporary Smithery had to be set up over the No.1 Dock. It was probably at this time that the original shop became known as the No.1 Smithery.

In 1865 three major extensions were made to the building. The enclosed yard was roofed over to form a steam harmer shop for a 5 ton hammer, flanked by two 25 ton cranes and two large furnaces. A Boiler House was added to the north of the 1841/2 engine houses to supply high-pressure steam to the harmers and engines. The roadway between the Smithery and the Iron Foundry was roofed over and incorporated into the Smithery by demolishing a section of the northern wall. (See Figs. 3 and 6).

Further enlargements were approved in 1869. An additional boiler house was constructed to the north of the existing one, and a roof was constructed between the boiler houses and the Iron Foundry. The shop thus formed is today the pipe bending shop and parts of the bending slab are probably original. (See Figs. 3. 8 and 9). By the 1880s Chatham Dockyard had been greatly extended by the construction of three great basins, dry docks, and numerous new workshops to the north of the original dockyard on land bounded by a bend in the river. In 1883 the Metal Mills were closed and their building became part of the No.2 Smithery. A new foundry started production at the modern end of the Yard in 1887, and, during a major remodelling of the No.1 Smithery, the old Iron and Brass founderies were incorporated into it, a new iron roof was constructed, and the windows were enlarged.

Submarines

As warships became larger towards the turn of the century the Dockyard no longer played such a major role in their construction. The depth of the river and basins was a factor in this change, as were economic considerations. For the Dockyard, a new era began when in 1908 the submarine C17 was built at Chatham. A sketch in one of the smiths' workbooks shows the forging needed for her towing bracket.

The old engine house had found a new use as a store. A diary kept there from 1892 until 1934 gives a vivid insight into the Dockyard during the earlier part of this century.

The change in equipment was most marked. Compressed air took over from steam as the main motive force for the hammers. Electric forge cranes were introduced in 1907. Gas and electric furnaces were used. Welding became increasingly sophisticated and machines for cutting and shaping metal became more powerful and worked to finer tolerances.

At 4.50pm on Monday 19th August 1940 the greatest tragedy suffered by the Smithery happened. A direct hit by a German bomb which landed on the pipe bending slab killed four men and injured many others.

Workers

The smiths did adapt to technological change and were still employed in construction work when the last submarine was built at Chatham in 1965. Until the closure of the Yard's technical departments in 1983, the smiths were still employed in traditional as well as more modern roles. Last year we photographed and filmed work being undertaken, including forging under pneumatic hammers, locksmithing, chainmaking, work on the galley of a modern frigate, galvanising, and chain testing. The smiths also still had a role in mooring parties for the anchoring or berthing of ships.

The smiths were still supported by hammermen and labourers. They were now however established civil servants, and the old system of hired or established men, and work being done by contract, had vanished. The piece work system, which had caused so much rivalry in the trade had also been superceded. Not so long ago, in the 1960s Shipwrights had acted as 'providers' fetching work from the smiths and others for the work gangs on the ships or submarines. Shipwrights had also worked alongside the smiths during the production of frames and plates. The work of the 'Smiths' Section' was now managed by a Trade Planning Office. For in 1974 the smiths had moved from the Nos. 1 and 2 Smitheries to the Boilershop, and come under the supervision of the Foreman of Boilermakers.

Preservation of the No.1 Smithery 1974-1984

The operational requirements of the Naval Base led to a demand for more car parking space. In 1979 the No.2 Smithery, which had been used for the manufacture of frames and plates, was demolished, and pressure was brought to bear to demolish the No.1 Smithery.

The building and equipment suffered from petty vandalism, and by administrative error the heavy forge cranes were disposed of as scrap. In 1981 approximately two tons of lead flashing were stolen from the roof of the old iron foundry where valuable equipment from the No.2 Smithery was being stored, including heavy forging tools, wooden moulds, pot fires, and a tyring slab and tools.

During 1983 historic smiths equipment and records which had been transferred to the modern end of the Dockyard were being disposed of. Intervention led to the salvaging of much of the equipment and some of the records. A further intervention before the final public auction this year, led to historic equipment being withdrawn from sale.

AN OPPORTUNITY

A great opportunity now exists to make the No.l Smithery into a permanent educational resource, a visitor attraction, and a viable part of a unique conservation area.

Management

In April 1982, Kent County Council, the local authority, and the Property Services Agency of the Department of the Environment, which in this country undertakes some of the functions of Ministries of Culture elsewhere, commissioned consultants '.... to study and report on the economic and environmental opportunities that will exist when the Historic Dockyard at Chatham ceases to be used for naval purposes'.

The consultants report was published later that year. They believed that a 'Living Dockyard' concept would ensure the preservation of the great majority of the scheduled buildings and of the character of the Dockyard ...' They considered that unified ownership of the Dockyard was essential and proposed that a Trust, possibly with charitable status, should be formed to direct and finance the operation. The government accepted the broad conclusions of the report and this year 'The Chatham Historic Dockyard Trust' took over management of the older part of the Naval Base with a substantial grant of money.

The consultants considered that a separate Trust or Company could lease space in various buildings for 'Tourist purposes'.

In my own view an organisation along these lines and fitting an already established pattern should be set up. Four major considerations have to be borne in mind.

A primary consideration must be the conservation of the Dockyard buildings, their equipment and archives, in order to preserve the Dockyard as a resource for future generations and to maximise its value at the present time.

Secondly, the Medway area, with the decline in its industrial base, has a high level of unemployment and related social problems. The local community should be welcomed into the Yard and their active participation encouraged.

Thirdly, the Dockyard has special importance as an educational resource, not only for the teaching of history, but for environmental studies, the study of applied technology, social relationships, and working practices.

Fourthly, it is essential that revenue be earned to cover the cost of maintenance and running expenses. The tourist appeal of the Dockyard must be vigorously promoted. Whilst concessions can be granted to restaurants, public houses, and cafeterias, it seems best that the gate money for historic attractions should accrue to a single organisation.

These essential aims would best be served by the setting up of a museum in the accepted sense. It should operate with a clearly defined role within the Chatham Historic Dockyard Trust's wider responsibilities, either under the umbrella of the Trust or at arm's length. This museum organisation should include curatorial, research, conservation, archival, educational, technical services, retail, and public relations components. The organisation would be able to draw an established profession for support, expertise, and personnel. It would work alongside the other activities in the Historic Dockyard to achieve the aims already stated.

A particular advantage of a museum organisation would be, that funding of educational and conservation services is already well established, at local and national level, through museums.

Whatever the administrative arrangements that are made, I firmly believe that the No.l Smithery should be developed as a project in its own right. The consultants recommended the sum of £575,000 for work on the building. The nettle should be grasped. Sufficient funds should now be made available to consolidate the building, conserve the equipment, and arrange for displays and interpretation. A timetable should be set both, for opening the building to the public, and for achieving conservation aims. The standards worked to should be the very best achievable, and suggestions or advice from this meeting or elsewhere, would be most welcome. The time seems particularly right as many of the workers who knew the building so well have been contacted. Most are willing to help with information about their work, and some are keen on demonstrating their skills. On Wednesday September 26th this year we invited the men and their families back to the Dockyard to see the film 'The Blacksmitns of Chatham Dockyard'. In the large room where we showed the film there was only standing room left. Later in the evening light I took some of the men around the Smithery; old men pointed out their tools and told stories of long ago. The shop became alive again.

Conservation

Conservation of the building offers a number of technical and organisational problems. The Smithery has been used as a store for Smithery and other dockyard equipment. This may have to be moved to enable structural consolidation to take place. The condition of the building is poor with defective brickwork, rotting windows, leaking roofs, and partial demolition of the north end caused by the wartime bomb. The condition of structural ironwork and the iron roof supports is thought to be fair althougn immediate work is needed. (See Figs. 6,7,6,9,10,11,12,13).

The equipment presently in the Smithery is mostly of iron or steel in poor condition, ranging in size from a 12 ton anvil to small callipers. Elsewhere in the Yard the original pneumatic hammers and other equipment have been preserved. Some of the equipment will take the work of skilled fitters to reinstall. The partially oxidised ferrous equipment might be treated in a number of ways; a technical expert has suggested boiling in oil, a treatment used by the naval smiths as a suitable method of preparing chain and fittings for sea.

Interpretation

The interpretation of the No.l Smithery should be part of a strategy of interpretation for the whole Historic Dockyard. The buildings grouped around the Smithery make a natural focus for a visitor attraction: they include a boiler makers shop, an old copper store, an iron store, a galvanising shop, joiners shop, joiners store, timber seasoning stores, wheelwrights shop, mast houses and a mould floor, and all these buildings are grouped next to the dry docks and covered slips. For the No.l Smitnery there are four principal interpretative themes to explore.

The first theme is ships and shipbuilding. The Smithery and the surrounding buildings are of greatest importance as a survival of shipbuilding technology. There completeness is of special significance, as also is their development to build ships that had such a marked global impact at crucial turning points of world history. The iron technology of the era of wooden ships, and the technical developments to construct iron ships, can both be demonstrated. The Foundry could house displays of work that was carried out in the related shops particularly frame bending and plate forming.
The second theme is people. For five centuries the smiths, harmermen and labourers reported for work in the Dockyard. It is at this local level that the Smithery can perhaps give its truest perspective. The building itself, and the existing environment inside it, speak volumes about working conditions in some trades until recent times. Craft skills and values, the dockyard and home communities can be explored. The willingness to help of the men now retired must not be undervalued. (Figs. 4, 15, 16, 17).

The third interpretative theme is national history. The smiths and other workers at Chatham were humble participants in the great historical struggles of the last five centuries. The very continuity of their work and their approach to it does though offer a very special viewpoint from which to interpret events on the national or international scale. Their products were used to repel the Spanish Armada and Dutch invaders, to assist the colonies during the struggles in America, to build and maintain HMS Victory which was in dock at Chatham fresh from the battle of Trafalgar when the foundations of the Smithery were being laid; played such a prominent part to develop the great iron, sail and steam ships of the Black Fleet, and Chatham and the smiths had a unique role in the construction of submarines by the Royal Navy. The bomb of 1940 gives a particular highlight, and interviews have been recorded with men who remember the full horror of the event, and with one man who was injured.

The fourth theme is applied technology. When the Smithery was built the main motive force used in the shop was human muscle. During the development of the building, steam at low and high pressure, compressed air, gas and electricity were all used. The increasing demand for energy is shown by the addition to the north-east corner of the original building of two steam engine houses, two boiler houses, and a compressed air house. The smiths' trade itself offers an approach to material science, and a dramatic demonstration of technology in practice.

CONCLUSION

In conclusion I would like to refer to the title cnosen for this paper. Two dates were identified which were important for the Smithery at Chatham and have a wider significance. In 1805 the smiths at Chatham requested a new building, and on a larger stage a great naval engagement off the Cape of Trafalgar established the pattern of world trade for more than a century. This year, 1984, reminds us of George Orwell's novel that explores the relationship of the individual to central authority in a world continually at war. In April the Chatham Historic Dockyard Trust took over control of the No.l Smithery and other buildings. An opportunity now exists to use a very special 'Ironworks' as an educational resource and a visitor attraction in an important conservation area.

The second part of the title quotes the words of a smith to his apprentice 'Let your eye be your guide and your money the last thing you part with'. The reference to economy is perhaps not only a suggestion as to personal conduct, but advice for the economical use of material and time in design. The words 'Let your eye be your guide....' refer most obviously to a craftsman's reliance on his eye for line and form. The eyes have been said to be the windows to the soul and I believe that these words also mean that we should work with understanding and love. It seems to me that as we progress in our 'Study, Conservation, and Adaptive Use' of buildings and sites that we should bear this advice in mind.



Fig. 1. Edward Holl's plan for the Chatham Smithery; approved in March 1806. NMM photograph C7520d.





Fig. 3. Plan signed by the Clerk of Works in 1859 and subsequently amended to show improvements. NMM photograph C7519.



Fig. 4. Principal architectural elements of the No.1 Smithery.



Fig. 5. Western facade of the No.1 Smithery today. NMM photograph C7386/7.



Fig. 6. Base of a furnace chimney in the 5 ton hammer shop. The 'Weighing place with Foremen's Cabin over' can also be seen. NMM photograph C7378/5.



Fig. 7. The eastern range of Holl's Smithery today, with donkey boilers and electric crane in store. NMM photograph C7379/10.



Fig. 3. The 1869 slab shop, which became the pipe bending shop. A bomb fell here in 1940. NMM photograph C7377/9.



Fig. 9. A furnace in the pipe bending shop. The mark at the top of the furnace door was caused by shrapnel. NMM photograph C7377/10.



Fig. 10. The roof of the 1855 Iron Foundry. The lead flashing was stolen in 1981. NMM photograph C7525/1.



Fig. 11. The roof of the 1841 Engine House, now in very poor condition. NMM photograph C7379/4.



Fig. 12. A 'coal fire' showing the boshes. NMM photograph C7376/2.



Fig. 13. Mr. Knowler's berth as it was in 1982. NMM photograph C9218/D. Original MOD, Chatham Reg. no. 66/182



Fig. 14. Mr. Knowler at work on the 7th February 1968. NMM photograph C9218/D. MOD Chatham 66/182.



Fig. 15. Making shackles in 1967. Mr. Cleaves, in the white coat, was the chargeman and had the most experience of heavy forging of the men working then. MOD photograph Chatham 497.



Fig. 16. Mr. and Mrs. Cleaves outside their home. In the background the Chatham Lines, defences for the Dockyard, can be seen. NMM photograph C9216/17a.



Fig. 17. Mr. and Mrs. Cleaves in their back room. NMM photograph C9216/23a.

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THE SWEDISH IRON INDUSTRY AND ITS INDUSTRIAL HERITAGE

NILS BJÖRKENSTAM*

SUMMARY

The paper gives a brief summary of the development of the Swedish iron and steel industry from medeival times to present days. It proceeds with a presentation of some of the promotors of the conservation of the industrial heritage of the iron industry, not only regarding iron monuments and historic ironworks but also paintings and picture collections, archives and so on. The Swedish Ironmasters' Association and its work on the industrial heritage of the branch is finally described.

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September, 1984

Historical background

In prehistoric and early mediaeval times Swedish iron-making was mainly or perhaps entirely based on lake or bog ores. The mining of haematites and magnetites in central Sweden began in the 12th century. These were hard rock ores and were found in parts of the country that had not yet been permanently settled, because they were not particularly suited to agriculture. But adjacent to ore deposits were forests and plenty of water-power.

It is now quite clear that the extraction of iron ore and the establishment of iron manufacturing in the mining districts are connected with the first appearance of the blast furnace in our country. Gert Magnusson will talk about this in greater detail. The blast furnace required waterdriven bellows and they had to be located by suitable fall of water. The furnaces were built and operated on a co-operative basis, and originally there had to be eight partners or "bergsmän". The average number was normally more like a dozen. Generally speaking, all the "bergsmän" lived in villages surrounding their blast furnaces. The charcoal blast furnace was their communal property. Each "bergsman" owned his arable land and he was compelled to use his woodland for the production of charcoal. A mediumsized furnace might have required forests covering 5,000 to 6,000 acres, but these acres also had to furnish timber for building and repair of the furnace as well as houses and the fuel for their heating.

Pig iron was converted into malleable iron in the same place as the blast furnace, and this was done in small hearths. To begin with the bellows were worked by hand and the forging was also done by hand. The end product was osmund iron in the form of small pieces weighing about threequarters of a pound. The bulk of this was exported to towns belonging to the Hanseatic League. The word "osmund" seems to be mentioned for the first time in 1280 in an English document, when it refers solely to iron and steel in small pieces transported from Sweden by the Hanseatic League via Bergen in Norway.

Already during the mediaeval period, the blast furnace process was developed for larger furnaces, and older facilities beside small watercourses were abandoned. Slag and other traces of such mediaeval furnaces are still to be seen in our forests.

During the 16th century, State-owned ironworks began to be built which included blast furnaces as well as hammer forges with helve hammers for hammering bar, sheet etc. The Government tried various ways of encouraging the "bergsmän" to make bar iron instead of osmund, but at the beginning of the 17th century it was realised that they were not responding very well to these measures, mainly because they lacked the capital for the requisite new installations. The Government then changed its policy and instead encouraged the merchants of the towns to build modern forges for bar iron. This had the desired result, and during the 17th century Swedish bar iron production and exports grew exponentially.

An additional factor now entered the picture, namely the fear that the forests in the mining districts might become completely denuded if they had to go on serving the mines as well as the furnaces and forges; for it should be remembered that, before the advent of gunpowder blasting in the mid-18th century, hard-rock mining could only be carried out by means of



The charcoal blast furnace at Åg in the province of Dalarna is owned and preserved by Stora Kopparberg. It represents the blast furnace technology of the 1890s and the production of pig iron came to an end in 1927. During the last years a large conservation programme has been carried out at Åg with grants from the Labour Market Board. Photo MN.

fire-setting, which required huge quantities of firewood. This problem was solved by preventing the production of bar iron in the mining districts. The "bergsmän" consequently had to abandon their osmund and bar-iron forges with some exceptions and concentrate their efforts on mining and pig iron production. On the other hand, these trades became virtually the exclusive monopoly of the "bergsmän" and they were given certain other privileges such as freedom from conscription in time of war, lower taxation and so on.

So new bar iron forges were usually only allowed to be built outside the mining district, and even then anybody wishing to start a forge had to obtain a charter from the "Bergskollegium", the Board of Mines which between 1630 and 1859 dealt with all questions concerning mining and ironmaking. To obtain this he had to prove that he owned enough woodland to sustain the proposed yearly production of charcoal. The English system of renting land, mining rights and even works was practically unknown in Sweden. Blast furnaces were allowed to be built outside the mining districts, generally by ironmasters who wished to supply their own forges with pig iron. However, the limiting factor was the expense of transporting the iron ore. But by 1820 about 50% of the total pig iron production was still in the hands of the "bergsmän". Not until 1859 were the regulations for the "bergsmän" and their production of pig iron finally abolished.

The development of the Swedish iron industry thus proceeded along two main lines until 1860. Blast furnaces owned co-operatively by "bergsmän" had been operating since the Middle Ages in and outside the mining districts. In the forests of central Sweden particularly, there were innumerable small forges owned by ironmasters. Large, integrated ironworks including mines, furnaces and forges existed only in a few cases. Soon after 1800, however, the "bergsmän" began to experience economic difficulties. The Swedish iron industry stagnated because of the Napoleonic Wars and competition from the English coal-fired iron industry. The furnaces of the "bergsmän" were gradually closed down or else taken over by other proprietors. The "bergsmän" lost their dominant position as producers of pig iron, and by about 1860 this type of production had lost virtually all significance in the Swedish iron industry.

Technical progress during the 19th century brought about a complete structural transformation. During the 1840s, the Walloon and German processes were superseded by a more efficient method imported from England and known in Sweden as the Lancashire method. The Bessemer process for manufacturing molten steel was introduced in 1858, and the open hearth (Siemens-Martin) came a few years later. This led to the widespread construction of large ironworks close to the main transport routes. Among other things the breakthrough of the steel industry resulted in the closure of hundreds of blast furnaces and small ironworks. Between 1860 and 1913 the number of blast furnaces fell from 312 to 117 and the number of ironworks from 440 to 140, at the same time as output multiplied several times over. The early decades of the present century were characterised by an extensive amalgamation of Swedish ironworks into large industrial groups which also entailed the closure of several small facilities.



Korså »lancashire» forge about 30 kilometres south of Åg. The pig iron from Åg was here forged into bar iron. The forge was set up in 1840 and production was stopped in 1930. A lancashire hearth, five hammers with their waterwheels and a blowing engine have been preserved. The machinery is still left on its original place and it is sheltered under a roof construction. Photo MN.



The impressing charcoal blast furnace at Iggesund's »bruk» in the province of Hälsingland from the late 19th century, built in slagstone and brick. The production of charcoal pig iron was stopped in 1953. The bessemer plant at Iggesund ceased to work in the 1940s and one bessemer converter has been preserved. The forge and the rolling mill adjacent to the blast furnace remain, but the equipment has partly been removed over the years. Conservation work was carried out in the beginnings of the 1970s and a museum has been set up in the forge. Further equipping of the museum will be completed in time for the 300 years' anniversary of the company in 1985. Photo MN.

The Swedish steel industry today

The situation today bears the impress of the profound recession which has afflicted the steel industry all over the world since the mid-1960s. This has led not only to further rationalisation measures and closures but also to a complete transformation of the structure of ownership. Of the 30 or more iron mines which were operating in central Sweden no more than a decade ago, only two are still being worked. More than 95% of Sweden's relatively heavy exports of iron ore today come from the Lapland mines in the far north, which have been operated on a large scale only during the 20th century. In contrast to the 250 or so blast furnaces and ironworks operating in 1913, we now have only about 30 iron and steel centres.

The persistence of ancient production methods

The last charcoal furnace was not taken off blast until 1966, and lancashire-produced or "Swedish" iron was still being made here at mid-century. The iron ores of central Sweden usually had very small contents of phosphorus and sulphur, resulting in an iron of good quality which long remained in demand, not least in England. A special Swedish version of the Bessemer process and the open-hearth method using an acid furnace, i.e. the original process, remained in use here fore a long time. It was not until new metallurgical processes began to be applied in arc furnaces and oxygen converters that these steelmaking methods were able to compete with the open hearth as regards freedom from slag inclusions and tensile strength, and with Bessemer steel as regards cutting sharpness.

As a result of those long-lived processes, quite a large number of charcoal blast furnaces and forges were still in use during the late 19th century and during the first half of the 20th century. A completely authentic German forge in Hävla, Östergötland, and a Walloon forge in Österby, Uppland, have survived intact. Similarly, a Bessemer plant built in Hagfors in 1880 and an open hearth furnace in Munkfors with a charge weight of only seven tonnes, both still occupying their original sites, have been preserved by the Uddeholm Group in Värmland. Quite a large number of Lancashire hearths are still to be seen in several places, and an impressive number of charcoal blast furnaces have survived and are being kept in good repair.

Historical interest shown by mining engineers

Ever since the Middle Ages, high-grade ores and abundant timber supplies have made it possible for Sweden to export iron famous for its good properties and excellent quality. For this reason, the iron industry has occupied a pivotal position in the Swedish economy and exports of its products have been critically important. Quite early on, every mining district had state officials to supervise production and check the quality of the iron. Starting in the 1630s, a special body of officials was trained for this purpose within the Bergskollegium, whose members were not only given instruction but also sent on instructional tours of the Euorpean countries to keep up to date with technical developments. Sweden's first civilian technical university was established in the early years of the 19th century for the benefit of the iron industry. Basic mining and metallurgy studies today are pursued at just one school, the College of Mining and Metallurgy in Filipstad, and the relatively few university-trained mining and metallurgical engineers acquire the distinctive, traditional title of Bergsingenjör. These two categories of specially-trained engineers are, of course, highly aware of the long history and ancient traditions of their profession, and many of them come from places associated with the iron industry.

As I said, earlier methods of iron production persisted for a long time and were phased out gradually, even though the iron industry was well abreast of technical progress. This is also an important reason why mining and metallurgical engineers today are so well-informed about the history of their industry and why they are so interested in the heritage of the past. But then again, where many of them are concerned, old, abandoned industrial sites represent the surroundings in which they grew up or where close relatives of theirs once lived and worked. In addition we have the influence of the numerous writers and artists who, ever since the turn of the century, have been captivated by the past glories of the Bergslagen district, with its hammer forges and manor houses, furnaces and "Bergsman" villages.

Conservation of the historical heritage of the iron industry, from the turn of the century to the present day

It was also at the turn of the century that efforts began to be made to preserve at least some typical specimens among the several hundred remains of a vanishing epoch. For the most part these activities were started in the large companies, usually with company directors and their immediate assistants as the moving spirits. During the process of concentration which hade taken place towards the end of the 19th century, these companies had gathered a large number of old furnaces and hammer forges within their domains. Most such acquisitions had been made in order to gain control of raw materials, rather than for the sake of the actual facilities.

I can give you the following examples of industrial concerns which were early starters in the field of industrial conservation. Stora Kopparberg originally developed around the Falun copper mines, which have a history going back a thousand years. Between the 16th and 18th centuries it was ranked as one of the biggest producers of copper in Europe. During the 19th century and until the 1970s, the group was mainly an iron and timber concern, but today it is almost exclusively concerned with forest industries, apart from small-scale activities at the old mine. In addition to making the old mine accessible to visitors, Stora Kopparberg maintains old facilities, buildings, museums and archives. It is also preserving and maintaining more than 30 more or less complete mining and iron-manufacturing centres of historic interest.

The Axel Johnson Group maintains historic industrial buildings and sites at the Sala silver mine, at Avesta Jernverk, at Engelsbergs bruk (closed soon after the turn of the century) and at Pershyttan, which is a "Bergsman" village having its own furnace. Engelsberg also has archives, dating back to the 17th century.

Uddeholm, founded in 1668, also has extensive archives which include collections from a number of older mining and manufacturing communities. This company also began many years ago, in the 1920s, to exempt a number of

older places and ironworks from demolition, with a view to their future preservation. Two blast furnaces which had recently been closed down at that time deserve special mention, Motjärnshyttan and Brattforshyttan.

Corporate history illustrated by archives and surviving workshops has of course had a great deal of public relations value. Partly with this in mind, several companies have established museums and exhibitions illustrating technical developments from the earliest times down to the present day. Bergslaget's Museum, for example, founded, owned and operated by Stora Kopparberg, is older than the National Museum of Science and Technology in Stockholm. Another very interesting museum is the one belonging to Surahammar Bruk. The original equipment of the oldest workshop, dating from 1845, in the existing plant has been preserved and supplemented with parts from other historic ironworks. Exhibits here include a couple of old rolling mills which have been kept in situ.

One of the pioneers of research efforts to illuminate Swedish mining history was Carl Sahlin, Managing Director of Laxå Bruk. During the 1890s he was employed by Stora Kopparberg, at which time he put their collections in order. He also created a museum at Laxå in 1901, and he amassed a comprehensive collection of pictures - reproductions of paintings and photographs from various ironworks and bruks - which is now in the possession of Jernkontoret and known as Jernkontorets bruksbildsamling. It was also very much due to Sahlin that the history of mining and metallurgy was made part of Jernkontoret's research programme.

Jernkontoret and historical research

Jernkontoret - the Swedish Ironmasters' Association - was founded in 1747 as an interest organisation and finance institute for the Swedish iron industry at a time when a regular banking system had yet to be developed. The articles confirmed by Fredrik I that year laid down that Jernkontoret was to supervise pricing in the iron market and provide financial loans for ironworks. This banking and credit business has long since been discontinued, and economically speaking Jernkontoret is now a sectorial institute concerned with the compilation of trade figures and the conduct of research.

Only a couple of years after Jernkontoret had been founded, however, its deputies proposed that its programme be made to include mining and metallurgical research, and industrialists were swift to adopt the idea of Jernkontoret also codifying experience and disseminating knowledge concerning new technical developments, so as to help to improve the quality of Swedish iron. To this end, during the 1750s, Jernkontoret's links with the iron industry were organised into districts corresponding more or less to the master inspector districts which had been set up by "Bergskollegium", the Board of Mines in the 17th century.

These advisory functions within Jernkontoret were reorganised in 1904 in the form of a Technical Bureau, which in 1926 was also made to include the research activities which have been undertaken ever since in association with the participating companies. Participants in these activities, now conducted under the aegis of the Jernkontoret Research Department, have since 1969 included Finland and Norway. Practically all iron, steel and copper enterprises in the Nordic countries now take part in this research.

Research into the history of mining and metallurgy cannot be said to have been included in Jernkontoret's regular activities before 1917, although the journal published by the organisation, Jernkontorets Annaler, did include the occasional historical articles. Then in 1917 Jernkontoret recieved a donation, known as the Prytz Fund, for the promotion and funding of research into Swedish mining and metallurgy history. The donor was a Göteborg merchant who was a part-owner and auditor of Laxå Bruk, where the Managing Director was Carl Sahlin. Sahlin at that time was attached to Jernkontoret and it is quite clear that, next to the actual benefactor, credit must go to Carl Sahlin.

A period of intense activity now ensued. The Prytz Fund financed a number and variety of theses on mining and manufacturing industry which initially took the form of separate publications. Money from the fund, however, was not only applied to archive research and printing costs. During the 1920s and 1930s, for example, extensive inventories of slag and iron traces from the earliest history of the iron industry were undertaken in various parts of Sweden.

Then in 1966 the idea was broached of Jernkontoret also including a Historical Metallurgy Group. The Group was to have the following tasks:

- (1) To promote historical research into mining and its products.
- (2) To facilitate co-operation between researchers dealing with related topics.
- (3) To suggest and give priority to urgent research tasks.
- (4) To arrange lectures, discussions and field studies.
- (5) To facilitate the prompt publication and dissemination of findings.

It was decided that the Group was to have up to 15 members and that these were to include technologists, archaeologists, historians, economic historians, ethnologists and human geographers. Furthermore, Jernkontoret was prepared to cover the administrative costs involved by the activities, but support for research projects rated urgent by the group would have to be obtained from foundations and other funding organisations.

The Group also provides expert and supporting committees to projects mounted by other institutions, in connection with which it has funded or contributed towards preliminary pilot investigations during the introductory phase. The Lapphytte Project, which Gert Magnusson will be describing in greater details is one such example.

Ever since the Historical Metallurgy Group was set up, a great deal of work has been devoted to the preservation of industrial remains in Sweden, and this has been expanded to include national inventories in all the Nordic countries of the charcoal blast furnaces and hammer forges found to be in reasonably good condition. Marie Nisser, who has been in charge of these activities, will be giving you a briefing on the subject in due course. Until 1970, one can say that selection and maintenance were mostly decided on a private basis, by the owners themselves or by local associations. In 1982, Jernkontoret and the National Board of Antiquities held a joint conference at Sandviken concerning mining and metallurgy monuments. The purpose of this conference was to evaluate, in a Nordic perspective, the preservation measures which had been taken, together with the documentation which had been completed and the current state of research. Another aim was, of course, to discuss the apportionment of responsibilities between enterprise and preservation authorities, as well as between representatives of regional and municipal planning agencies and between university specialists and local historians.

The changes undergone by the Swedish steel industry in recent years have caused considerable difficulties and problems with regard to both preservation and the location of responsibilities for the conservation of industrial monuments. For example, the enterprises I mentioned earlier are still in existence, but their operational basis and in some cases their geographical locations have changed. All steelworks producing stainless steel have now been gathered within a single company. To take another example, Sweden today has just one group which is ore-based and operates blast furnaces. This group now includes a majority of steelworks producing ordinary steel. In this way the Swedish iron industry has unquestionably recovered its economic strength, but the old division of responsibilities for the historical heritage has more or less broken down.

During the autumn of 1980, Professor Erik Höök, Managing Director of Jernkontoret, called for discussions concerning ways of preserving and saving private documents and archives in the industry, within individual companies and in trade union organisations, as well as interviewing persons active during the structural transformation of the Swedish steel industry between 1965 and 1980, so as to secure material on which to base future research.

During 1981 and 1982, two researchers systematically visited companies in Sweden, cataloguing material from the period in question, interviewing people who had played a prominent part during this transformation period and, finally, sizing up the archive situation in each of the companies visited. On the basis of this review, the two researchers, together with two fellow economic historians, have applied for and obtained grants from the Bank of Sweden Tercentenary Fund for research projects aimed at analysing the structural transformation of the industry.

The review of company archives showed that filing routines were in need of revision in several places. Even so, steel company archives are among the best preserved in Swedish enterprise, and several companies can boast continuous series of accounts dating back as far as the 17th and 18th centuries. During the spring of 1984, an in-service day was held for filing company staff and archivists in order to examine the company archive situation more closely. A committee of the Historical Metallurgy Group was started to look into the best way of ensuring that company historical archives are preserved and made available for future research.

Within a short space of time, the documentation of events in the industry has encountered almost indescribable difficulties. Process computerisation, automation and the ongoing mechanisation of production are rapidly eliminating equipment which are only a few years old, parallel to an unceasing process of specialisation and concentration within new industrial localities. The first step taken by the Historical Metallurgy Group to avoid losing touch with these developments altogether has been to recruit a number of retired managers and engineers, some of whom are preparing description of their companies during their active years, while others have undertaken to compile historical retrospects of processes and methods of production during the past hundred years. In addition, company photographs of exteriors and interiors from 1920 down to the present day have been collected, so as to augment and complete the collection of pictures and photographs donated to Jernkontoret by Sahlin.

Otherwise, in the light of experience gained at the Sandviken conference, efforts are being concentrated on recruiting wider assistance from regional and municipal authorities, from preservation bodies and from enterprise, and also on establishing funds or foundations with preservation commitments. There have already been some instances of foundations being specially set up for the preservation of industrial monuments. One such example can be seen in the province of Värmland. Following an inventory of industrial remains in the province in 1973, a number of companies entrusted those industrial monuments whose preservation was judged to be a matter of national concern with a foundation, the Värmland Industrial Monuments Assocation. The list of holdings includes mines, charcoal blast furnaces, ironworks, power stations, waterpowered grain mills, waterways and a railway. Several monuments were already in good condition, while others have been restored on grants from the Swedish Labour Market Board. These activities are being directed by the Värmland Museum, with fixed annual grants from owners and municipalities on whose land the facilities are situated. In addition, the participating companies have promised that their own personel will take care of day-to-day maintenance. The Värmland archives, incorporating records from the entire region, are a similar joint venture between industry and municipal authorities in Värmland. Uddeholm, which I mentioned earlier, is one of the companies which have availed themselves of both these opportunities.

The prime concern of an industrial enterprise is to achieve and maintain the greatest possible efficiency in its production and sales. This precludes any extensive cultural commitments. There is nothing new about this, but the distinction between benevolence and business has been heightened by the recent recession. No company, however, can cut itself off completely from its history. Society as we know it today is not the exclusive handiwork of the present generation. Given the positive interest of iron industry employees in the history of their industry and the growing interest which preservation authorities are now also showing in the conservation of industrial monuments, there should be every chance of settling the question of preservation responsibilities within the iron industry.

It is no exaggeration to say that, in this particular case, Sweden not only owes a duty to its own industrial history but also has a great international responsibility to live up to.

Traces of the iron industry, from the prehistoric times down to yesteryear, are particularly abundant in Sweden. Ever since 1920, the National Board of Antiquities has been annually compiling and augmenting a register of archaeological remains, including those relating to the history of the iron industry. This inventory includes everything from remains of primitive iron production and ruined blast furnaces from various centuries to complete 18th- and 19th-century settlements. So far about 7,000 early iron production sites have been recorded, including something like 1,000 early blast furnaces. Sweden is a sparsely populated country. The early iron industry developed in places which were unsuitable for farming and further settlement after the industry had died out. For special reasons, ancient ironmaking methods and processes developed during the 19th century persisted here for a long time. A large number of companies have complete archives dating back to the 17th century, and there are Government archives concerning the iron industry which date back to the early years of the 16th century.

All in all, this would suggest that Sweden occupies a unique position in the world as regards both studies and the illustration of technology and process developments and of life and work in the iron industry.

Gert MAGNUSSON

SUMMARY

Swedish historians and archaeologists were looking for a site able to provide answers to some of the many remaining questions about early blast furnace technology in Sweden. They chose Lapphyttan, which seemed to be the oldest site in the important Norberg mining area in central Sweden. Six years of excavation work at Lapphyttan produced a lot of material, improving knowledge of technological history and about the mutual influences between iron-making and societal development in the l2th-l4th century period. Efforts are being made to develop in the Norberg mining district a kind of museum network, illustrating iron making technology and economy through history, in which Lapphyttan will have a very important role to play.

October 1984

Since 1938 a survey of ancient monuments of Sweden has been undertaken by the National Board of Antiquities. For the moment more than 500.000 monuments have been registered and described. Most of these monuments are prehistoric graves, but a lot of other things such as sites and, in this context, many ironproduction sites have also been found. More than 5000 bloomery sites have been registered and about 700 sites with different remains from medieval and later iron production of the blast furnace technology.

Most of these remains of an early blast furnace technology are to be found in the 10 mining districts of the middle of Sweden, called Bergslagen. There are also some remains of early blast furnaces in the south mining district of Sweden, Tabergs bergslag. In history research and among the archeologists, there is a great difference of opinion concerning the age of the introduction of the blast furnace technology in Sweden and the opening of rock ore mines. Also discussed is the question whether the great iron export from Sweden during the medieval age was based upon an iron production of bloomeries, German stückofen or blast furnaces.

These were a few of the important questions that have been discussed among Swedish historians and archeologists. Another question was the conservation of the constructions and what a medieval iron production site looked like. How was the whole site arranged? What different constructions were to be found on a site?

In order to try to answer these questions one looked around for a site good enough for this purpose.

Archeological investigations at Lapphyttan began during the late 1970s. The work started with a series of C₁₄ datings of a number of furnace sites in the Norberg mining area (bergslag). These investigations revealed several surviving traces of medieval furnaces, of which Lapphyttan proved to be the oldest.

Lapphyttan is situated at Olsbenning, Norberg, 190 km northwest of Stockholm. The furnace site took six years to investigate, and the project was coducted under the joint auspices of Jernkontoret, the Västmanland County Administration, the Västmanland County Museum, the National Labour Market Board and the National Board of Antiquities. By the time the fieldwork was completed in 1983, a complete medieval industrial facility had been investigated.

This comprised a ruined furnace, a roasting pit, five slag heaps, eight fairly well-preserved refining ^ hearths, fragments (i.e journal stones and iron wedges) of the waterwheel system powering the furnace blast, two pools and a store. In addition to the industrial facilities, the remains of a dwelling house were also investigated.

In and around the facilities, the archeologists salvaged more than 10,000 objects, mostly of iron. The bulk of the material comprises pig iron waste and forging waste, but there are also complete and broken-up pigs. The commonest finds are nails, horse-shoes, occasional knives and iron rods. The finds must also be said to include the abudance of iron ores included in the furnace charges, This, then, has made it possible to reconstruct work at a medieval furnace in detail.

At least two chronological horizons can be distinguished in the waste strata surrounding the furnace. The older of the two is mainly 12th century, the younger 14th century. The facilities investigated, it is true, reflect the situation here in the mid-14th century. The slags included in the slag heap, however, do not present any clearcut differences to suggest that the older horizon represents any different type of iron production. Referring to the old horizon, we are now prepared to speak seriously in terms of the blast furnace and a process industry attached to the

same having been established before the 14th century and, in all likelihood, as early as the 12th century in the Norberg Bergslag. Preliminary investigations of similar facilities elsewhere in the Bergslagen region have resulted in similar datings.

The development, function and social impact of mining and metal working had manifold effects on life in certain parts of northern Europe during the medieval period. In terms of production technology, a change took place from small-scale to more large-scale operations. The older technique of producing iron in rudimentary small bloomery furnaces with a relatively small yield did not require any elaborate organisation and was perfectly compatible with the agrarian scheme of production, The advent of mining and blast furnace technology involved completely ned demands in the way of social organisation and economic resources. The technology required investment capital, and the excess local production required a market.

It is in these terms thas we have discuss the iron industry and the role of early process industry in early medieval society, because it was this period which laid the foundations of modern society. This was the time when the preconditions were established of the national state with its defined frontiers, complete with a power of state represented by the crown and with the kingdom divided up territorially for administrative purposes.

During this same period in the towns of northern Germany, trading factories were established which, with their efficient entrepreneurial organisation and with new cargo vessels that were heavy by the standards of the time, fundamentally transformed the export trade of Northern Europe. This probably also boosted the development of agrarian production and economics in southern Scandinavia, which in turn made possible the earliest urbanisation process in northern Europe. Thus the agrarian heartland of southern Scandinavia probably became linked already in the 12th century with mining operations in central Sweden, as Lapphyttan seems to confirm. In this way an economic system evolved which included an extensive trade in primary materials, both by land and by sea.

The forgeable Osmond iron manufactured from the pig iron produced in the furnaces developed, together with copper, from the early Middle Ages onwards into a major Swedish export commodity - a quality product which dominated the European iron trade

During the last few years efforts have been made to make the whole mining destrict of Norberg into a living network museum where the whole development of the Swedish iron industry from the medieval ages to our time can be studied.

It is possible to show the technical evolution of the blast furnaces of the 14th century onwards by studying the ruins of a 16th century blast furnaces at Hyttjärn, the restored blast furnace of the 18th century at Landforsen and the early 20th century Ironworks at Engelsberg. The latter has already been presented by both Nils Björkenstam and Marie Nisser.

It is from the 16th century an onwards also possible in many ways to follow the development in mining in some of the mines of the district. The last mine here was closed down in 1981.

The villages around Norberg and Norberg it self and their social structure is still very dominated by the mining and the inron production. The very special kind of villages in the district built according to a medieval pattern for the iron priduction and is still very common even if the iron production was closed down more than 100 years ago and the farmers turned from iron production to forestry and farming. There are also very good opportunities of studying, in the monuments, the social evolution from the old cooperative mining society to a society with different socialgroups like the workers and the owners of the ironworks for instance in Engelsberg.

The people of Norberg are very proud of their history and their history is very much alive. One of the most important proofs of this and also a great manifestation is an open air theatre in one the old mines about a great strike in Norberg 1891. I would also like to inform you about the discussion concerning the presentation of the results of the archeological dig at Lapphyttan and the constructions. Of course Lapphyttan is a very important site in the whole discussion about the network museum in Norberg is it possible to reconstruct the ruin of the old blast furnace or should it stay as a ruin? If you make a reconstruction, should it be built on the site or somewhere else? Closer to a museum or somewhere where it is easy to get in contact with public. Is it possible to reconstruct a copy of the medieval blast furnace? Could it be made to function?

These questions have been very much discussed. For the moment, I think there is more or less only one vay to carry out the responsebility for both preservation of the monuments at the site and to present the results from the archeological excavation for the public. The site of Lapphyttan will be preserved with its ruins as an open area in the forest. Here you can visit the original site and study the monuments. There are some plans for building a copy of the site close to the open air museum at Karlberg in Norberg. One would like to build a copy of the blast furnace, some of the

eight finery hearths, one of pools, the roasting pit and the dwelling house. There is also a dream of having a campain in the blast furnace and to use it as a theatre.

Finally I would like to say the same as Nils Björkenstam, that Sweden occupies an unique position in Europe as regards both studies and the illustration of technology, process development and of life and work in the iron industry.



The Medieval Mining Districts of Sweden. (After Ake Hyenstrand 1977. Hyttor och järnframställningsplatser.)
Registered remains of blast furnaces in parts of Dalarna and Västmanland. The map shows the sites that have been in use since the llth century. (After Ake Hyenstrand 1977. Hyttor och järnframställningsplatser.)



The Mining District of Norberg in Västmanland.

The circles show blast furnace sites and the half circles show the forges. (After Ake Hyenstrand 1977. Hyttor och järnframställningsplatser.)

NORBERG Hyperbekeng KAGERSTA VASTERVALA

Norbergs bergslog







Radio carbon datings of the constructions at Lapphyttan.

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Lapphyttan. A proposed reconstruction of the furnace.



Proposed reconstruction of the blast furnace at Lapphyttan.



 A view over the industrial site at Lapphyttan from the pool for the waterwheel.



2. The remains of the blast furnace.



3. An airphoto of the remains of the blast furnace.



 The roasting pit. In the bottom of the pit there is still a layer with roasted ore.



5. One of the eight fineries of the site at Lapphyttan.



6. The remains of the iron store at Lapphyttan.

DOCUMENTATION AND PRESERVATION OF SWEDISH HISTORIC IRONWORKS

MARIE NISSER*

SUMMARY

The paper is concerned with landscape and building patterns of Swedish iron industry and it deals with the documenation and preservation of buildings and sites. It starts with the expansion of ironmaking in the 17th century and describes briefly building development from that period onwards. The existence of a conservation ideology and an active preservation programme at the turn of the century 1900 is emphasized. Financial contributions to historic ironworks' preservation are mentioned as well as legislative and planning instruments used for the protection of iron monuments. The documentation of plant and equipment carried out by the Swedish Ironmasters' Association is finally presented.

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Introduction

The two previous speakers, Gert Magnusson and Nils Björkenstam, have presented the Swedish ironmaking district, Bergslagen, and its plants as they were in the middle ages. The more recent history of Swedish ironmaking and the preservation of its industrial heritage was also sketched by Nils Björkenstam. In my paper I will treat some of the efforts which have been made to conserve and document historic environments of the iron and steel industry. To do so, I must first describe how the communities in Bergslagen were located, how they were developed and how they were built during the last few centuries.

The transformation of Swedish ironmaking during the 17th century

An important breakthrough for Swedish ironmaking took place during the 17th century. An essential element in this development was technical innovation and structural metamorphosis in the medieval ironmaking communities of central Sweden. New entrepreneurs, more infused with the spirit of capitalism, were encouraged to start manufacture and trade in iron. Financiers, technical experts and skilled workers were attracted from outside Sweden. Pigiron was produced more efficiently and osmund iron was replaced by bar iron. Sweden's natural resources – ore, forest and waterpower – began to be exploited on a larger scale. The encouragement of mining and smelting became an important part of government policy. An unbridled exploitation of natural resources was imposed by the Swedish state by the strict system of regulations. The well-known quality of Swedish bar iron was guaranteed by a well established control organisation.

During this period the export of iron was reorganised and increased to dimensions unthought of in the middle ages. The annual production of iron for export increased from about 4,000 tons osmund iron around 1530 to 27,000 tons of bar iron by the end of the 17th century. Together with the export of copper the iron trade became of paramount importance for the whole Swedish economy in that century. These changes in mining and smelting were so fundamental that they have been described as an industrial revolution in miniature (Hildebrand, 1957).

By the middle of the 18th century Sweden seems to have been responsible for 25-30 % of Europe's total iron production. During the second half of the century Sweden even increased its lead in bar iron production and the export of bar iron rose to an average of 48,000 tons. But at the same time other countries, such as Russia, France and Britain also increased their production, so that Sweden eventually lost its leading position. By the end of the century Sweden's share of the world market was probably not more than 15 %.

Community location and building in the iron industry

These developments during the 17th and 18th centuries were naturally apparent in the industrial communities and their buildings. Technical improvements were of decisive importance for pig iron smelting and bar iron forging. The timber clad blast furnace »mulltimmermasugnen» based on older Swedish blast furnaces, was improved, as was also the German forge »tysksmedja». The Walloons introduced the stone built blast furnace and the Walloon forge. Bar iron from the Walloon forges came to be sought after for its excellent quality. Walloon iron constituted however only a small proportion of the total Swedish bar iron production, that is to say, about 10 % while German forged bar iron made up about 90 % of Swedish iron production.

The location of communities in the central Swedish iron district – Bergslagen – was also affected by these new techniques and scales of production. The Board of mines – Bergskollegium – laid down rules for good husbandry with forest resources and granted privileges to new iron manufacturers. Apprehensive for the supply of timber, the central – Bergslags – district was reserved



Plan and section of a timber clad blast furnace according to Garney: Handledning uti Svenska Masmästeriet, 1794. Drawing published in Ivar Bohm, Den svenska masugnen under 1800-talet. Jernkontorets Bergshistoriska utskott, Hyttrapport 1, 1974.



Landfors timber-clad blast furnace in the province of Västmanland. The blast furnace was founded shortly after 1630. From 1792 onwards it was owned by Engelsberg's »bruk» and produced pig iron for the bar iron forge at Engelsberg. Landfors blast furnace was closed down in the 1840s. It has been preserved by its owner, Avesta Jernverks AB and it is protected according to the law of ancient monuments of 1960. Photo MN.

for mining and smelting. Thus the peasant ironmakers »bergsmännens» pig iron production was protected. On the other hand, the new bar iron forges were relentlessly directed to the periphery of the Bergslags district - to forest areas with good access to water power.

Two characteristic patterns for iron-producing communities evolved during this period: the »bergsman» village and the »bruk». They became two diametrically opposed solutions, where different production organisations shaped the communities, their landuse and building traditions.

The Swedish terms »bergsman» and »bruk» describe institutions so peculiar to Sweden that I think it is better to explain them than to translate them.

The »bergsman» village had an agricultural peasant character, combined with ironmaking. Farming, mining and smelting were combined with the other tasks for the different seasons of the year. In such a village each »bergsman» farmed his own land but he worked the charcoal blast furnace as part-owner. Each part-owner arranged independently for the production of pig iron in all the necessary stages. In the winter, when he could use a sledge, he fetched his ore from the mine. In the autumn he burned his charcoal. In the spring, when the melting snow gave water power sufficient to drive the water wheel for the bellows, the blast furnace was started up. Each »bergsman» in turn produced his pig iron during the weeks when the blast-furnace operated. Around the blast furnace each »bergsman» built his roasting pit, his charcoal shed and his pig iron shed. The blast furnace was thus surrounded by a multitude of small turf-roofed log houses sometimes arranged according to a regular plan.

A »bergsman» had certain tax privileges and certain obligations. These were dissolved in 1859. Some »bergsman» properties were aquired by industrial companies. The remainder found it difficult to compete with the large ironworks. Thus under the last years of the 19th century an industrial organisation and at the same time a significant cultural institution became extinct, after many centuries' service to the history of the Swedish economy.

Today only fragments remain of the ancient »bergsman» villages. The timber clad furnaces have generally disappeared. We have, however, a few remaining blast furnaces in good condition. The »bergsman» homesteads have survived better, although many have been demolished over the years. To understand and experience life in a former »bergsman» village demands considerable imagination and knowledge. We have here a comparatively unexplored field of research. We need also new efforts in documentation and better planning to care for the environments worth preserving for future generations.

The blast furnace in a »bergsman» village was run by an organisation of independent farmers who were also miners and ironmakers. In their villages the random layout of the buildings reflects this organisation. The regular plan of a Swedish »bruk» reflects a very different pattern. These were ironworks with a patriarchal organisation, with an ironmaster at the top followed by officials, regular workers and seasonal workers. This pattern which evolved during the 17th and 18th centuries can be seen most clearly in the ironworks in Uppland, north of Stockholm. During this period they were the largest independent iron producers. Here the manor house and the church stand as symbols for worldly and spiritual power. Between them the skilled workers' dwellings, the warehouses, the blast furnaces, the forges and the charcoal stores had their appointed places. Industrial and residential buildings stood side by side, indissoluble parts of a whole.

This pattern was more or less the same for every »bruk». A regular plan characterised the community, but within this tradition there were many variations, according to the master's architectural ambitions, the size of the plant and a number of other factors.

The ironworks were the core around which the other buildings were arranged, but they were not the only activity within the framework of a Swedish »bruk». The »bruk» owned more than just a





Pershyttan charcoal blast furnace was rebuilt in 1856 and modernized in 1896 och 1940. It was closed down in 1953. The blast furnace has been preserved by its owner, Avesta Jernverks AB and conservation work has been carried out during the last decades. Not only the blast furnace plant but also other buildings have been preserved. Photo MN.



Stimmerbo »bergsman» village is known in documents documents from the 16th century. The two maps give an illustration to what has happened to landscape and building during the last hundred years. The blast furnace at Stimmerbo was closed down in 1873. The map at the top shows the village area in 1866 and the map below it the same area in 1979. Published in: Bergslagen. Arbetsplatser och bostäder under hundra år. Konsthögskolans arkitekturskola, 1983.



Plan of Lövsta bruk. Published in: Architectural Conservation in Europe. Bergslagen by Marie Nisser, 1975.

mill. It was not only a small, well-defined industrial plant with workers' housing, it was an extensive domain with agricultural land, grazing, forest and water. The company had its own complex transport organisation. A host of neighbouring farmers were engaged in the transport of charcoal and other material. Their work for the »bruk» was often a sideline or seasonal employment, as a complement to their purely agricultural activities. Farms and cottages for tenant farmers, seasonal workers and independent farmers surrounded the »bruk».

Building developments in »Bergslagen» during the 19th and 20th centuries

The next phase began with the breakthrough first of the Lancashire forges and then the ingot steel processes in the second half of the 19th century. As Nils Björkenstam has mentioned, hundreds of small charcoal blast furnaces and forges were closed down during this period because they could no longer compete with larger, more modern and more efficient ironworks. There remained nevertheless a possibility of manufacturing iron according to the old methods. A number of blast furnaces and forges were able to continue as before without any fundamental changes. Among these were the Walloon plants, which could still find a market for their renowned iron. They kept their plant going on traditional lines with old-fashioned equipment. They never considered expansion, everything went on as before. As enclaves leftover from the golden age of Swedish iron manufacturing, these bar iron works survived, inaffected by modern industrial environments and ways of living. The last Walloon forges ceased production as late as during the first half of this century.

In the most expansive iron-manufacturing districts, on the other hand, development during the second half of the 19th century was dramatic. New communties grew up, with compact industrial areas and a core of workers' tenements, all arranged in a regular town plan. These town plans were often based upon older planning principles, but the quantity and scale of the new buildings made them quite unlike the old building complexes. Sometimes small trading communities grew up nearby, together with sparsely scattered buildings of every conceivable sort, all dependent on the urban conglomeration: ancient villages in the process of becoming semiagricultural suburbs for industrial workers, and here and there cottages housing those who earned their living wherever they could – in the mills, in the forest or on the farms – a meagre income and an uncertain employment. But the population structure did change, and with it both the landscape and its buildings.

Our knowledge of this period of transition is quite good, but we still need considerable efforts in documentation and research if we are to understand more completely how these changes were interrelated.

In the late 1940s an industrial boom began and continued with some interruptions for more than 20 years. Naturally this left its mark on the buildings. The mines were refurbished and equipped with high concrete towers and gigantic silt deposits. Radical changes occurred in the company towns: the steelworks were expanded and modernised, industrial areas began to assume enormous proportions. Late 19th century worker's housing was demolished to make way for apartment buildings.

In a previous paper we have learnt about the readjustment problems of the Swedish steel industry with the result of closures, further rationalisation and in some cases a complete tranformation of the structure in ownership. In this period of recession and need for survival the future of the industrial heritage of the branch is, of course, a minor problem. It is nevertheless important. The change in ownership of former large groups could be a backdraw when we look at the future protection of iron monuments. New owners may not be prepared to maintain those monuments and there will be a heavier burden on communities and official preservation bodies to take actions for preservation.



Siggebohyttan »bergsman» manor from 1797, taken over by Örebro regional museum in 1909 and soon after that it was opened to the public as a museum. Photo MN.



Engelsberg's »bruk» with the bar iron forge to the right and the manor of the owner in the background. Engelsberg's »bruk» with its old charcoal blast furnace, bar iron forge and a number of other buildings has been preserved by the owner Avesta Jernverks AB since the closure of the blast furnace in 1919. In the beginning of the 1970s a large conservation plan for a number of buildings at Engelsberg was drawn up and and carried through. The work was financed by the owner with subsidies from the Labour Market Board. Photo MN.



(sten- eller mulltimmermasugn), ej vårdad. Blast furnace of early construction, preserved but not taken care of.

Hytta av äldre konstruktion. Blast furnace of early

construction, preserved and taken care of.

Hytta av nyare konstruktion, helt eller delvis bevarad. Antingen använd för nytt ändamål cller ej vår-

Blast furnace of later construction, completely or partly preserved. In use for new purposes or not taken care of.

Hytta av nyare konstruktion, helt eller delvis bevarad och vårdad. Blast furnace of later construction, completely or partly preserved and taken

Observera att symbolema endast definierar hyttornas nuvarande tillstånd, ej värderar desamma.

Charcoal blast furnaces still standing in 1973. Röfors and Bredsjö blast furnaces have been pulled down since then. Map published in : Hyttor i Örebro län. Jernkontorets Bergshistoriska utskott, 1974.

Conservation policies

Nils Björkenstam has spoken of the efforts which were made at the beginning og this century to conserve plant and environments of historical importance for the iron mining and manufacturing industry. Let us however take another look at them, for they have become the keystone for Swedish industrial conservation today.

The demist of so many blast furnaces, forges and ironworks in central Sweden was a stage in the process of industrialisation which gathered speed towards the end of the 19th century and which with increasing significance left its mark on Swedish society in general. The dissolution of the old manor-, peasant- and »bergsman» systems were an inevitable consequences of these changes. In this way long-established settlements were deprived of the importance they once had had in the Swedish economy. At the same time, however, poets, artists and architects turned towards this same countryside, so rich in associations and suggestive environments. The wave of nationalistic romanticism which swept over Sweden at the turn of the century drew some of its inspirations from the world of the ironmasters and their works. Contemporary art and poetry produced lyrical illustrations of the smoke rising from the charcoal burners deep in the forest, of the flaming blast furnaces in the winter darkness and of sweat-drenched ironworkers forging bar iron under heavy hammers the light of the hearths.

As we have heard, it was not only poets and artists who were fascinated by the changing character of the Bergslag district. The contributions of these other were more prosaic, but gave nevertheless a permanent result in the field of conservation of the historic environments from this district. Among these contributors were the managers and local historians, who succeded in ensuring that a number of the redundant blast furnaces and forges continued to be maintained. Other contributors were architects who held up those environments to admiration and used them as models when they designed new residential areas.

Among the earliest rescue efforts was the saving of Siggebohyttan, an impressive »bergsman» manor. In 1910 it was acquired by a society at the regional museum in Örebro; a few years thereafter it was opened to the public. Very many of the blast furnaces and forges which became redundant were not immediately demolished. They stood instead derelict and waited either that nature should reestablish itself over these places where men used to work, or that some interested owner should keep them standing through a minimum of maintenance throughout the year, as indeed often happened. The blast furnace at Löa in the Örebro region was for example used for the last time in 1907. During several years there was hope of starting up again, but eventually it came to be considered rather as something worth preserving. The same applied to the Walloon bar iron forge at Österbybruk in the Uppland region, when it was closed in 1906. The charcoal blast furnace at the »bruk» in Engelsberg in the Västmanland region was closed in 1919, but the owners decided that the whole environment should be preserved intact. During the years that followed the buildings in this »bruk» were looked after, as were the blast furnace and forge. In the 1920's a light engineering business was located in Engelsberg to keep the community going. For the same reason one of the old barns was rebuilt to house the central archives of the Axel Johnson Group - one of Sweden's wealthiest businesses, with a very large collection of historical documents. In these cases we can see both the protection of buildings against decay and an active programme to keep alive the characteristic environment of a Swedish »bruk»

I could give you many other examples. By efforts like these a number of »bergsman» and»bruk» environments have been preserved — old charcoal blast furnaces, forges and the characteristic communities around them. The initiatives which were taken at the turn of the century have been of utmost importance for the continued upkeep of the industrial heritage of the iron industry.

Conservation legislation

The legal possibilities for ensuring the conservation of industrial environments in Sweden are quite modest. There is a law of 1960 on the designation of buildings as historic monuments, but it can only be applied if the owner is himself prepared to assume the economic responsibility for looking after the building. This law is principally intended for individual monuments and is not applicable to complete environments. The restoration and maintenance of industrial environments can be very expensive. A plant often consists of a number of buildings, all of which are important and irreplaceable components in the whole. In such situations the law on historic monuments runs into obvious difficulties. Nevertheless about 20 industrial structures and environments have been designated historic monuments. Among these are a number of »bruks» such as Gålsjö in the Ångermanland region, Engelsberg in the Västmanland region and Forsmark in the Uppland region etc. But there are few comprehensive industrial environments that are protected.

One of the requirements of this law is that the owner shall not use the building for his own profit if the state has contributed to the restoration costs. The law is thus not applicable to parts of the industrial heritage which are still working.

A law from 1942 on ancient monuments protects abandoned ruins, foundations and other traces of older industrial plants. In this category come the prehistoric remains of primitive iron-making, such as ruins of furnaces and slag heaps. Current practice is to apply the protection afforded by this law to former places of work and dwelling which have been abondoned for at least hundred years. Many sites of relatively recent date can be scheduled according to this law. Among them are some charcoal blast furnaces which ceased to work in the late 19th century.

Preservation work during the last decades

The past years have seen considerable investments in the care of old industrial plant and a good proportion of this has been devoted to the iron industry. Until the beginning of the 1960s it was always the companies themselves who met the bill, but during the 1960s and 1970s a number of industrial plants have been restored thanks to contributions from the National Labour Market Board, who has engaged unemployed buildings workers in the restoration work on historic buildings. Thanks to the Board's subsidies a number of industrial buildings have been preserved. Among the larger plants are some impressive charcoal blast furnaces rebuilt and modernized in the 19th and 20th centuries and finally closed down in the first half of the 20th century: Pershyttan in the Örebro region, Långbanshyttan in the province of Värmland, the blast furnace at Iggesund's bruk in Hälsingland and Åg's blast furnace in the Dalarna region. The Walloon forge at Österbybruk in the Uppland region and the Lancashire forge at Karmansbo in the province of Värstmanland have also recently been restored with grants and assistance of the Labour Market Board. All those preservation schemes are carried out under the supervision of the National Board of Antiquties in co-operation with the Regional Offices of Antiquities.

During the last two years the State has also increased its contributions to building conservation. It was, however, only a third of what a national commission on building conservation had estimated to be necessary. In 1982-83 the National Board of Antiquities had 46.3 million SEK —about US \$ 6 million — available for buildings conservation. In 1983-84 the contribution is 18.1 million SEK — about US \$ 2.3 million — and that must suffice for the care and conservation of every sort of culturally valuable buildings in the country; naturally industrial buildings are only a small fraction. The annual financial contribution from the Labour Market Board to industrial building preservation is estimated to be about 5 million SEK — US \$ 0.65 million.



Moviken charcoal blast furnace in the province of Hälsningland. The production of pig iron came to an end in the 1950s. The owner, Aktiebolaget Iggesunds Bruk, wanted to preserve the blast furnace and for that purpose a foundation was created to bear the responsibility of future preservation. Photo MN.



Charcoal blast furnaces which have been working in the province of Närke at some time between 1500-1900. Published in: Hyttor i Örebro län. Jernkontorets Berghistoriska utskott, 1974. The map has been compiled according to B. Waldén, Örebro stad och län i relation till äldre svensk bergshantering. Med hammare och fackla. VIII, 1937.

Strategies for preservation

The taking care of industrial buildings is usually more complex than the conservation of historic monuments. It must be recognized that there are many different strategies for the preservation of an industrial plant.

The situation for the preservation of historic ironworks in Sweden is favourable. Almost all of the blast furnaces and forges have been preserved as monuments in situ. They are usually to be found on land which has not been reclaimed for other purposes. Quite a number of those old ironworks have been left relatively intact and they have kept their original equipment. The preservation work is intended to secure the buildings and equipment from decay. At the Engelsberg blast furnace and forge, one further step was taken. The water-wheels driving the blower in the blast furnace and the hammers in the forge were repaired to working condition, and on special occasions visitors may see them work.

At the blast furnace at Löa in the Örebro region restoration work went a bit too far away, when they started to reconstruct buildings and equipment which had already dissappeared. The conservation policy is normally to leave a monument as it stands without carrying out fargoing reconstructions. The authentic state of the monument is regarded as important.

Alas, we cannot preserve all the remaining blast furnaces and forges as monuments. In some cases the owner has already altered the interior of the plant but he may have kept the building as it was. One of the charcoal blast furnaces has been turned into flats. Another has been used as a store with a lift installed in the furnace pipe. But it is preferable with such compromises than to pull the buildings down — many furnace buildings and re-adapted forges are important elements in the industrial environment.

There are few attempts to re-erect iron monuments when the main structure has already disappeared. Sometimes local societies want to reconstruct an old ironworks on its original site. We try to convince them that financial resources should be spent on monuments still standing.

It is regarded as important that a preserved monument should be accessible to visitors if public money have been spent on it. Normally, some sort of information is given at the site. Much more could, however, be done to present and to explain the site. Very rarely our historic sites have been exploited on commercial basis. As soon as a site is recognized as a tourist centre, so many facilities are needed and added and the original outlook of the historic environment is threatened. No doubt many more tourists could be convinced to visit many of the historic ironworks, but sometimes that cannot be arranged without certain complications.

The recording and documentation of historic ironworks

Current Swedish laws on historic buildings and ancient monuments provide a formal possibility for protecting industrial buildings and environments, albeit a limited possibility. There is however in the official planning process the possibility of designating buildings and environments as worthy of conservation. A nationwide effort has been made since 1970 for better husbandry with our land and water resources, and in this town and country planning, conservation aspects have been accorded a considerable interest. Regional conservation programmes are now being drawn up in every region of Sweden under the care of the regional conservation officer and the regional museum.

The Historical Metallurgy Group of the Swedish Ironmasters' Association – Jernkontorets Bergshistoriska utskott – has commissioned an inventory of all the charcoal blast furnaces and forges still standing in Sweden. Corresponding inventories have been made in Norway and Finland. When the results of these very comprehensive documentations have been summarized and evaluated, we shall have a good grasp of which objects are worth preserving from the Nordic perspective.



A map showing some of the larger preserved charcoal blast furnaces and forges in Sweden.

It is not easy to tell exactly how many charcoal blast furnaces, forges and other plant are still standing in Sweden. One must first define what we mean by still standing». The inventory made for the Historical Metallurgy Group is restricted to relatively intact objects, so well preserved that both the building and its equipment are still there. In some exceptional cases only the building remains, but at least for the most part the building is still standing with the roof on. In a few cases we have even included larger ruins, but we have not documented the hundreds of blast furnaces and forge-sites where perhaps nothing more than the foundations remain. Such objects are, however, recorded in the register of ancient monuments, and to include them in the inventory in question would have made our task too massive. It has naturally been difficult to be consistent when taking this inventory but the essential achievement is that we now have quite good grasp of how many objects it would be valuable to preserve, how many are already cared for and how many it is intended to preserve in the future.

Eight of the old timber-clad blast furnaces - mulltimmerhyttorna - can be said to remain; some of them are becoming delapidated for want of maintenance. Four of these blast furnaces are preserved in good condition, two of them as part of complete blast furnace plants with all the associated equipment and two of them only as blast furnaces.

A number of other blast furnaces remain, some of them in use as late as this century. Many of them are of medieval origin. A large number were started during the 17th century. Generally they were extensively rebuilt during the 19th and 20th centuries, to compete with more modern plant. About fifteen such blast furnaces exist today, of which about ten were restored during the 1970s and 80s. Among the best preserved are the blast furnaces at Iggesund and Moviken in the Hälsing-land region and the blast furnace at Avesta in the province of Dalarna – not to mention again the blast furnaces which have recently been preserved by grants from the Labour Market Board. As we already have heard, there is one well preserved Bessemer plant at Hagfors and an early openhearth furnace – Siemens-Martin method – in Munkfors, both in the Värmland region.

That was a brief presentation of the inventory we have carried out. It is now more or less ready for publication and will include a presentation of the development of iron production in the different regions of Sweden as well as a catalogue of preserved plants. This documentation has only covered the industrial buildings, whichs is a drawback. Many of these objects are in fact just elements in a well preserved environment, which would be worth caring for for its own sake. In such situations the documentation ought to be extended. It has become more and more apparent, that iron production ought to be documented in the broadest possible context. We still have before us so many charcoal furnaces, forges, transport systems, workers' houses and iron-masters' manors that it would be possible to present the different phases of historical development with reference to existing monuments, buildings, environments and landscapes.

Conclusion

Conservation has a good starting position in the fields of mining and iron production. We still have a number of objects and environments worth caring for. But the future gives us cause for uneasiness. Every year a number of objects dissappear because we cannot maintain them. During recent years the pattern of ownership has changed and a number of plants, which previously were cared for by the companies have found new owners who perhaps do not feel the same responsibility as their predecssors. Too few of the iron-producing environments are protected by law. It still depends on the owner's sense of responsibility and on the economic circumstances, which of our existing iron production plants shall survive in the future. We therefore need better planning to safeguard the interests of iron production history.

On the other hand a considerable number of charcoal blast furnaces, forges and other of our historic ironwork's buildings have been preserved during the last decades thanks to the grants from the Labour Market Board.

There is also an increasing awareness of the importance of the industrial heritage of the iron industry, not only among official preservation bodies but also in communities, in local societies for the protection of the cultural history and among people in general.

All this is very encouraing and gives us confidence to carry on our documentation and preservation projects.

Do I dare claim that it is not only of national interest but even of international importance that we try to find a future for the industrial heritage of the Swedish iron industry?

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LES MONUMENTS HISTORIQUES ET LA POLITIQUE DE PROTECTION

DES ANCIENNES FORGES

Françoise HAMON *

SUMMARY

In 1929 the Beaux-Arts Service decided to register as a "Monument historique classé" a cannon foundry in the city of Strasbourg, a beautiful building with a baroque ornament.

In 1943, the Forges de Buffon, located in Montbarb (Burgundy) were registered in accordance with the law of 1913, no doubt thanks to the fame of the founder, the scientist and encyclopedist Buffon.

Not until 1971 did the Ministry of Culture take a similar decision. Since then, the protection of historic iron factories has gone on with regularity with an average of one "classement" per year.

From 1982 the number of "classements" increased, with five favorable decisions, and during 1984, three other monuments will be officially registered in the list of second-level "Monuments historiques".

All the iron foundries registered date from the late eighteenth and early nineteenth century. They are selected according to their architectural and picturesque qualities rather than on the basis of their technical and historic characteristics. Architectural elements have been registered even when completely isolated from their original industrial context and significance.

Weak criteria and empirical approaches to protecting industrial monuments are nowadays unacceptable. The greatest scientific knowledge with consequences for the best restoration and reutilisation is required for today's standards.

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Préalable indispensable : il faut préciser la nature des instances qui ont officiellement à veiller sur l'ensemble du patrimoine bâti, à en assurer l'étude et la protection : le Ministère de la Culture est seul chargé de cette double tâche qui est exercée par les services de l'<u>Inventaire général des Monuments et Richesses artististiques de la France</u> (étude), et par le service des <u>Monuments Historiques</u> (protection juridique et travaux). Le premier organisme existe depuis plus de vingt ans ; le second, qui a plus de cent ans d'âge, a longtemps assuré seul les tâches de connaissance et de protection/restauration.

Les deux organismes sont nés de la même tradition monumentalisie, très forte en France, héritée de l'érudition locale du XIXe siècle et fondetrice du culte moderne des monuments. Selon cette tradition, il existe deux critères pour juger de l'intérêt d'un édifice : la valeur artistique, c'est-à-dire une qualité esthétique intrinsèque, particulièrement exprimée par le décor architectural et/ou la symétrie et l'organisation du plan et des façades. Autre critère : la valeur historique pourla nation, histoire politique ou histoire de la civilisation (la maison de Jeanne d'Arc, par exemple, pourtant très controversée, très défigurée, ou celle de Victor Hugo).

Dans les années 1920 est apparue une nouvelle notion de valeur, la seule "ancienneté". Cette notion s'est d'abord appliquée aux architectures mineures des villes, puis à celle des campagnes : des rues entières de vieilles maisons ont été déclarées "Monument historique", des villages dans leur totalité. C'est alors que l'architecture du travail est apparue : il y avait dans ces ensemblesdes ateliers, des boutiques, des manufactures.

Mais la métallurgie restait en dehors de ces zones d'intérêt : isolée presque toujours en milieu rural, l'usine à fer restait encore en 1960 complètement méconnue. Seuls, quelques historiens de l'économie régionale connaissaient l'existence des forges anciennes et en évoquaient l'histoire technique et la production. L'édifice n'y était qu'à peine évoqué dans sa réalité bâtie et sa valeur patrimoniale.

Le Ministère de la Culture ne comptait alors que des historiens de l'architecture formés aux disciplines les plus académiques. Au cours de leurs enquêtes sur le patrimoine rural, les conservateurs des services de l'Inventaire général ou des Monuments historiques rencontraient ces édifices de production dont on ne leur avait jamais mentionné l'intérêt, ni au cours de leurs études, ni dans les services où ils travaillaient. Maladroitement, et il faut bien le dire, dans l'indifférence des milieux scientifiques spécialisés en matière de patrimoine (notons qu'il n'existe pas de bibliographie sur le sujet avant 1970 au plus tôt), ils tentaient de défendre ces édifices "anciens" ni esthétiques, ni vraiment historiques). Il faudra plus de dix ans pour que leur intérêt, pas toujours très clairvoyant, aboutisse à des procédures systématiques d'étude et de protection. C'était le temps où l'archéologie industrielle naissait en France () avec des publications encore confidentielles (rapport de Maurice Daumas), la création d'une association fédérative et bientôt la multiplication des initiatives locales.

Un rapide coup d'oeil sur les statistiques de protection et un examen des étapes parcourues constituent la meilleure démonstration. Premier chiffre à donner : 15 édifices liés à la métallurgie ont été protégés entre 1928 et 1982 :

- en 1928, très précocément, ce qui était alors le service des "Beaux-Arts" classe une ancienne fonderie de canons de Strasbourg (bâtiment sur cour et sur le quai Schoepflin).

L'examen du dossier de présentation de l'édifice à la Commission des Monuments historiques (chargée de donner les avis que le ministre de tutelle suit habituellement) est très révélateur : pas un mot sur l'histoire de la production métallurgique, mais des commentaires - maigres - sur les qualités <u>esthétiques</u> de l'édifice (une photo de la façade).

La protection a été obtenue très rapidement, en moins d'un an, pour protéger l'intégrité de l'édifice où s'installait alors une manufacture de tabacs. Fait significatif, en 1949 on affecte la fonderie à une synagogue provisoire (il s'agit de réparer les destructions de la guerre). La preuve est faite que ce n'est pas une fonderie de canons qui a été protégée en 1929, mais un édifice à façade maniériste.

En 1943, la protection de l'ensemble des Forges de Buffon a une toute autre signification : le souvenir du grand savant qu'on exalte, et les critères sont alors <u>historiques</u>. L'histoire de la science française est ainsi mise à l'honneur.

Il faut attendre près de vingt ans pour voir proposer un autre dossier et tout a changé : à <u>Beaumont-la-Ferrière</u> en Bourgogne, en 1971, seul est répertorié à titre de "monument historique" le haut-fourneau, ou du moins ce qu'il en reste, sa partie inférieure. L'argumentation met en avant l'intérêt historique : ce serait le seul témoin de l'ancienne métallurgie si riche dès le XVIe siècle dans la Nièvre ; l'intérêt esthétique du très bel appareillage des trous de coulée, le pittoresque romantique du lingot de fer resté en place sont soulignés. On ne protégera pas le bâtiment qui abrite le haut-fourneau, pourtant bien caractéristique des années 1820.Ici , seul a été pris en compte le caractère technique.

L'année suivante, on soumet le classement d'une fonderie(1816-1820) à peu près complète à l'avis de la Commission de classement ; pour la première fois, c'est la lisibilité des dispositifs techniques qui va être invoquée pour demander la protection du haut-fourneau, de la halle à bois, des vestiges de l'installation hydraulique (le patouillet), encore lisibles après leur transformation en pisciculture dès 1909. Le dossier s'appuie sur une bibliographie ancienne et des archives privées et publiques. Le dossier a été entrepris en 1966 : le conservateur attire déjà l'attention du ministère sur l'intérêt d'un ensemble fonctionnel presqu' intact. Il lui aura fallu six ans de patience pour obtenir une décision de Sauvegarde. En 1972, également, en Dordogne (Chaleix), on protège un bâtiment isolé, un logement d'ouvriers (10 familles), d'une forge disparue dont il ne reste aucun bâtiment d'exploitation. Protection d'un vestige isolé, devenu insignifiant, maladroitement restauré, mais très intéressant pour l'histoire du logement ouvrier au XVIIIe siècle et au tout début du XIXe.

La protection de vestiges se poursuit avec le haut-fourneau de Cousla-Granville, dont M. Daumas conteste l'intérêt, car il le trouve à la fois trop tardif (1865) et isolé de son contexte de production. C'est aussi l'avis de l'architecte des Monuments historiques qui considère que l'édifice ne relève que du "folklore lorrain" et ne présente <u>aucun intérêt</u>. Pourtant, l'argumentation du conservateur qui présente le dossier sera entendue : l'archaïsme d'un fourneau pour la fonte au bois en 1865 est un élément à prendre en compte. En outre, la Lorraine a une vocation métallurgique et dans ce contexte, le fourneau prend un sens particulier. Dix ans plus tard, le fourneau donné par la famille du constructeur à la chambre de la métallurgie de Longwy, est très mal présenté derrière ses grilles au bord de la route, mais il a été restauré et sauvé (il tombait en ruine en 1974). En 1975, on retrouve ce parti à Saint-Front-sur-Lemance, où on inscrit à l'inventaire des Monuments historiques un haut-fourneau tardif (1854).

Le dossier signale l'existence de quelques "bâtiments de fonction", mais ne juge pas utile de les photographier ni de les décrire, encore moins de les protéger.

La description du fourneau est rédigée en termes d'architecture savante :"arc en plein-cintre, crossettes, voûte en cannonière, corniche en talon " ..., mais pas un mot sur les dispositifs techniques.

En 1976, pour la première fois, un dossier prend véritablement en compte la dimension technique d'un haut-fourneau de Dordogne. C'est qu'il existe une importante étude sur ces forges de Ruelle, à Saint-Front-sur-Lemance créées au XVIE siècle, agrandies au XVIIIe, abandonnées fin XIXe. Outre le fourneau, ce classement prend en compte l'ensemble du dispositif hydraulique, mais ne dit rien des autres bâtiments, qu'on devine sur les photos.

La forge de Saint-Front sur le Bandiat fait partie d'un ensemble qui n'a pas été évoqué dans le dossier. La notion de séries de forges échelonnées sur un cours d'eau est encore complètement absente.

Les années 78-80, très proches de nous, sont encore des périodes de tatonnement. Le ministère commande une étude 'Quelles usines protéger ?" à un architecte. Les réponses ne sont pas très claires. Les protections de forges historiques se ressentent de ces incertitudes : ensemble architectural de grande qualité, mais très mutilé :-Baignes (1978) dont le fourneau a disparu, mais que le conservateur qui décrit les écuries et le colombier considère comme un petit Arc-et-Senans.

- Contes (1979) est une petite forge rurale, sans fonderie, un moulin à fer avec martinet, dont l'intérêt essentiellement ethnologique (atelier conservé avec ses outils) repose sur l'utilisation récente et la mémoire - orale conservée.

- Savignac-Ledrier , au contraire, est le type même de la forge liée à un château, particulièrement spectaculaire par son site, par la silhouette majestueuse du fourneau. Dans une région très touristique, la forge de Savignac devient le pôle d'un nouveau tourisme. Les restaurations sont déjà très avancées ; et on étend actuellement la protection aux parties qui n'avaient pas été considérées comme liées étroitement au fonctionnement technique.

- Perret (1981) est une protection globale d'un ensemble complet : fourneau, magasin, écuries, dispositifs hydrauliques, maison de maître de forges et logements ouvriers. C'est après Savignac l'ensemble des plus significatifs, complet, lisible, qui soit protégé en France.

- Val-Suzon (1982) : là c'est le danger de destruction qui a incité à protéger cette fonderie créée en 1836, déjà bien dégradée mais importante du point de vue typologique, car représentative du modèle "compact", où tous les bâtiments, y compris les logements ouvriers sont intégrés dans un gros quadrilatère massif.

- Le Champ de la pierre (1982) est un autre cas de figure encore : les forges sont intégrées dans un parc de loisir, et leur mise en valeur constituera un des pôles d'attraction du lieu. Au moment de la demande de protection, le haut-fourneau et la maison de maître étaient plus qu'à moitié ruinés. L'ensemble est aujourd'hui méconnaissable...

Toujours en 1982, année faste (cinq mesures de protection ont été prises), le haut-fourneau complètement ruiné de Longuyon, ne présente guère d'intérêt. On s'interroge surl'interet de cette mesure de sauvegarde.

Au contraire, à Aube-et-Rais (1982),il s'agit d'une protection très amplement motivée par l'établissement d'un gros dossier d'étude historique et architecturale. C'est aujourd'hui le plus important établissement métallurgique protégé, restauré, animé par une association, une sorte de modèle "idéal" - par la qualité de l'architecture, exceptionnellement homogène, (mais moins specuaculaire peut-être que Savignac-Ledrier, protégé trois ans auparavant.).

Enfin, la dernière en date des protections signées par le ministre pour une usine métallurgique concerne une immense fonderie royale du XVIIIe siècle (1720-1781) où étaient fabriquées des chaines et ancres de la Marine; l'intérêt majeur signalé dans les motifs de protection, c'est le fait qu'il s'agisse du plus important exemple d'urbanisme industriel avant les Salines de Ledoux (Arc-et-Senans). Le dossier de protection déposé en 1977 auprès du Ministère mettra pourtant cinq ans à aboutir, après avoir été amputé d' une partie de sa consistance, le nouveau propriétaire d'une partie de l'ensemble (château du maître de forge, halle à bois, sans doute la plus belle existant en France, et communs du château). s'opposant à toute intervention de l'Etat. On touche ici à l'une des limites de l'action de l'Etat : la loi ne permet pas, sauf procédure très longue (l'édifice peut s'effondrer pendant ce délai) de prendre une mesure de sauvegarde sans l'autorisation des propriétaires.

En 1983, le ministère a créé une cellule d'étude du patrimoine industriel. Les enquêtes systématiques faites sur le domaine prioritaire de la métallurgie ancienne vont permettre désormais des protections tenant compte à la fois de l'intérêt de l'édifice pour l'histoire de l'économie. l'histoire des techniques, l'histoire sociale, l'histoire architecturale aussi. La communication de J.F. Belhoste, celle aussi de B. Riguault exposent les études en cours. Des protections "sérielles" vont être proposées pour la Bourgogne, la Franche-Comté, la région du Centre, l'Aquitaine (Dordogne), la Bretagne (Ile-et-Vilaine , Morbihan et Loire-Atlantique.) la Normandie. La protection d'une série met en valeur des notions quantitatives très importantes : l'activité industrielle ancienne y apparaît dans sa dissémination dense. On pourra combiner la protection d'établissements exceptionnel, avec celle de séries, et également sélectionner en fonction d'un meilleur état de conservation et des possibilités de présentation au public. La métallurgie sera alors l'industrie historique la mieux connue, et ses usines seront les mieux protégées, les plus utilement et intelligemment restaurées et présentées; ceci après avoir été les parents pauvres et méconnus. Restera alors le problème de la métalhurgie plus récente et abandonnée par les restructurations depuis vingt ans.

La Lorraine pose en effet un problème nouveau ,celui de la désindustrialisation de toute une régionvouée à la métallurgie depuis plus d'un siècle ;jusqu'ici , les Monuments Historiques n'ont protégé que desdispo sitifs destinés àla fonte au bois , tous antérieurs à la véritable révolution industrielle .Une nouvelle doctrine de protection , de restauration, de présentation va devoir êtreélaborée , en tenant compte des modèles anglo-saxons, et , plus largement,occidentaux,pour faire face aux nouvelles urgences et répondre aux voeux des travailleurs ce ces régions soucieux de voir reconnu leur patrimoine. L'INVENTAIRE DES FORGES FRANCAISES ET SES APPLICATIONS

Jean François BELHOSTE *

SUMMARY

This paper presents the Metallurgy program of the Inventaire général. First, it explains the method of the inventory and summarizes the status of the different activities currently in operation.

In a second part, it is shown how the collected information can deal, for example, with the field of the transfer of technology. Some results are given for the case of the western part of France: introduction of the blast furnace process, development of the large forges with slitting mills, spreading of the puddling furnaces and the rolling mills.

In a third part, a brief survey is presented on another aspect: the industrial organization of the forges belonging to the princely family of the Condé. It appears that the majority of them were designed on the same pattern.

 Ingénieur, Cellule du Patrimoine Industriel, Inventaire général des Richesses et Monuments artistiques de la France, Ministère de la Culture.

Paris, November 1984

En 1983. le service de l'Inventaire général des Richesses et Monuments artistiques de la France (Ministère de la Culture) a créé une Cellule du Patrimoine industriel, chargée de promouvoir et de coordonner l'étude des bâtiments et des objets de l'industrie. L'étude de la métallurgie du fer a été choisie dès l'origine comme programme de recherche prioritaire. Cette industrie, base de l'outillage domestique, agricole et artisanal comme de l'équipement industriel et militaire, présente sur presque tout le territoire, à l'histoire longue et mouvementée et qui réunit toutes les strates de la société, depuis les grands nobles et rois du fer jusqu'aux pauvres ouvriers de la mine et des charrois est. en effet, un phare du phénomène d'industrialisation en France. Elle offre, en outre, l'avantage de posséder de très importants vestiges, de toutes époques, et dont les plus intéressants ont déjà suscité la mise en place d'opérations de conservation et d'animation comme à Buffon (Bourgogne), Savignac Lédrier (Périgord), Aube (Normandie), Moisdon (Pays de la Loire).

Le programme de la Cellule du Patrimoine industriel porte essentiellement sur la période qui s'étend du XVe siècle à la fin du XIXe siècle, c'est-à-dire en gros depuis l'apparition de la technologie révolutionnaire du haut fourneau, jusqu'à la fin de la métallurgie du bois et l'avènement de l'industrie de l'acier. Il prolonge en quelque sorte, avec quelques recouvrements, les programmes, bien développés en France, des archéologues sur les périodes antiques et médiévales.

L'objet d'une étude d'inventaire est de mettre en perspective. pour une collection de sites à l'intérieur d'un territoire donné, des observations recueillies sur le terrain et des informations collectées dans les bibliothèques et les centres d'archives. Ce genre d'études pose à l'évidence deux types de questions : jusqu'où pousser la normalisation de l'information, sachant qu'une forte normalisation entraîne une stricte sélection des données collectées ? Que retenir, en outre, du contexte économique et social, comme de l'histoire ancienne des sites étudiés. qui permettent de passer du descriptif à l'explicatif ? A l'heure actuelle, il n'existe pas de doctrine rigide en la matière, sinon d'admettre que la normalisation est d'autant plus nécessaire que la collection étudiée est plus large, et l'étude contextuelle, pour des raisons pratiques, forcément plus mince. Pour l'étude complète d'un bassin métallurgique, il est difficile, en tout cas, d'imaginer de ne pas combiner deux approches parallèles, l'une large et sommaire, l'autre profonde et quasiment monographique.

En 1983 et 1984, la Cellule du Patrimoine industriel de l'Inventaire général a aidé une vingtaime d'opérations d'inventaire, d'importance variée, puisque si certaines couvrent tout un département, d'autres ne portent que sur quelques sites. Bien que plusieurs grandes régions françaises ne soient pas encore représentées, comme la Franche-Comté, la Champagne (Haute-Marne) ou le Poitou, la plupart sont déjà prises en compte : l'Ouest depuis la Normandie jusqu'aux Pays de la Loire, à l'exception encore du Maine, le Sud-Ouest avec des opérations en Dordogne, dans l'Agenais et dans les Pyrénées (procédé catalan), la région Rhône-Alpes, tant dans les Alpes que dans le bassin stéphanois, l'Est avec la Bourgogne, les Ardennes et la Lorraine, la Région Centre enfin, région frontière où se déployait la riche métallurgie berrichonne. Ces études sont conduites soit par des asso-
ciations ou groupes de recherche, tels ceux des forges de Buffon ou de Savignac Lédrier, soit par les Commissions régionales d'Inventaire.

Encore une fois, l'ambition de ces inventaires est variable, extensive lorsque le champs est large, intensive s'il s'agit de quelques sites exemplaires. Dans tous les cas, ils comprennent au moins une mention des vestiges subsistants, aussi bien les vestiges d'installations productives (hauts fourneaux, forges d'affinerie, fenderies, platineries, aciéries. martinets) que ceux des bâtiments de stockage (halles à charbon, entrepôts de fonte et fer) et installations annexes (halles de machines à vapeur, charpenteries, maréchaleries et même moulins à blé) ou encore des logements d'ouvriers et de maîtres de forge. A ce sujet, rappelons que la métallurgie du fer est sans doute l'industrie qui a suscité le plus tôt, c'est-à-dire au moins dès le XVIIe siècle, la construction d'un habitat groupé, sorte de cité ouvrière, sur le site même de la forge pour le logement des forgerons les plus qualifiés. Dans les cas d'études très fouillées, il est souhattable de prendre aussi en compte le contexte de l'implantation des forges, non seulement la répartition des mines et minières de fer, mais aussi les circuits hydrauliques sur lesquels étaient installés les établissements métallurgiques et, enfin, tout l'aménagement forestier nécessaire à l'approvisionnement en combustible des hauts fourneaux et des affineries. Rappelons, en effet, qu'il fallait 2 à 3 000 hectares pour faire marcher régulièrement une grande forge. L'étude s'élargit ainsi à tout un paysage qui environne et que modèle la forge.

Du côté de la documentation écrite ou figurée, sont recherchés en priorité les plans - nombreux pour la première moitié du XIXe siècle, puisque les propriétaires étaient en principe obligés d'en fournir à l'Administration des Mines lors de chaque demande d'établissement ou de rétablissement d'usine - et les descriptions concrères que l'on trouve par exemple dans les rapports d'ingénieurs des mines et dans les baux notariés, ou mieux encore dans les visites (rendues) de forges qui s'effectuaient à l'issue de chaque période de bail. Ces documents sont souvent les seuls dont on puisse disposer pour le XVIIe siècle et le début du XVIIIe siècle.

Application à l'étude des transferts de technologie

Une recherche fondée sur un inventaire ne saurait, cependant, n'être qu'une collecte, aussi raisonnée soit-elle, d'informations plus ou moins normalisées. Tout l'intérêt, en effet, de la prise en compte d'une collection réside dans le traitement d'ensemble qu'elle permet d'opérer. L'importante question des transferts de technologie constitue, parmi d'autres, un champs de recherche auquel il est possible d'apporter par ce biais d'intéressantes contributions. La France, de ce point de vue, est particulièrement favorisée, puisqu'elle se trouvait au carrefour de toutes les grandes technologies européennes : technologie wallonne longtemps dominante dans toute la moitié nord du territoire, comtoise, c'est-à-dire allemande, dans l'Est à partir du XVIIIe siècle, bergamasque dans les Alpes, catalane dans les Pyrénées. Grâce à des programmes en cours en Basse Normandie (conduits par l'Association Histoire et Patrimoine industriel) et en Pays de la Loire (conduit par la Commission régionale d'Inventaire) et d'études plus ponctuelles dans l'Eure, le Maine et en Bretagne, il a été possible de dresser un premier bilan de cette question pour le Grand Ouest, depuis le Pays de Bray jusqu'à la Loire. Cette très large région qui possédait une réelle cohérence, identifiable précisément par l'homogénéité de ses caractères technologiques, mais aussi par des mouvements internes de maîtres de forge et de forgerons, constituait l'un des plus précoces et des plus importants foyers métallurgiques français jusqu'à la ruine de la métallurgie en bois, dans la deuxième moitié du XIXe siècle.

Comme la plupart des autres régions, il est possible d'y discerner trois grandes phases de l'évolution technologique, depuis la fin du Moyen-Age jusqu'à cette époque charnière qui vit le triomphe de la fonte au coke et de l'acier :

1. à la fin du XVe siècle et au début du XVIe siècle, l'apparition et la lente diffusion du haut fourneau et de la forge d'affinerie :

2. dans le courant du XVIIe siècle, l'implantation des grandes forges, dotées d'un haut fourneau, d'une forge d'affinerie et d'une fenderie ;

3. à partir des années 1820, la substitution des anciennes forges d'affinerie et fenderies par les nouvelles forges à l'anglaise, comprenant des fours à puddler pour l'affinage et des laminoirs animés généralement par des machines à vapeur.

Trois cartes résument le sens général de ces transferts. Voici les commentaires succints qui peuvent les accompagner

Concernant la diffusion du haut-fourneau et de son complément nécessaire la forge d'affinerie - phénomène capital dont l'importance économique reste trop souvent méconnue -, il faut, dans l'état «ctuel de la recherche, se contenter de juxtaposer à certaines mentions d'anciens auteurs, généralement du XIXe siècle, quelques observations plus récentes. Il en ressort cependant assez nettement que la technique venue du Pays de Liège, d'où le nom de wallon réservé jusqu'au XIXe siècle au procédé d'affinage qui incorporait des forges d'affinerie et des foyers de chaufferie, s'est propagé du Nord-Est vers le Sud-Ouest. Des mentions des années 1460 existent pour le Pays de Bray, un peu à l'Ouest de Beauvais, où du reste l'origine wallonne des maîtres de forges est explicitement mentionnée. Dans le département de l'Eure, au Sud d'Evreux, l'apparition du haut fourneau est datée, de manière incontestable, des années 1480 pour le site de Breteuil sur l'Iton et de La Neuve Lyre sur la Risle. S'agissant du Perche, à l'Est de Chartres, les dates sont moins sûres, mais il est vraisemblable que le haut fourneau y fut également implanté dès la fin du XVe siècle.

Par contre, aussi bien pour la partie plus occidentale de la Normandie - le Bocage - que pour le Maine, au Nord-Ouest du Mans, le haut fourneau ne fit vraisemblablement son apparition qu'au début du XVIe siècle. La construction des forges de l'Aulne, sur un affluent de la Sarthe, proche du Mans, est ainsi antérieure à 1530. Enfin, c'est dans une période sans doute légèrement postérieure qu'il conquit la Bretagne : à la Poitevinière au Nord-Est de Nantes, peut-être dès les années 1515-1520, à Avaugour à côté de Saint-Brieuc, avant 1540.

Ces données sont tirées des archives. Ajoutons qu'elles révèlent encore que la métallurgie du Pays de Bray, disparue au milieu du XVIe siècle, a fourni les forgerons qui, traversant la Manche, ont fondé la métallurgie du Sussex. Par contre, ces anciens sites n'ont pas encore fait l'objet d'études archéologiques qui cependant devraient pouvoir donner d'intéressants compléments à des informations écrites qui restent extrêmement fragmentaires.

Pour une époque, enfin, où les documents figurés de forges sont extrêmement rares, on a la chance de disposer d'un plan de 1508 représentant distinctement un haut fourneau et une forge d'affinerie, avec leurs retenues d'eau et leur environnement forestier (la forêt de Belloy) à Rainvilliers près de Beauvais.

Au début du XVIIe siècle, dès la fin du XVIe siècle, au sortir des guerres de Religion, la métallurgie prit un nouvel essor. Un type d'usine moderne apparut, plus large, dotée sans doute de moteurs hydrauliques plus puissants et qui comprenait en tout cas un nouvel établissement, la fenderie, avec son appareil muni de deux cylindres tournant en sens contraire, destinés à aplatir et à fendre, lorsqu'ils étaient munis de taillants, les barres de fer sortant de la forge. Il avait été mis au point en Principauté de Liège à la fin du XVIe siècle et se répandit en France dans le premier tiers du XVIIe siècle. Cette nouvelle technologie s'avérait particulièrement bien adaptée aux conditions de l'Ouest, riche surtout en minerai de fer dit cassant utilisé dans la clouterie. Aussi, la plupart des usines de cette région accueillirentelles les trois installations - haut fourneau, forge et fenderie - réparties selon les capacités hydrauliques sur un, deux ou trois sites. En principe, les schémas concentrés correspondaient à une conception moderne et homogène, alors que les schémas dispersés résultaient d'une développement progressif avec adjonctions successives d'établissements complémentaires.

La carte jointe montre les implantations réalisées dans le courant du XVIIe siècle, en deux vagues successives, l'une dans le premier tiers, l'autre dans le dernier tiers du siècle. Contrairement à la diffusion du haut fourneau, il n'y a pas eu de progression du Nord-Est vers le Sud-Ouest, mais implantation initiale simultanée sur tout le territoire concerné et densification progressive ultérieure. On voit aussi que certaines usines disparurent dans le courant du XVIIIe siècle, surtout celles de la périphérie dont la ruine résulta souvent d'un épuisement ou d'une réaffectation des forêts qui les environnaient.

Pour l'étude de ces grandes forges, la documentation ne manque pas. Des archives seigneuriales, notariales et administratives renseignent sur histoire générale et fournissent même parfois des descriptions précises. Il existe des plans, surtout lorsque les propriétaires f aisaient partie de grandes familles nobles. On en trouve encore dans les archives de l'administration des mines, qui, bien que du début du XIXe siècle, montrent un aménagement d'ensemble qui est souvent celui du XVIIIe siècle. Enfin, les vestiges restent abondants. Les plus nombreux sont les logements de maîtres et d'ouvriers et les halles à charbon à bois, mais il subsiste aussi des hauts fourneaux, forges et fenderies. Les premiers sont les plus fréquents, quoique le plus souvent partiellement détruits. Les autres, moins massifs et davantage sujets à des réutilisations, ont souvent disparu. A ce jour, si aucun site complet n'a pu être repéré, il existe heureusement quelque part un specimen de chaque atelier. Les forges, à part celle d'Aube, n'ont cependant pas sauvegardé leur matériel intérieur, c'est-à-dire les marteaux et les foyers de chaufferie et d'affinerie. La présence de roues, pourtant souvent conservées dans l'Ouest pour les autres types d'usines hydrauliques, reste également exceptionnelle.

Une troisième carte mentionne l'implantation des grandes forges à l'anglaise dans la première moitié du XIXe siècle, c'est-à-dire la substitution des anciennes affineries wallonnes et fenderies par des batteries de fours à puddler à la houille et des laminoirs. Cette nouvelle technologie transforma profondément le cycle de la production métallurgique mais elle n'entraîna pas la disparition des hauts fourneaux su bois. Au contraire, pour répondre à une demande d'affinage croissante, ils se modernisèrent et se multiplièrent sur les anciens sites et à proximité des réserves forestières disponibles dans l'intérieur du territoire.

Les grandes forges à l'anglaise de l'Ouest se sont, par contre, développées le long du littoral et des deux grands fleuves, la Loire et la Seine. Les implantations les plus précoces, dès les années 1820.furent celles de la Basse-Loire et de la Bretagne méridionale, à la fois pour bénéficier de la proximité des gisements charbonniers exploités dès le XVIIIe siècle à l'Ouest d'Angers et pour recevoir facilement par le fleuve la houille des régions de la Haute-Loire et par la mer celle du Nord de la France ou de l'Angleterre. Ce n'est que plus tard, dans les années 1840-50, que le même phénomène se produisit en Basse Vallée de la Seine, à Pont-Audemer, Evreux, puis au Havre. Dans plusieurs de ces entreprises, parmi les plus importantes, comme à Basse-Indre, Pont-Audemer ou Graville, près du Havre, la présence anglaise fut déterminante pour l'apport de la technologie et des capitaux. A la Jahotière, au Nord-Est de Nantes, entreprise éphémère où son créateur Achille de JOUFFROY d'ABBANS, fils de l'inventeur de la navigation à vapeur, projetait en 1827 de construire plusieurs hauts fourneaux au coke et une forge à l'anglaise, c'est un technicien anglais du Straffordshire, WALFORD, qui fut l'un des principaux concepteurs. Plus tard, dans les années 1840, une société anglaise, propriétaire des mines de houilles voisines de Languin, exploita et modernisa les installations qui avaient pu être construites avant que JOUFFROY ne fit faillite.

Dans l'ensemble, ces entreprises sont facilement identifiables grâce aux dossiers de l'Administration des Mines. Les archives les concernant sont néanmoins souvent plus rares que celles des entreprises du XVIIIe siècle. Mis à part les plans que contiennent ces dossiers, représentant un état de l'usine projetée ou juste construite, la documentation figurée est rare et il est souvent difficile de suivre l'évolution ultérieure de l'usine. D'ailleurs, comme la plupart de ces sites ont fait l'objet d' un constant réaménagement au cours du XIXe siècle et du XXe siècle, les vestiges datant de la première moitié du XIXe siècle sont très peu nombreux. L'usine de La Jahotière abandonnée vers 1860, est l'un des rares endroits qui conserve notamment les restes d'un premier haut fourneau au coke.

Autre traitement d'ensemble

L'étude de la diffusion des techniques par une sorte d'osmose à l'intérieur d'un territoire homogène n'est pas la seule application de l'inventaire. On peut aussi imaginer des traitements d'ensemble sur une échelle géographique plus large. La confrontation d'observations faites sur des forges dispersées, mais comprisestans un même patrimoine a permis, par exemple, de mettre en évidence une stratégie de développement national, homogène non seulement sur le plan financier, mais aussi pour la conception des usines et de l'organisation du travail.

Le patrimoine en question est celui des Princes de Condé, premiers princes du sang qui, à la fin du XVIIe siècle et au début du XVIIIe siècle, furent certainement les plus gros propriétaires de forges du royaume de France, et aussi - c'est ce qui a été précisément révélé par les inventaires - ceux qui développèrent à cette époque les usines les plus importantes et les plus modernes. L'étude de leurs forges a commencé par celles de Moisdon, au coeur du Pays de Chateaubriant en Loire-Atlantique, grâce à Perrine RAMAIN-CANAVAGGIO dans le cadre d'une thèse de l'Ecole des Chartes, puis Hubert MAHEUX, au sein de la Commission régionale d'Inventaire des Pays de la Loire. A partir d'importantes archives conservées, entre autres, au château de Chantilly et dans les fonds notariaux de Paris et de Chateaubriant, et compte tenu de la bonne conservation du site avec sa retenue, sa halle, ses logements, même si toutes les installations productives ont disparu, il a été possible d'étudier l'histoire et l'aménagement de cette grande forge. Construite à partir de 1668 par René SAGET, un maître de forge voisin, elle avait la particularité de concentrer au pied d'une même chaussée et avec un strict parallélisme, les trois unités productives, haut fourneau, affinerie et fenderie, divisés de telle manière que le produit de fabrication puisse transiter le plus directement possible d'un atelier à l'autre. En outre, le haut fourneau était double, c'est-à-dire qu'il possédait dans la même masse deux cuves juxtaposées. Ce type d'établissement complètement intégré était jusqu'alors inconnu. Les forges de Moisdon ont constitué un prototype de grande forge moderne de la fin du XVIIe siècle.

Cette déduction s'est trouvée confirmée par les constatations que firent ensuite Jacques TOURNAIRE pour les forges de Clavières dans l'Indre et Marie Vic OZOUF et Frédéric STIGNANI, pour les forges de Senonches, à Dampierre, dans l'Eure et Loir, deux forges appartenant . aussi aux CONDE à la fin du XVIIe siècle. En effet, l'étude historique rendue encore possible par la conservation d'importantes archives (du fait que ces forges passèrent ensuite aux mains de deux frères du roi) montra

qu'elles avaient été construites juste après celles de Moisdon : les Forges Hautes de Clavières sans doute en 1670 ou début 1671 par René SAGET, le fondateur de celles de Moisdon, qui fit venir spécialement des ouvriers de Bretagne, celles de Senonches dès 1669, mais sans doute avec d'autres entrepreneurs (elles appartenaient du reste à Henri Jules, alors fils du Prince dit le Grand Condé). Tout semble donc indiquer que ces trois grandes forges ont bien été construites presqu'en même temps par les CONDE, et selon un plan d'ensemble qui visait en particulier à améliorer la rentabilité de leur patrimoine forestier. De plus, ces trois grandes forges - c'est l'autre constatation essentielle - ont été conçues selon un même parti d'ensemble, c'est-à-dire d'une manière concertée, au pied d'une même chaussée et avec un haut fourneau à double cuve. Certes, les matériaux utilisés étaient différents, mais les formes et les dimensions, telles qu'elles apparaissent dans les plans disponibles, comme aussi la disposition des logements ouvriers et des halles à charbon, étaient très voisines. Et si à Moisdon les établissements productifs ont disparu, il reste à Clavières le bâtiment de l'ancienne fenderie et, surtout, à Senonches, le haut fourneau double avec ses appentis. L'étude historique de ce site, confrontée à celle des sites jumeaux, a pu montrer qu'il s'agit très vraisemblablement du haut fourneau d'origine.

Marie-Vic OZOUF a repéré, en outre, que les CONDE avaient fait construire ultérieurement une forge du même type sur leur Principauté d'Anet, aujourd'hui complètement disparue. Les forges de Montblainville dans la Meuse et de Marcenay en Bourgogne, les unes antérieures, les autres postérieures à la fin du XVIIe siècle, bien qu'appartenant aussi au patrimoine des CONDE, relèvent apparemment de modèles assez différents. C'est sans doute que la forme intégrée, au pied d'une très large retenue et nécessitant de très grandes réserves forestières, si elle convenait à la métallurgie de l'Ouest prise au sens très large, n'était pas adaptée à celle de l'Est.

Ces exemples sont là pour illustrer les possibilités de traitement synthétique qu'offre la confrontation de données collectées lors d'inventaires à la fois thématiques (dans le domaine de la métallurgie du fer) et topographiques (sur un territoire déterminé). Il ne s'agit là que d'ébauches, à partir de matériaux provisoires (l'inventaire des forges du Pays de Chateaubriant étant le seul achevé), présentées autant pour servir d'exemples que pour la signification de leurs résultats.

TRAVAUX EN COURS

Histoire et patrimoine industriels de Basse Normandie, Inventaire des hauts fourneaux et forges du département de l'Orne. Etude en cours par Yannick Lecherbonnier, sous la direction de Gabriel DESERT.

Association Patrimoine industriel d'Eure-et-Loir, Etude historique et archéologique des forges de Dampierre-sur-Blévy et Boussard et de leurs sites d'extraction minière. Etude en cours par Marie-Vic OZOUF et Frédéric STIGNANI, sous la direction de Geneviève DUFRESNE.

Comité d'Animation de la ville d'Ardentes, Etude historique et archéologique des forges de Calvières. Etude en cours par Jacques Tournaire, sous la direction de Patrick Léon.

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 Carte N°1. Diffusion du haut fourneau dans l'Ouest de la France entre la fin du XVe et le début du XVIe siècle.



 Carte N°2. Les grandes forges de l'Ouest, avec haut fourneau, forge d'affinerie wallone et fonderie, à la fin du XVIIE siècle et au début du XVIIIE siècle.



 Carte N°3. La diffusion des grandes forges à l'anglaise dans l'Ouest au cours de la première moitié du XIXe siècle.



 Carte N°4. Implantation des forges appartenant aux Princes de Condé (fin XVIIe siècle - XVIIIe siècle).



5. Plan de la Forge Neuve de Moisdon (Loire-Atlantique) levé par Demolon en 1774 Archives nationales W. 521 (Cliché Inventaire général, Sous-Direction, Bernard Emmanuelli). Cette grande forge, construite en 1669 et 1670, rassemblait au pied d'une même chaussée un fourneau double, une affinerie et une fenderie. Elle était l'une des plus importantes de France (cf. le Cahier d'Inventaire N^{*}4 cité en bibliographie).



6. Le site de Dampierre, près de Senonches (Eure-et-Loir) (Cliché Inventaire général, Sous-Direction, Philippe Fortin). La grande forge de Dampierre, construite peu après celle de Moisdon par les Princes de Condé et sur un même modèle, comprenait derrière un large étang un haut fourneau, dont on distingue les installations en contrebas de la chaussée sur la droite de la photo, juste à gauche du pignon de la halle à charbon, et la maison de maître.



 Haut fourneau double de Dampierre (Cliché Inventaire général, Sous-Direction, Philippe Fortin).
Sur le devant, se trouvent l'ancienne halle à coulée et, à droite, adossé contre la chaussée, l'un des appentis des soufflets.



 Haut fourneau de Dampierre (Cliché Inventaire général, Sous-Direction, Philippe Fortin).
L'intérieur de la halle de travail, avec les deux trous de coulée.



Forges de Dampierre sur Blévy. Haut fourmeau double.



 Vue axionométrique et coupes du haut fourneau de Senonches. Relevés réalisés par Frédéric Stignani.



10. Dépendances des forges de la Jahotière à Abbaretz (Loire-Atlantique). Vues de la cour de la maison de maître (Cliché Inventaire général, Pays-de-la-Loire, D. Pillet). Cette usine édifiée en 1827 par Achille Jouffroy d'Abbans n'eut qu'une existence éphémère. La forge à l'anglaise qu'il était prévu d'installer ne fut pas réalisée et seul un haut fourneau au coke fut construit. Les dépendances qui abritaient sans doute des ateliers annexes et des magasins, rappellent par leur architecture la forte influence anglaise que connut cet établissement durant sa courte histoire (cf. le Cahier d'Inventaire N°4 cité en bibliographie).

11. Coupes horizontale et verticale du haut fourneau au coke de la Jahotière à Abbaretz (Relevés réalisés par François Corbineau, Inventaire générale, Pays-de-la-Loire). Ce haut fourneau construit en 1827 et remanié sans doute dans les années 1840 a été la seule installation productive effectivement réalisée, bien que le projet initial ait été beaucoup plus ambitieux.



LES FORGES DE BASSE-NORMANDIE: CONSERVATION ET REUTILISATION

A PROPOS DE DEUX EXEMPLES

Yannick LECHERBONNIER *

SUMMARY

Situated in the southeast of Normandy, the "Département de L'Orne" offered conditions favorable to the settlement of metallurgic industry: iron ore, wood and water.

Among the ironworks still in activity during the last century, Aube and Champ-de-la-Pierre have been rehabilitated for a few years. In both cases, this rehabilitation has been carried out by associations sponsored by local, scientific and cultural authorities.

At Champ-de-la-Pierre, it has led to the creation of a footpath along which posters explain the process of iron-making. The "Forge d'Aube" building will soon house a regional museum of metallurgy; before allowing public access to the forge it has appeared necessary to know the different states of occupation, and archaeological excavations have been set for a year.

* Permanent de l'association "Histoire et Patrimoine Industriels de Basse-Normandie".

3 July 1984

LES FURGES EN BASSE-NORMANDIE

La Basse-Normandie, région du Nord-Uuest de la France composée des départements de la Manche, du Lalvados et de l'Orne participa pleinement, dés le dernier quart du XVéme siécle, à l'essor de la métallurgie que l'on observe alors un peu partout, marqué par l'abandon des bas-fourneaux et le passage des forges à bras aux forges hydrauliques. Un inventaire systématique des établissements métallurgiques (hauts-fourneaux, forges et fenderies) dressé à partir des différentes sources d'archives - cadastre napoléonien, baux, séries E (familles et seigneuries) et H(fonds religieux) des archives départementales, chartriers etc... - a permis jusqu'alors de recenser pour le seul département de l'Orne 29 hauts-fourneaux, 30 forges et 22 fenderies.

Des trois départements bas-normands, celui de l'Orne apparait de loin le plus métallurgique (seuls deux sites importants pourraient être mentionnés dans la Manche et le Calvados) et l'abondance des toponymes évoquant cette activité ("rerriére", "les Miniéres", "les Laitiers" etc...) témoigne bien de son ancienneté et de sa persistance.

Les caractères géographiques et géologiques de ce département expliquent la présence de cette industrie;les trois éléments nécessaires à l'installation d'une forge y sont en effet réunis:

= le minerai de fer,présent en maints endroits,en couches peu profondes,ce qui facilita son extraction.

= les bois et forêts,qui occupaient à la fin du Moyen-Age une vaste superficie;celle-ci est fortement entamée au cours de la période moderne,les grosses forges ayant,selon la formule du géographe L. Houzard,"mangé la forêt"(G. Houzard:les grosses for ges ont-elles mangé la forêt?,Annales de Normandie,uctobre I980, numéro 3).

= l'eau enfin pour animer les roues des soufflets et des marteaux.

La présence de ces trois éléments,qu'il conviendrait cependant de nuancer - qualité variable du minerai,disparition progressive des massifs forestiers,alimentation irréguliére des cours d'eau - devait permettre à la plupart de ces établissements de se maintenir en activité jusqu'au XIXéme siécle.

LES FORGES D'AUBE ET DU CHAMP-DE-LA-PIERRE

Présentation géographique et historique:

Attestée dés ISD2, la forge d'Aube est située à l'Est du département de l'Urne, dans le canton de l'Aigle; alimentée en eau par la Kisle, affluent de la Seine, elle est encore aujourd'hui bordée de vastes massifs forestiers(forêt de St-Evroult au Nord, forêts de Moulins et du Perche au Sud); le sous-sol d'Aube et des environs est particuliérement riche en minerai de fer.tn amont de la forge se trouvaient la fenderie(commune d'Aube) et, un peu plus loin, le haut-fourneau du Logeard(commune de St-Pierre-des-Loges).

La forge est seule parvenue jusqu'à nous, avec tout son appareillage, fours, marteau latéral, martinet terminal, outils de manipulation (pinces, tenailles...); cet état de conservation exceptionnel tient à l'acquisition de la forge vers 1850 par un industriel de la région, Pierre-Jean Baptiste-rélix Mouchel qui abandonne le forgeage du fer pour celui du cuivre; cette mutation put se faire sans modifier considérablement le bâtiment et les appareils de production qu'il abritait.N'ayant pas à souffrir comme les autres forges, vouées à la métallurgie du fer, de la concurrence des fers anglais ou de celle des fers d'autres régions françaises, de meilleure qualité, la forge d'Aube put poursuivre sa production jusqu'en 1939 environ.

Les grosses forges du Champ-de-la-Pierre sont installées dans le Sud du département de l'Orne,(canton de Carrouges);plus récentes que la forge d'Aube - elles sont construites vers 1619 par le seigneur du Lhamp-de -la Pierre) - elles sont aussi économiquement plus défavorisées:le sous-sol de cette région n'abrite pas de minerai de fer,les massifs forestiers sont plus éloignés;enfin,elles ne sont pas établies sur une riviére mais sur le bord de trois étangs.

L'ensemble comprenait un haut-fourneau, une grande forge, une petite forge et une fenderie; au XIXéme siécle la petite forge fut remplacée par la forge neuve; autour de ces ateliers s'élevaient la maison du maître de forges, les maisons ouvriéres, les écuries, les fours à pain etc...Vers 1065 les forges du Champ-de la-Pierre cessérent leur activité; depuis 1701 elles étaient aux mains de la famille Kicoeur de Bâmont représentée encore aujourd'hui par le sénateur Hubert d'Andigné, propriétaire des lieux. Aux possibilités d'aménagement qu'offraient ces deux sites s'ajoutait une documentation exceptionnelle, composée essentielement de fonds privés:le fonds Mouchel pour la forge d'Aube inéressant la période consacrée à la métallurgie du cuivre et le chartrier du Lhamp-de-la-Pierre(archives privées d'Andigné;XVII éme,XVIIIéme et XIXéme siécles.

Les premiers pas vers la réhabilitation:

A Aube comme au Champ-de-la-Pierre la mise en valeur des sites métallurgiques fut et est encore aujourd'hui le fait d'associations composées, au départ, d'une partie de la population locale.

Le ler Juillet 1980 l'association des"Amis des forges du Champ-de-la-Pierre" (créée le 14 Octobre 1978)passa un bail de vingt ans avec le propriétaire des lieux afin de restaurer et de sauvegarder le haut-fourneau,mener des études historiques sur le site et y créer une animation.

A Aube,les éléves du lyçée de l'Aigle,sous la conduite de deux de leurs professeurs -Mrs Guengant et Monfouilloux-,remettaient à jour depuis 1978 durant les vacances scolaires les bâtiments de la forge cachés depuis leur abandon par une végétation envahissante et nettoyaient les canaux envasés;deux années plus tard,la société Tréfimétaux,propriétaire de la forge,la cédait à la commune pour le franc symbolique et en Octobre se créait l'association"pour la mise en valeur de la vieille forge d' Aube"

Un ne manquera pas de noter l'écart entre le moment où l'on a,pour la premiére fois,manifesté le désir de protéger les restes de ces établissements industriels et leur prise en charge par des essociations de sauvegarde,support indispensable à toute politique de réhabilitation; dû dans une certaine mesure à des problémes d'organisation - les membres des associations de sauvegarde,en dépit de leur bonne volonté ne sont pas toujours préparés pour y faire face - cet écart résulte aussi de la réticence alors presque générale,tant de la part du grand public que des instances culturelles, à cosidérer comme élément du patrimoine digne d'être protégé un établissement industriel quel qu'il soit.

En 1982 les efforts de ces deux associations ornaises étaient cependant récompensés:le 17 Mai les vestiges du haut-fourneau du Lhamp-de-la-Pierre étaient inscrits sur l'Inventaire Supplémentaire des Monuments Historiques et le 21 Septembre la forge d'Aube, "avec ses fours et son systéme hydraulique" était classée Monument mistorique.

La réhabilitation des forges du Champ-de-la-Pierre :

La fermeture des forges du Lhamp-de-la-Pierre vers1865 ne leur permis pas d'arriver jusqu'à nous dans un état de conservation aussi heureux que celui signalé tout à l'heure pour la forge d'Aube;l'isolement du site et son maintien, au delà de la fermeture des forges, dans le patrimoine des héritiers des seigneurs du Champ-de-la-Pierre, joua cependant en leur faveur: si les pierres des bâtiments de la fenderie et de la petite forge furent rapidement réutilisés pour d'autres constructions, la végétation recouvrit bientôt les autres vestiges(grande forge, fourneau et leurs dépendances), protégeant au moins le gros-oeuvre de toute dispersion; en contrepartie, ces bâtiments subirent l'agression des ronces, lierres et autres plantes ligneuses qui contribuérent à leur dégradation; leurs volumes et une partie de leurs assises furent au moins conservés en grande partie.

En l'absence de tout outillage - le seul atelier de production en place étant le fourneau, mais dépourvu de sa machineriela mise en valeur du site devait nécessairement passer par une reconstitution graphique de l'activité métallurgique et des techniques de production; celle-ci était facilitée par la richesse du chartrier, renfermant plusieurs baux, des descriptifs des différents bâtiments etc...

Les travaux de terrain permirent à l'association de dégager et de consolider le fourneau,l'un des rares encore en place dans le département de l'Orne;quant aux autres structures(maison de maître ,maison ouvrière de la fenderie)leur remise en état fut l'oeuvre de la famille d'Andigné prouvant ainsi qu'elle entendait également participer à la mise en valeur de son patrimoine;en même temps elle contribuait largement à redonner une vision globale de ce qu'était un site métallurgique au siéle dernier en recréant les lieux de vie qui entouraient chaque atelier de production.

L'association sut enfin tirer profit des éléments originaux du site -succession de trois étangs entourés de bois - qui promettaient à eux seuls d'attirer bon nombre de promeneurs;les travaux réalisés autour de chacun de ces éléments se sont finalement concrétisés par la création d'un circuit pédestre marquant indiscutablement la réussite de l'alliance entre le tourisme et la culture scientifique et technique.

Le circuit pédagogique permet de suivre le processus de la fabrication du fer depuis le concassage et le nettoyage du mi-

nerai jusqu'au découpage des barres de fer à la fenderie,ce,au moyen de panneaux où le texte et l'image se complétent.L'est en somme un retour da ns le passé -le site n'a pas subi,hors les disparitions signalées,de remaniements depuis le XIXéme siécleque propose cette réhabilitation en ne négligeant aucun des éléments puisque tant l'activité de production que la vie quotidienne sont içi pris en compte.

La réhabilitation de la forge d'aube:

La mise en valeur de la forge d'Aube; entreprise peu aprés celle du Lhamp-de-la-Pierre et toujours en cours -les structures conservées posant en termes différents son aménagement- bénéficia de l'intérêt de plus en plus grand porté par les instances culturelles et scientifiques à l'égard du patrimoine industriel: l'autorisation d'ouvrir un chantier de fouilles archéologiques délivrée par la Direction Régionale des Antiquités Historiques en e sans doute l'un des meilleurs exemples; avec celles organisées aux forges de Buffon et qui font figure de pionniéres, les fouilles entreprises à Aube depuis Juin 1983 sont, à ce jour, les seuls exemples français d'archéologie appliquée à l'étude des sites métallurgiques.

Engagées à l'initiative de l'association de sauvegarde,qui prouvait ainsi qu'elle entendait mener la mise en valeur du site le plus rigoureusement et le plus scientifiquement possible,les fouilles répondaient à une double préoccupation:

=d'une part, présenter au futur public les outillages encore visibles(marteau latéral, martinet terminal, fours, soufflerie à piston...)en les replaçant dans leur contexte, la métallurgie du cuivre; cela imposait de dégager le prolongement de ces structures dans le sol(dallages, pavages, fosses, socle de l'enclume du marteau...)

=d'autre part, mettre à jour, pour une parfaite reconstitution du site, les niveaux ensevelis afin de dégager les assises d'appareillages liés à la métallurgie du cuivre mais aujourd'hui disparus(les textes du fonds Mouchel mentionnent en effet l'utilisation d'un pilon à vapeur et d'un four à lunette dont seule la fouille à permis de retrouver l'emplacement); cet-te mise à jour doit aussi permettre de mieux comprendre comment s'est fait le passage de la métallurgie du fer à celle du cuivre, en particulier la réutilisation des fours.Les fouilles éffectuées jusqu'alors(chantier 1983) ne permettent pas encore de répondre d'une maniére sôre à l'ensemble de ces questions.

La mise en valeur du site de la forge d'Aube doit finalese concrétiser par l'installation, dans les bâtiments rénovés de la forge, d'un musée de la métallurgie de la vallée de la Kisle; la petite métallurgie(tréfilerie,empointerie,épinglerie et aiguillerie)s'est en effet implantée trés tôt dans cette région, d'abord dans des petis ateliers dispersés à la campagne puis, au cours du premier quart du XIXéme siécle pour la plupart, le long de la Kisle.ll s'agit donc ici de reconstituer,autour de bâtiments et d'appareillages particuliérement évocateurs de.l' activité métallurgique du siécle dernier,l'histoire de la vallée de la Risle à travers son activité artisanale et industrielie.

Les deux établissements offrent finalement un exemple intéressant de mise en valeur du patrimoine industriel:outre la nécéssité d'une recherche historique approfondie, à laquelle l' apport de la fouille archéologique ne saurait être négligé, et de prendre en considération non seulement des éléments encore présents mais aussi le site dans son ensemble il apparait important d'insister sur le rôle des propriétaires du site et de la population l'environnant; les premiers ont, au Lhamp-de-la-Pierre, montré l'intérêt qu'ils portaient à l'aménagement de ce site en restaurant eux-mêmes certains bâtiments; à Aube la fouille archéologique a permis à bon nombre d'habitants de la région de concrétiser activement leur attachement à leur patrimoine.

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Fig. 1 - Aube : Bâtiment de l'affinerie.



Fig. 2 - Aube : Forge, vue intérieure : à gauche les deux foyers d'affinerie, à droite le marteau, la chaufferie et la soufflerie à piston.



Fig. 3 - Aube : Forge, détail de l'arbre à cames animant le marteau.



Fig. 4 - Le Champ-de-la-Pierre : Vestiges du haut-fourneau avant restauration.



Fig. 5 - Le Champ-de-la-Pierre : Maison ouvrière.

Photos : P. CORBIERRE

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FORGES ET HAUTS FOURNEAUX EN BOURGOGNE DU NORD : UN PATRIMOINE AU SERVICE DE L'IDENTITE REGIONALE.

Bernard RIGNAULT *

Limitée d'abord à la sauvegarde des Forges de Buffon, l'action de notre association a pris progressivement en compte l'ensemble de la Bourgogne du Nord. A la démarche initiale indispensable de l'inventaire des Sites sur le terrain a été associée la perspective d'une recherche scientifique empruntant les méthodes de l'histoire, de l'architecture, de l'ethnologie ou encore de l'archéologie. C'est ainsi qu'a pris corps l'idée d'un musée de territoire ayant pour tème la sidérugie Nord-Bourguignonne.

Devant un bâtiment, plusieurs solutions d'intervention sont possibles ; le choix s'effectue en fonction de la place que lui assigne le chercheur mais aussi de la sensibilisation qu'il aura suscitée chez le propriétaire privé ou public et, bien sûr, de l'indispensable appui financier des Collectivités territoriales et de l'Etat.

Octobre 1984.

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Haut fourneau de Marcenay - 1742. Etat des lieux en 1981 avant la restauration

Photo. Ph. Lair

LA GENESE D'UN PROJET

Dans quelques jours, l'Association au sein de laquelle j'assure la fonction de Secrétaire Général, coordinateur de ses activités remettra au Président du Conseil Régional de Bourgogne, l'étude de faisabilité du "musée de la sidérurgie du Nord de la Bourgogne".

C'est en avril 1982 que cette collectivité territoriale a pris la décision de financer l'étude que nous appelions de nos voeux.

Les conclusions et les propositions qui s'en dégageront permettront aux élus régionaux et locaux ainsi qu'aux instances ministérielles de connaître de façon précise les finalités du projet, les modalités proposées pour sa réalisation, et les coûts prévisionnels d'investissement et de fonctionnement qui seront nécessaires à l'existence du musée. L'ensemble de ces données leur permettra de se prononcer sur l'intérêt d'une telle réalisation qui nécessitera l'engagement sur plusieurs années de fonds publics après qu'une convention réglant les droits et les devoirs de chacun soit intervenue entre les divers partenaires.

La réalisation de cette étude aura nécessité plus de deux années de travail elles-mêmes assises sur les trois années d'activités antérieures. Elle marque un moment décisif dans la croissance d'une structure culturelle telle que la nôtre, née en 1978 d'un mouvement d'enthousiasme bénévole de quelques-uns pour le site des anciennes forges de Buffon, alors méconnu et menacé, et qui est aujourd'hui parvenue à une certaine notoriété par les diverses activités qu'elle déploie en faveur du patrimoine et de l'histoire industriels.

L'aventure des premières années a entraîné au fil des ans la recherche de moyens de plus en plus importants pour soutenir son développement arborescent : recherches historiques, fouilles archéologiques, enquêtes ethnologiques, activités muséales et de formation, constitution de la documentation et de collections. Aux ressources passagères, ponctuelles et aléatoires devront succéder des ressources plus assurées sans lesquelles il ne serait pas raisonnable d'envisager un avenir durable, caractère qui est un des fondements de toute institution muséale.

Ce musée de techniques et d'industrie qui fera référence à l'approche ethnologique pour les périodes contemporaines, sera un musée "éclaté" sur le territoire d'une petite région s'étendant sur 2463 km2 dont 1911 km2 pour le Châtillonnais (6 cantons, 114 communes) et 352 km2 pour le canton de Montbard (28 communes). Sa philosophie s'inspire à la fois de celle des musées de plein-air et des écomusées avec toutefois, comme différence notoire par rapport à ces derniers, qu'un thème unique en constitue la raison d'être : s'appuyant sur les sites naturels et aménagés et surtout sur des traces bâties, il veut montrer les spécificités de l'histoire locale tout en les replaçant dans le temps et dans l'espace, depuis les époques géologiques pendant lesquelles se formèrent les productions ferrugineuses jusqu'aux aspects les plus contemporains des industries mécaniques. Cependant le musée comportera un temps fort relatif aux XVIIIe et XIXe siècles, moment d'apogée de la sidérurgie traditionnelle.





Les établissements sidérurgiques dans le nord de la Côte-d'Or. Carte dressée par Serge BENOIT. in Monuments historiques, n° 107, 1980. Sept lieux permanents, aménagés pour recevoir le public et présenter des expositions permanentes sont proposés ; ils renverront éventuellement à d'autres, occasionnels. Ces lieux, propriété de collectivités locales ou de particuliers, sont ou seront donnés par bail-conventions d'une durée minimale de trente ans à l'Association qui aura la maîtrise d'oeuvre des travaux d'aménagement muséaux et la gestion générale. Ces lieux sont : forge de l'abbaye de Fontenay (XIIIe siècle), haut fourneau de Marcenay (1742) (1), la grande forge de Buffon (1768), logements ouvriers de Sainte-Colombe-sur-Seine (1840), haut fourneau d'Ampilly-le-Sec (1829), forge de Chenecières (1840), espace en forêt de Châtillon-sur-Seine pour évoquer le travail du bois et l'extraction minière.

Pour qu'un tel patrimoine puisse jouer le rôle culturel qu'on lui assigne aujourd'hui c'est-à-dire être le témoignage privilégié et objectif d'une activité humaine à un moment de l'histoire, il faut certes pouvoir l'étudier et le conserver, mais aussi disposer de ressources humaines et matérielles capables de transcrire sous des formes appropriées et lisibles par le plus grand nombre, le message aux multiples écritures dont il est le révélateur.

En effet, ce type de musée est basé sur le pouvoir évocateur et sensible que confère la vision de lieux authentiques réhaussés, pour mieux les comprendre, par des données historiques et techniques transcrites grâce à une muséographie dont la forme doit obligatoirement s'adapter à chacun d'entre eux.

On comprendra vite qu'un semblable projet nécessite la mise en oeuvre de moyens financiers d'importance, dont l'échéancier peut toutefois, étant donné l'éclatement des lieux, être modulé avec plus de facilité que dans le cadre d'un programme monolithique qui souffre dans son avancement du moindre retard.

L'évaluation globale du coût d'investissement dans lesquels sont inclus les travaux préparatoires déjà réalisés s'élève à 17 000 000 francs.

(1) Il s'agit des dates de construction des édifices.



L'ECLATEMENT DES ACTIVITES

Comme nous l'avons dit précédemment, le premier objectif que s'était fixé l'Association consistait à tout mettre en oeuvre pour permettre la sauvegarde du site de l'ancienne forge de Buffon. Cependant, dans la déclaration de ses buts publiée au Journal Officiel du 14 novembre 1978, l'on n'avait pas restreint ceux-ci à cette seule mission, prévoyant ainsi les développements de l'avenir (1).

A Buffon, les premières aides, modestes mais salutaires, vinrent esere sentiellement de la Caisse nationale des Monuments historiques, du ministère de la Culture et du département de la Côte-d'Or. Elles permirent la sauvegarde de toitures et la réalisation d'étanchéités sur les parties voûtées du haut fourneau.

Ensuite, de 1980 à 1984, quatre tranches annuelles de travaux, pour lesquelles la participation de la Région Bourgogne s'éleva jusqu'à 80%, purent être engagées. Elles permirent de mener à bien les opérations de reprise du gros-oeuvre déstabilisé, le curage du bief (3000m3), la réfection de couvertures, les fermetures par menuiseries, l'aménagement de bureaux pour l'Association et de réserves, enfin le dégagement de remblais pour faciliter les fouilles archéologiques. Le montant total de ces 4 tranches s'éleva à 1 640 000 francs. On a tenu à ce qu'elles se réalisent durant les périodes creuses de l'année afin de ne causer nulle gêne aux visiteurs lors de la saison touristique. Par ailleurs le fait pour ces derniers de pouvoir suivre chaque année l'avancement des travaux est apparu comme un facteur dynamisant pour tout le monde.

Dorénavant, les travaux futurs seront engagés dans le cadre du programme du musée ; ils porteront à la fois sur les bâtiments existants, par la poursuite de leur restauration, et sur des constructions nouvelles à élever à l'emplacement de bâtiments détruits dont on s'efforcera de restituer la volumétrie d'ensemble. Leur traitement architectural extérieur s'intégrera au cadre bâti existant, mais leur intérieur s'adaptera le plus possible aux exigences fonctionnelles du musée.

Le maître d'ouvrage de ces travaux est le Syndicat intercommunal de Montbard, qui a reçu à bail emphytéotique, de la part de sa propriétaire, les anciens locaux à usage industriel et les anciennes habitations ouvrières et de maître. La maîtrise d'oeuvre est assurée à la fois par l'ar-

(1) Aux termes de ses statuts, l'Association a pour objet de : "Sauvegarder et animer les bâtiments à usage industriel et annexes des anciennes Forges de Buffon ; ouvrir ceux-ci à la visite du public et organiser toutes manifestations culturelles ayant trait à l'histoire de la sidérurgie locale et régionale ; recenser, collecter et étudier tous documents et objets mobiliers s'y rapportant ; associer à cette tâche, responsables locaux et habitants et favoriser toutes les initiatives de nature à conserver et mettre en valeur le patrimoire industriel ; publier tous documents s'y rapportant. chitecte en chef des Monuments historiques (1) et par un architecte privé. L'Association, à qui reviennent par convention la jouissance et la gestion du site, apporte sa contribution par sa connaissance des lieux et de leur histoire. Elle effectue en particulier une couverture photographique suivie de l'exécution des travaux.

Dans le Châtillonnais, les différentes démarches entreprises à partir de 1980 en faveur du patrimoine industriel local ont commencé de porter leur fruits depuis deux ans.

Ainsi le Syndicat intercommunal du lac de Marcenay-Larrey a entrepris, de sa propre initiative, la restauration du haut fourneau de Marcenay en tenant compte des recommandations techniques de l'association.

La tour du haut fourneau a été entièrement restaurée et le dégagement des abords a permis de mettre à jour les anciennes installations hydrauliques. Une prochaine tranche de travaux devra permettre la restauration de la halle aux charbons, futur lieu d'exposition du musée.

A Ampilly-le-Sec, après quatre années d'incertitude, le haut fourneau et d'autres bâtiments du site font l'objet d'un programme de sauvegarde. On développera plus loin par quel mécanisme il est devenu la propriété du Syndicat intercommunal du canton de Châtillon-sur-Seine.

Enfin, d'autres sites du Châtillonnais où ne sont pas encore effectués de travaux, donnent lieu à des procédures administratives de protection au titre des Monuments historiques. Il s'agit du haut fourneau d'Essarois pour lequel l'accord des propriétaires a été obtenu après trois années d'hésitation, des forges de Rochefort-sur-le-Brevon dont la Conservation régionale des Monuments historiques envisage l'inscription à l'Inventaire supplémentaire et des logements ouvriers de Sainte-Colombe-sur-Seine, dont la société industrielle propriétaire est disposée à se désaisir au profit d'une collectivité. Il reste, dans ce dernier cas, à obtenir que la ville acquière l'ensemble.

Quant aux actions de recherche, si elles se raccordent de plus en plus étroitement au projet du musée pour ce qui regarde la diffusion de leurs résultats vers le public, elles conservent néanmoins, dans un souci de rigueur scientifique, leur maximum d'autonomie quant à leurs objectifs et leur méthodologie.

Parmi ces recherches, les plus importantes regardent :

1/ l'inventaire des sites, réalisé avec le concours de l'Inventaire général des monuments et richesses artistiques de la France, un des services de la Direction du Patrimoine au ministère de la

(1) Les Forges de Buffon ont été en partie classées Monument historique en 1943, en partie inscrites à l'Inventaire supplémentaire en 1967. Dernièrement, à la suite des actions menées par l'Association, la totalité des bâtiments ont été classés.

Culture, et qui porte sur :

- * l'étude architecturale de plusieurs sites monumentaux de la sidérurgie indirecte en Châtillonnais.
- * le pré-inventaire des sites monumentaux de la sidérurgie indirecte en Dijonnais.
- * l'inventaire des sites de la sidérurgie directe dans l'Auxois.
- 2/ un programme de fouilles aux forges de Buffon qui se poursuit depuis 1981 dans le bâtiment de l'affinerie. Ces fouilles sont destinées à permettre la compréhension de l'évolution de l'espace de travail de cette partie de l'usine qui n'a pas conservé de vestige aérien à l'exception de ses murs périphériques. Un sondage réalisé en 1984 dans les halles du fourneau débouchera sur une fouille systématique en 1985-1986. D'autres ateliers restent à prospecter: la fenderie et le martinet, l'aire de lavage des minerais en sont les principaux.
- 3/ une approche ethnographique du Châtillonnais et du Montbardois qui s'est attachée, dans un premier temps, à la collecte de témoignages oraux des personnes qui ont vécu les périodes transitoires de la première moitié de ce siècle. La connaissance des populations avec leurs migrations, les rapports sociaux et professionnels sont autant de données qui ont fait l'objet de collectes. Dans un second temps, l'on abordera les problèmes plus immédiats posés par les mutations actuelles, génératrices de crise au sein de cette branche d'industrie.
- 4/ la poursuite d'une recherche archéologique et historique sur la sidérurgie Châtillonnaise, engagée en 1979 dans le cadre d'un appel d'offre de la Délégation générale à la recherche scientifique et technique dont l'Association avait été bénéficiaire. Après que deux tranches annuelles aient été réalisées, une troisième et dernière doit s'achever en 1984 et donner lieu à la production d'un rapport général.

Cette recherche, menée par des chercheurs associés au laboratoire d'archéologie de l'Ecole normale supérieure de Paris, et le Groupement d'intérêts scientifiques, Université Paris I/Ecole des hautes études en sciences sociales, concerne les périodes médiévales et modernes.

Depuis la création de l'Association, les recherches menées sous son égide ou en liaison avec elle ont donné lieu à plus d'une vingtaine de travaux, articles ou communications, à des manifestations scientifiques.

Ainsi, en avril 1984, lors du dernier congrès national des Sociétés savantes tenu à Dijon, cinq communications sur l'industrie et l'archéologie sidérurgiques de la région ont été présentées par des membres ou collaborateurs.

Afin de constituer les collections du futur musée, l'acquisition par don ou par achat de pièces diverses, de documents d'archives et de livres a été pratiquée dès l'origine. Mais celle de pièces importantes (peintures, oeuvres de Buffon et fonds d'archives relatif au naturaliste) n'a pu être réalisée qu'avec l'aide financière de la Région Bourgogne et de l'Etat. Parmi les actions de diffusion, l'exposition est celle qui touche le plus vaste public. Des expositions à caractère permanent sont installées dans les sites monumentaux : depuis six années à Buffon, trois années à Sainte-Colombe. Les expositions à caractère de préfiguration ne sont présentées que durant la période estivale, du 1er juin au 30 septembre, et visitables sur demande, pour les groupes, en avril-mai et octobre-novembre, en attendant que l'installation du chauffage les rende visibles toute l'année.

En 1979, ce sont 2500 personnes qui ont visité le site de Buffon ; en 1984 ce chiffre s'est élevé à 8000 pour les deux sites de Buffon et de Sainte-Colombe, le public étant composé à la fois de nouveaux visiteurs et d'habitués.

Les actions pédagogiques menées en coopération avec l'Education nationale depuis 1980, suivent deux axes :

- * la participation de la communauté scolaire à la mise en valeur du patrimoine sidérurgique.
- * la mise à la disposition des enseignants de moyens pédagogiques.

La première de ces actions fera l'objet d'un développement ultérieur dans le corps de ce texte.

La seconde consiste en la réalisation d'expositions itinérantes destinées aux milieux scolaires du cycle primaire et secondaire, et par la conception d'un livret pédagogique sur l'évolution de la métallurgie dans les quatre départements bourguignons. Enfin, des stages de formation permanente des enseignants sur l'archéologie industrielle sont organisés en collaboration avec les services du Rectorat de l'Académie de Dijon.

Les liens tissés avec les partenaires d'origines diverses, la connaissance de nos activités par d'autres organismes poursuivant des buts similaires, la prise en compte de nos activités et de leurs résultats par les élus locaux et les services administratifs, tout cela amène de plus en plus l'Association à apporter son concours à un ensemble varié d'associations ou d'organismes privés ou publics. C'est ainsi qu'en 1983, le secrétaire général a dû animer un groupe de travail créé sur la décision du ministre français de la Culture sur le thème de l'insertion sociale des recherches et actions en archéologie industrielle (16).

Pour pénétrer plus avant la réalité quotidienne, mieux saisir la complexité des actions menées et la philosophie qui préside à celles-ci, nous allons prendre deux exemples : le premier regarde la sauvegarde du patrimoine, le second l'action de sensibilisation des milieux scolaires.
LA SAUVEGARDE D'UN SITE : LE HAUT FOURNEAU D'AMPILLY-LE-SEC.

Lorsqu'en 1980 nous avons réalisé, dans le cadre du contrat d'études conclu avec la Délégation Générale à la Recherche Scientifique et Technique, un pré-inventaire sommaire des vestiges monumentaux attachés à l'histoire sidérurgique du Châtillonnais, plusieurs sites se sont alors imposés comme des témoignages remarquables de cette ancienne activité industrielle. Il s'agit en particulier des hauts fourneaux d'Essarois, de Marcenay, d'Ampilly-le-Sec, des forges de Rochefort sur Brevon et de Tarperon (1).

Pour parvenir à sensibiliser les propriétaires, collectivités locales ou personnes privées, à l'intérêt que représentaient pour l'histoire collective ces vestiges, pour leur prouver le bien-fondé de notre démarche et pour que les procédures préalables à des actions de protection soient engagées par les services de l'Administration, il nous a semblé préférable de faire précéder ces démarches par des actions de reconnaissance de la part des habitants locaux en leur restituant une partie de l'histoire attachée à ces bâtiments.

Plusieurs réunions-débats eurent lieu ainsi qu'une exposition à laquelle furent invités les propriétaires concernés.

Si, aujourd'hui la conservation du fourneau de Marcenay est acquise et celle d'Essarois très probable à moyen terme, celle des anciens logements ouvriers de Sainte-Colombe-sur-Seine reste encore problématique. Quant au site d'Ampilly-le-Sec qui s'impose par son architecture monumentale comme témoignage du savoir-faire et de la maîtrise technique des bâtisseurs du début du XIXe siècle, il constitue l'une des ultimes productions d'architecture traditionnelle encore empreintesdes techniques du XVIIIe siècle. Son plan, les matériaux mis en oeuvre dans une stéréotomie remarquable le désignaient comme l'un des monuments à sauvegarder en priorité pour les générations futures.

Dans ce cas, le statut juridique du site n'avait pas la clarté de celui des forges de Buffon parce qu'il était propriété d'une Société Civile Immobilière dont le seul but était la liquidation de ses biens.

Déjà des parcelles de l'ancien site industriel avaient été revendues, séparant de façon quasi définitive des bâtiments qui avaient entre eux des liens organiques. Ainsi, un corps de logements ouvriers et la halle aux charbons de bois avaient trouvé un acquéreur de même que l'ancienne habitation du maître fondeur.

Seul restait à vendre le lot constitué du haut fourneau (1829), d'un ancien bâtiment de tréfilerie (1845) et de logements ouvriers en partie modifiés dans les dernières décennies, le tout étant implanté autour d'une cour.

(1) L'ensemble de ces lieux fait aujourd'hui l'objet de démarches de protection au titre des Monuments historiques ; certains, sous notre impulsion sont en cours de restauration.





Haut fourneau d'Ampilly-le-Sec (1829).

Ci-contre,	en	haut	:	Elévation-coupe sur la halle de coulée, relevé établi par JL. Lasnier et O. Juffard en octo- bre 1982.
	en	bas	:	Etat des lieux, printemps 1981, Photographie, Ph. Lair.
Ci-dessus,			:	Plan général, relevé établi par JL. Lasnier et 0. Juffard en octobre 1982.

Dans une perspective de conservation, il fallait de toute urgence trouver à ce site un propriétaire pour que l'on puisse engager une procédure de protection au titre des Monuments historiques, et obtenir par convention la jouissance des lieux. A quoi servirait une protection au titre de la législation sur les Monuments historiques si le propriétaire n'était pas décidé à engager réellement les travaux nécessaires à sa conservation ?

NOus pensions que le seul propriétaire capable de remplir ce rôle ne pouvait être qu'une collectivité locale, soit la ville de Châtillon-sur-Seine soit le Syndicat du canton regroupant les 28 communes qui le composent.

Il a fallu que l'Association mène alors de front les travaux d'études, en particulier des relevés architecturaux et la couverture photographique qui allaient permettre la constitution des dossiers administratifs, et d'autre part la sensibilisation des élus locaux, maires, conseillers généraux, membres d'association, par des visites de terrain et la participation aux différentes assemblées de ces élus.

Toutes ces actions en faveur de ce site ont été menées, il est vrai, parallèlement aux autres que réalisait l'association à Buffon, à Marcenay ou à Sainte-Colombe, l'ensemble créant un climat de confiance indéniable.

Le 10 décembre 1982, grâce à l'appui de son Président, la question de l'achat par le Syndicat fut officiellement posée à l'assemblée, laquelle, dans son ensemble, réagit favorablement. Pourtant, le renouvellement du mandat des élus devant avoir lieu dans les 3 mois suivants, dans le cadre des élections municipales, la décision resta en suspens. La nouvelle assemblée composée d'anciens et de nouveaux membres demanda alors de visiter les lieux avant de se prononcer. Le montant de l'acquisition qui s'élevait à 200 000 francs fut jugé trop élevé par une grande partie des présents, cependant conscients de l'intérêt des lieux. Il fallut alors l'intervention d'un membre de l'Administration du service des Domaines qui estima ces lieux à un chiffre très proche de celui qui avait été proposé (195 000 F) et dans lequel le haut fourneau apparaissait paradoxalement en valeur négative, les bâtiments annexes et le terrain possédant seuls une valeur immobilière !...

A sa séance du 10 juin 1983, la question de l'achat fut miseau vote à bulletin secret. L'acquisition fut votée par 26 voix pour, 14 contre et 3 abstentions, acte culturel d'importance pour un syndicat dont la vocation première restait le ramassage des ordures ménagères, l'entretien des routes et des chemins et l'organisation des transports scolaires.

Mais il reste évident que cet achat ne serait pas intervenu, si l'Association n'avait "apporté" au Syndicat un plan de financement de la première tranche de restauration à hauteur de 90% et pour un coût total de 500 000 francs, la Région Bourgogne participant pour 50%, le département de la Côte-d'Or et de l'Etat pour 40% ; ce plan de financement n'a d'ailleurs été acquis qu'au sein d'administrations elles-mêmes déjà sensibilisées à l'ampleur de la tâche.

Il n'était que temps ; pendant les quatre années qui s'étaient écoulées depuis 1980 les dégradations avaient empirées. Grâce à la diligence et à l'appui du Conservateur Régional des Monuments Historiques de Bourgogne, la protection du site devint effective le 9 janvier 1984 au titre des monuments inscrits.

Actuellement, confiée à un entrepreneur local, la première tranche de travaux est en cours et porte essentiellement sur des travaux de réfection des toitures, reprises des maçonneries et ouvrage de nettoyage. Un architecte désigné par le syndicat assure la maîtrise d'oeuvre de ces travaux, assisté par notre Association et le service départemental d'architecture.

Une seconde tranche de travaux d'un montant de 300 000 francs a été programmée dans le cadre de l'exercice budgétaire 1985 qui permettra d'achever les travaux de restauration.

Ainsi le premier volet, celui de la conservation et de la sauvegarde sera assuré. Ensuite, dans le cadre du programme du musée, une exposition permanente sur les moteurs hydrauliques se tiendra dans un autre bâtiment plus récent et contigu à l'ancienne tréfilerie, qui couvre actuellement l'ancien bief de la forge.



198.000 F

pour un

patrimoine

à sauvegarder

Au cours de cette assemblée, M. Rignault, secrétaire de l'Association des forges de Buffon, présentait les forges d'Ampilly, doit tenter M. Jeanniard, directeur départemental de l'habitat rural, présentait les activités de l'ODEAUF qui vise à l'amélioration de l'habitat rural. Par le biais de ces permanences, qui se déroulent aux silos, l'ODEAUF dispense conseils et informations aux personnes qui souhaitent leur logement et les aide à constituer les dossiers.

Au cours de cette séance, le SI-VOM acceptait d'attribuer trois délégués titulaires à la commune de Sainte - Colombe. Les personnalités présentes : M. Angelier, sous - préfet de Montbard ; M. Protte, représentant de M* Mathieu, député; M. Sordel, sénateur - maire ; M. Petitfour, ancien conseiller général, ancien président du SIVOM ; M. Rignault, secrétaire de l'Association des forges de Buffon ; M. Jeanniard, directeur départemental de l'habitat rural ; M. Bukovatz, ingénieur TPE.



Sous la houlette de M. Rignault, secrétaire de l'Association des forges de Button, les délégués ont visité les forges d'Ampilly que le SIVOM veut racheter pour les sauver

(Photo F. Scheurer)

COMMENT FAIRE SE RENCONTRER L'ENSEIGNEMENT PROFESSIONNEL ET L'HISTOIRE DES TECHNIQUES.

Dès 1979, après une première année d'ouverture du site de la forge de Buffon au public, l'espace des usines était apparu trop statique aux visiteurs qui devaient faire un effort énorme pour comprendre dans ses grandes lignes le fonctionnement et la disposition ancienne des lieux. Nous avons pris alors la décision de réaliser des montages audio-visuels qui permettaient par l'image et le son d'évoquer la chaîne des opérations techniques qui s'effectuaient dans les ateliers. Par ailleurs, la restitution de certaines parties techniques, particulièrement évocatrices, était envisagée. La réalisation d'une roue hydraulique s'imposait ; moteur de base de toutes les machines, elle justifiait la présence de l'eau et pouvait, par son fonctionnement continuel, amorcer la rennaissance du site.

A la fois pour des questions économiques (coût de réalisation élevé par un professionnel qu'il aurait d'ailleurs fallu trouver) et pour amorcer un dialogue avec le milieu de l'enseignement technique local, des contacts furent pris avec les deux établissements techniques de Montbard : le Lycée d'Enseignement Professionnel (section métaux) et la Section d'Education Spécialisée du Collège d'Enseignement Secondaire.

Si ce projet parut de prime abord fantaisiste, la persévérance déployée et la persuasion finirent par rendre ce projet progressivement crédible ; il fallait que l'idée cheminât dans les esprits non préparés. Il le devint complètement lorsque nous proposâmes les plans de cette roue dont nous avions effectuél'étude et réalisé les dessins techniques.

Une année fut nécessaire pour mettre les choses en route. Après avoir reçu l'accord des services administratifs, la réalisation occupa l'année scolaire 1980–1981 ; la coordination au sein des professeurs fut le fait du du professeur métallier, âme de la S.E.S.

La réalisation des travaux de bois et l'assemblage général furent assurés par la S.E.S. et la grosse partie mécanique (paliers d'arbre flasques...) par le L.E.P. tandis que la Société industrielle Vallourec façonnait dans ses ateliers l'arbre métallique.

Les élèves réalisèrent d'abord la roue hydraulique, d'un diamètre de 3,20 mètres d'après une maquette d'étude à l'échelle du 1/50e puis ils façonnèrent chacune des pièces à partir de bois débités en scierie. Ils procédèrent enfin au montage en atelier. En juin 1981, l'ensemble fut mis en place dans le coursier de bois installé dans le bief par un charpentier professionnel.

L'intérêt éveillé chez les élèves par ce type de démarche et les liens de confiance, voire d'amitié, qui se nouèrent entre les membres de l'Association et certains des enseignants amenèrent ceux-ci à proposer d'eux-mêmes la continuation de la collaboration.





Ci-contre et ci-dessus : construction en atelier et montage dans le site de Buffon d'une roue hydraulique par les élèves de la Section d'Education Spécialisée du Collège de Montbard (1981).



Les élèves du Collège de Montbard devant l'un des deux soufflets du haut fourneau de Buffon, réalisés d'après des documents historiques, juin 1984. En 1981-82, deux martinets de forge suivirent, inspirés de ceux qui sont dessinés dans l'*Encyclopédie*. Les dessins et le calcul furent alors pris entièrement en charge par le professeur métallier du C.E.S.

L'un de ces martinets, actionné par la force humaine est une transcription du document de base, l'autre fut adapté à la roue hydraulique.

Ces premières productions ne furent pas des reconstitutions fidèles, mais plutôt des interprétations, dans lesquelles les types d'assemblages ou certains éléments mécaniques réalisés en fonction des connaissances des élèves se greffaient sur des techniques anciennes.

En 1983, le pas fut franchi vers la réalisation de travaux plus proches de la réalité historique de la technologie. En effet, en fonction du projet général de musée, l'Association a engagé un processus de restitution d'ensemble de la machinerie de la soufflerie du haut fourneau que viendra compléter ultérieurement celle de la forge. Elle s'appuye pour cela, à la fois sur les traces visibles dans l'architecture, sur celles qui sont enfouies dans le sol, sur les écrits se rapportant au site et sur ceux qui décrivent de façon générale les techniques anciennes, en particulier les écrits de Buffon.

Programme ambitieux et long qui nécessitera des chercheurs aux formations multiples (18).

La restitution de toutes les parties mécaniques (de bois ou de métal) composant la soufflerie (vannage, coursier, roue, système de transmission, soufflets) sera prise en charge par la S.E.S. du collège de Montbard qui, pour l'occasion, se groupera avec d'autres établissements du département.

La totalité de la machinerie nécessitera la construction d'une roue à aubes de 6 mètres de diamètre et d'un coursier d'alimentation de 21 mètres, d'un mécanisme comprenant deux lanternes et deux rouets dont le plus grand aura un diamètre de 3 mètres, enfin la construction du système de relevage des soufflets et de deux soufflets en bois (5,70m de long, 2,30m3 de capacité).

Si une telle réalisation nécessite des moyens financiers importants (20m3 de bois sont nécessaires, en majorité du chêne), elle demande également un travail préparatoire non négligeable.

Aussi cette opération est-elle programmée sur 2 ou 3 années, afin de laisser le temps à l'archéologie de poursuivre ses investigations dans le sol des anciens hallages du fourneau et d'en tirer les conclusions qui permettront les restitutions projetées.

Les premiers travaux ont porté sur les deux soufflets ; objets techniques indépendants qu'il suffira par la suite de replacer en bonne place, ils étaient tout indiqués pour ouvrir les opérations.

Deux ouvrages techniques anciens servirent de base à ces réalisations : l'article "Grosses Forges" de l'*Encyclopédie* de Diderot et surtout le mémoire de Grignon sur l'art des soufflets. Après une transcription des mesures anciennes en mesures actuelles et une interprétation des textes, un premier modèle général animé de la machinerie fut construit à l'échelle du 1/5.

Au mois de juin dernier les deux soufflets en grandeur nature prenaient place provisoirement dans la fenderie en attendant que les sondages archéologiques de la halle de la soufflerie soient terminés. Chacun d'eux, réalisé en sapin, pèse environ 1 tonne.

Aujourd'hui les premiers bois pour la construction de la roue de 6 mètres de diamètre commencent à être façonnés.

L'intérêt pédagogique d'une telle action a été reconnu par tous les échelons de l'enseignement ; il offre l'avantage d'ouvrir sur l'extérieur les activités scolaires tout en valorisant le travail des élèves. Parmi les visiteurs du site, on n'a pu constater que des remarques élogieuses sur cette action et des encouragements à la poursuivre.

EN GUISE DE CONCLUSION... PROVISOIRE !

Actuellement la sauvegarde d'un patrimoine de ce type ne semble pouvoir être assurée avec un maximum de garanties que par une véritable volonté de la collectivité locale, laquelle agit par l'intermédiaire de ses représentants élus sur les mécanismes politiques et financiers qui permettent la réalisation d'actions d'envergure.

Cependant le lancement d'un tel mouvement en un temps si court n'a pu être le fait que d'une structure légère, indépendante, capable de mettre sur pied et de réorienter rapidement ses programmes en fonction des opportunités tout en restant cependant fidèle à ses objectifs à long terme. Il n'a été possible, surtout, que parce que les membres constituant l'équipe permanente et bénévole, à quelque niveau que ce soit, ont fait preuve d'un militantisme communicatif permanent. Il semble, par ailleurs, incontestable que les relations humaines simples et cordiales et l'honnêteté intellectuelle ont permis à l'équipe, loin de tout appareil administratif, d'établir et de multiplier les liens qui jouent en faveur des objectifs visés.

La règle est aussi d'accepter tous ceux qui désirent apporter leur contribution, avec leurs qualités et leurs défauts, sans les forcer à entrer dans un moule préparé. Il faut plutôt que chacun trouve dans l'action générale une direction qui lui convienne et dont il demandera vite d'être l'agent responsable.

Ainsi chacun peut développer ses propres potentialités et s'ouvrir ensuite sur d'autres domaines.

Si la dynamique va de soi dans les actions de recherche, qui ne mettent en cause que les individus, il y a "risque" d'enlisement lorsqu'on se heurte aux contraintes dues à la conservation des éléments du patrimoine et à la gestion des lieux. Mais comment ne pas accepter ce que l'on a appelé de ses voeux ?

La difficulté restera de maintenir un équilibre entre ces deux aspects afin que la passion et la raison continuent à se valoriser et à s'enrichir mutuellement.

Pour qu'un patrimoine jusqu'alors délaissé puisse bénéficier au sein de la conscience collective de la place qui lui est due, il faut qu'il retrouve une signification dans l'histoire mais surtout qu'il soit créateur de liens avec les membres de la collectivité, liens affectifs créés par souvenir des générations passées, venant aussi de la possibilité pour chacun d'intervenir intellectuellement ou matériellement dans l'oeuvre de réalisation en apportant ses connaissances, son savoir-faire. Alors, les rapports du patrimoine à l'histoire prendront une valeur positive. En valorisant le patrimoine on se valorise soi-même à la fois par les acquis que l'on reçoit des autres partenaires, et par ce que l'on apporte aux autres.

Les singularités de chacun deviennent complémentaires, elles s'enrichissent mutuellement dans la dynamique d'une projet commun.

Le patrimoine et l'histoire industriels, s'ils exigent des spécialistes, venant d'ailleurs de milieux divers (universitaires ou industriels), restent aujourd'hui un domaine propre à faire converger un large éventail d'intérêts et de participations, à condition que l'on veille avec vigilance à ce que tel ou tel groupe ne s'institue pas comme seul et unique porte-parole. Depuis cinq ans, c'est l'attitude que tente d'observer notre Association.



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APPROCHE ETHNOLOGIQUE ET TECHNOLOGIQUE D'UN SITE SIDERURGIQUE.

La forge de Savignac-Lédrier (Dordogne)

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In the wider movement for the preservation of industrial objects, this research into Périgord's charcoal metallurgy aims at associating the study of a material civilisation with the study of the social heritage linked to it - that implies the study of ways of life (including for example: social intercourse within and without the factory, relationships between workers of different trades).

The fact that Périgord's metallurgy is deeply rooted into the rural milieu is a guide to the understanding and rediscoverting of traditional peasant society seen under three aspects:

The industrial capacity of the estates considered as timberland.

The local ironmasters' and industrials' political and social notability wich feeds on the prestige attached to wealth, be it derived from commerce or from large estates. The structural phenomena of double or pluri-activity characteristic of workers who were both field hands and factory hands.

The relative proximity of this history at the ironworks and in the area of Savignac-Lédrier makes it possible to call upon collective memory based upon the remains of the industrial site.

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Carte postale - début du XX° siècle-

SIDERURGIE AU BOIS & DOMAINES FONCIERS

Toute forge, en Périgord, appartenait traditionnellement à un domaine foncier parceque le travail sidérurgique représentait le mode d'exploitation par excellence de la propriété forestière.La transformation d'une partie de la réserve forestière en charbon de bois pour la fonte et le fer supposait que l'on retire de cette opération une plus-value supérieure à la simple commercialisation du bois brut.

La forge s'insérait ainsi dans la chaîne de gestion et d'exploitation du domaine,réglait l'aménagement en taillis de courte révolution (autour de 15 ans en moyenne) et contraignait à de multiples achats à l'extérieur (à la forge de Savignac-Lédrier, au XIX°,on achetait plus des trois quarts consommés).

On ne pouvait donc penser "fer" sans penser "bois", non pas seulement à cause de la nécessité technique du combustible végétal, mais d'abord parceque la rentabilité globale de la forêt ne s'opérait, tant pour les maîtres de forges que pour les propriétaires, que par l'industrie sidérurgique.

Pivot du système agro-industriel, la forêt apparaissait à tous comme une donnée incontournable, et, à ce titre, comme un enjeu économique de premier plan. Des habitudes séculaires avaient relié techniques sylvicoles et techniques sidérurgiques et étaient l'héritage en droite ligne du système domanial.

Avec la révolution industrielle, la pression des nouveaux besoins en métal, et les lois de libre échange qui en ont découlé ont menacé cette "dialectique" entre milieu naturel et technologie.La nouvelle conjoncture économique imposait à terme la séparation des deux pôles et brisait leur homologie.Mais à l'horizon c'était aussi un type de société qui était en cause.

Les maîtres de forges appréhendèrent cette crise de la sidérurgie au bois sous son aspect commercial et du point de vue de la cherté des transports.Ils ne remirent en question ni le type de matière première ou de combustible traditionnellement employé dans le pays,ni a fortiori la structure de production.L'analyse qu'ils faisaient était trop "courte".Mais,propriétaires fonciers et forestiers eux-mêmes,ils eurent pour la plupart la tentation de se replier sur leurs domaines ou de les vendre,laissant alors leurs industries à l'abandon. En même temps, la conjoncture provoqua la disparition progressive des activités minières assurées par la paysannerie locale. Du reste, ni le niveau technique, ni l'état des connaissances n'avaient jamais rendu possible une exploitation d'envergure, même si l'appoint monétaire dégagé par l'exploitation minière touchait, outre la paysannerie, certaines franges de la petite bourgeoisie et de la petite noblesse rurales cherchant à dominer le marché par le biais des contrats notariés.

Ainsi,en matière d'industrie rurale dispersée et de sidérurgie en particulier,il sera difficile de parler de "perennité" du Périgord.

Déjà les vestiges n'évoquent-ils pas les cassures économiques de ce pays?

Et les sites de forges ne disent-ils pas clairement l'importance que n'a plus la technologie de l'eau?

Le déclin de la sidérurgie dans les nombreuses régions rurales françaises a correspondu à l'extension progressive d'une autre sidérurgie dans d'autres régions,l'Est et le Nord.Bénéficiant des apports scientifiques et techniques des vingt dernières années du XIX°,elle s'est mécaniséé après les grèves de 1905 en Lorraine de manière ininterrompue jusqu'en 1930.Outre cela, elle s'est détachée définitivement de la force de travail rurale qui la faisait exister,en recourant le plus souvent à la main d'oeuvre immigrée.

Le cadre génèral de cette étude justifiait l'approche plus fine d'un cas particulier.La forge de Savignac-Lédrier se présente à la fois comme illustration et comme exception.Son appareillage technique n'a pas été démantelé et se trouve en voie de conservation.L'ensemble des"papiers" de l'entreprise et de la famille des maîtres de forges est pratiquement intact et vient de faire l'objet d'un dépouillement et d'une analyse systématiques. Vestige de la vieille sidérurgie française, la forge de Savignac-Lédrier a connu son apogée dans la deuxième partie du XIXème siècle en surmontant la crise du libre échange.

Elle a continué de travailler selon des rythmes quasi inchangés de production jusqu'en Février 1930 (en moyenne 300 tonnes de fonte par campagne de fondage). A cette date, le haut fourneau et le dernier four à puddler sont définitivement éteints. Mais l'atelier de pointes de mouleurs et de clés de conserves fonctionnera encore pendant 45 ans. En 1974, c'est l'arrêt de toute installation et le dernier couple d'ouvriers de cette longue histoire quitta alors la "cantine" de la forge.

Aujourd'hui, cette forge fait figure de symbole à plusieurs titres:

Comme image préservée de la culture ouvrière et paysanne en Périgord. Si en effet aucune froutière étanche ne sépare techniques agricoles et techniques sidérurgiques, en retour, l'existence de la forge trace bien une ligne de démarcation entre le métayer attaché à la grande propriété foncière et le paysan ouvrier, petit propriétaire ou journalier lié à la petite industrie rurale , à ses charrois, et aux multiples "coups de main" qu'elle demandait.

Comme lieu d'émergence de la revendication individualiste des travailleurs ruraux. L'intention déclarée d'accéder à l'acquisition d'un bien propre se lit au travers de cette expression populaire "se mettre chez soi". Candidat à la propriété, le paysan ouvrier n'offre aucune connotation prolétarienne classique: ouvrier parce que paysan et pour continuer à l'être.

Comme point terminal de la sidérurgie au bois. En marge du mouvement d'industrialisation qui après 1830 façonne l'économie française et à côté des grands circuits capitalistes, cette forge a prolongé son "règne" sous la forme d'une entreprise aux dimensions et aux performances modestes. Restée aux mains d'une seule famille de maîtres de forges de 1819 à nos jours,elle a continué à progresser parallélement à la grande sidérurgie au coke.Enclave à la fois archaïque et exotique dans le contexte industriel français,elle offre à la mémoire un point d'ancrage original pour en comprendre à la fois la diversité et les limites. Comme exemple a-typique de l'histoire économique.Le maintien d'un apareil de production dont les marchandises en quantités infimes furent commercialisées à des prix trois ou quatre fois supérieurs au cours moyen de l'époque pose la question du mode de reproduction d'un processus aussi profond dans l'histoire économique en période d'accumulation du grand capital.

Un double élément explicatif se dessine:

L'enracinement terrien de la famille et de la forge,c'est à dire la connexion entre l'unité familiale et son identité représentée par les générations successives construisant patiemment le patrimoine commun,à la manière d'un message que chaque génèration aurait pour rôle de rendre de plus en plus lisible.

La finalité d'une industrie détournée de toute production sidérurgique de masse pour s'isoler dans la recherche de la meilleure formule technologique qui soit conservatoire du patrimoine foncier.

SITE & ARCHIVES

Les petites unités métallurgiques rurales de Dordogne, depuis longtemps hors du circuit économique, se caractérisaient déjà à l'époque de leur fonctionnement par divers archaïsmes que la révolution industrielle a fini par mettre en évidence. Avec la sidérurgie au bois, nous ne sommes pas en présence d'une industrie poussée par une capacité interne d'élaborer de nouveaux modes de production, mais devant une activité étroitement liée à des sites et à des sociétés locales encore largement autarciques.

La lenteur et les limites des transformations techniques de ce type d'industrie constituent pour nous des atouts dans la re-Cherche des traces de se formes premières.Les vestiges en effet sont encore visibles.Et quand il n'y a pas eu de reconversion de la forge, le type d'architecture qu'elle présentait la fait souvent confondre -pour un non averti- avec un ensemble de bâtiments ruraux quelconques ou avec un moulin.

Cependant les traces du travail du fer ne font aucun doute: présence de petits monticules de laitier et de scories sont là pour en témoigner.Surtout, dans les sites, les bâtiments d'usines formaient avec les maisons d'habitation des maîtres de forges (manoir, château, maison bourgeoise) un ensemble organique ayant sa logique propre.

C'est cette logique que l'analyse d'un paysage industriel doit restituer.Le site doit en effet "parler" à la manière d'un fonds d'archives puisque l'un et l'autre,le visible et l'écrit,ont été secrétés sur place par une activité de production. En outre,la double méthode que leur étude respective suppose (archéologique et historique) est de nature à compenser les lacunes de l'écrit par les témoignages du site,et inversement la disparition des traces matérielles par les informations écrites.

Dans cette optique, la forge de Savignac-Lédrier et le château du maître de forges qui la surplombe représentent un type classique de site sidérurgique.

On y décèle d'abord une architecture de la représentation sociale.Le château en lui-même n'a rien de patronal,mais,occupé par le maître de forges qui a ainsi son usine à ses pieds,il présente une évolution fonctionnelle intéressante:

Il reste sans aucun doute un symbole de l'aristocratie et le maître de forges bourgeois qui l'occupe tire un premier avantage de la conservation des traits anciens qui lui correspondent. Dans cette perpective, la forge de Savignac-Lédrier et le château du maître de forges qui la surplombe représentent un type classique de site sidérurgique. On y décèle d'abord une architecture de la représentation sociale.

Le château en lui-même n'a rien de patronal, mais occupé par un maître de forges qui a de la sorte son usine à ses pieds, il présente une évolution fonctionnelle intéressante : il ne fait pas de doute qu'il reste un symbole de l'aristocratie et le maître de forges bourgeois tire un premier avantage de la conservation des traits archaïques qui lui correspondent. Il est également le centre d'un domaine foncier, et le maître de forges cumule un deuxième avantage en s'honorant du titre de propriétaire et des fonctions subsidiaires que ce titre implique.

Ce double avantage n'est possible que si l'acquisition d'une forge et de ses espaces domestiques correspondent pour le maître de forges à une promotion sociale et à la représentation sensible de cette promotion.

Précisément, à Savignac-Lédrier, l'installation en 1819 des Combescot, famille connue de maîtres de forges depuis le XVIIème siècle, semble signifier une forme de consécration du chemin patiemment construit, qui la conduit de la propriété d'humbles forges rurales et de l'afferme de diverses forges voisines (Born, Anlhiac, Veaux, Malherbeaux, Fayolle, Payzac), à la propriété prestigieuse d'un château et de sa forge.

La représentation sociale s'appuie ainsi sur une occupation de l'espace que l'on pourrait dire "tripolaire" : En bas, au pied de la colline et au bord de l'Auvezère, le haut fourneau et sa forge à battre, en haut, sur le replat, le château et son ensemble de communs, avec la ferme de la réserve agricole, enfin l'ensemble du domaine concédé en métayage et découpé en tenures.

En outre la complémentarité économique et pécuniaire du domaine et de la forge, et la communauté d'intérêt des trois pôles, épousent en même temps l'unité du plateau et de la vallée : le paysage social s'inscrit dans le cadre écologique.

L'ostentation renforcée du propriétaire et du maître de forges prend son sens dans l'organisation de la société paysanne locale où le rapport à la terre non seulement décide du degré de notabilité mais aussi motive le paysan ouvrier dans les tâches annexes de l'industrie.

Le côté spectaculaire de l'habitation patronale se prolonge aussi dans certains bâtiments industriels majeurs comme le haut fourneau. En revanche il se nourrit de son opposition totale avec les divers bâtiments, halles ou hangars de travail et d'entrepôt toujours conçus sur le modèle des bâtiments agricoles les plus sommaires. Ce sont eux pourtant qui fournissent une partie des renseignements relatifs à la fraction laborieuse de la forge puisque l'aspect extérieur des murs nous renvoie à ce qui se passait à l'intérieur et que, à l'intérieur même, l'objet technique devient, selon l'expression de Marcel Mauss, un "fait social total" avec lequel s'accordent le site, le produit, le geste.

TECHNOLOGIE ET ESPACE DE TRAVAIL DE 1868 à 1903

Vers 1868 - 1870, le haut fourneau avec ses machineries annexes prit définitivement la forme que nous avons sous nos yeux aujourd'hui. Encore cette forme ne fut-elle acquise qu'étape après étape ou, pour le maître de forges, en hésitant entre avancées techniques et replis sur les installations traditionnelles.

On connaît maintenant l'importance de cette période pour le devenir de cette usine rurale. La restructuration a porté sur les moyens de production et sur l'espace de travail, mais la mentalité du maître de forges en fut également affectée. L'ampleur de la crise sidérurgique obligeait à donner toute sa place à l'ingénieur chargé de réduire les coûts de production par des solutions techniques.

Les transformations du fourneau dans cette période allaient représenter exactement un type d'investissement destiné à faire l'économie du combustible pour la fabrication du fer : ce fut le puddlage aux gaz du haut fourneau. On peut "lire" sur sa structure d'aujourd'hui les marques de cette orientation majeure.

Le fourneau et le gueulard de chargement

La cuve du fourneau précédent, à fortiori du fourneau primitif, s'enveloppait d'une chemise réfractaire en contact direct avec le massif. C'était la raison pour laquelle on n'avait aucun accès à l'intérieur du fourneau. L'inventaire de 1981 a montré clairement les disposition nouvelles conçues par l'ingénieur :

- Exhaussement du gueulard de deux mètres, l'ensemble du fourneau faisant désormais 11 m. avec une capacité de 18 m3. L'objectif était d'adapter à la hauteur convenable la prise des gaz de l'appareil récupérateur.

- Fermeture du gueulard par un entonnoir obturé par une cloche en fonte sur les rebords de laquelle les ouvriers disposaient les charges.

L'étanchéité de la fermeture obligeait les gaz à prendre les conduits métalliques de l'appareil récupérateur et épurateur. La cloche permettait en outre de répartir au mieux le minerai, qui est la partie la plus lourde du lit de fusion, à la circonférence du fourneau pour ne pas gêner le mouvement des gaz au centre. L'appareil de fermeture est en même temps l'appareil de chargement. - Construction de deux cuves concentriques séparées l'une de l'autre par un espace rempli de poussières de charbon et de matières meubles analogues. La plus centrale, en briques réfractaires, avait, en haut, une épaisseur de 25 cm. et en bas, dans l'ouvrage, de 30 cm. La plus excentrée, était en pierre, voligée de planches et cerclée de fer. De la sorte, l'ingénieur avait imaginé une dilatation plus libre des matériaux sans perte de chaleur.

La chemise se trouvait désormais complètement dégagée de la masse de pierre et, située au centre du deuxième étage, elle offrait l'avantage de pouvoir être facilement surveillée, voire réparée après les dégradations des fondages : le briquetage et le cerclage en fer étaient parfaitement accessibles et renouvelables sans toucher au reste de fourneau.

Le monte-charge hydraulique

Dans un premier temps, l'évidement de la masse de pierre permit de monter les charges au gueulard par un escalier interne. Mais comme l'élévation du fourneau avait nécessairement provoqué des intervalles plus rapprochés entre les charges, il fallait trouver un moyen d'entretenir régulièrement le fourneau sans perte de temps dans les trajets entre le bas et le haut.

La solution choisie à Savignac consista à élever le minerai, le combustible et le fondant à l'aide d'un monte-charge à double effet dit "à balance d'eau". Dans un corps de charpente longiligne adossé à la façade Est et tenu par des croisillons, deux bennes porteuses suspendues aux extrémités d'un câble s'enroulant sur deux poulies, montaient et descendaient alternativement à l'intérieur de leur "guide" respectif.

Lorsque la benne était en haut de sa course, un ouvrier remplissait d'eau la caisse qui l'entraînait. L'excès de poids ainsi fourni entraînait la benne et sa caisse vers le bas tandis que l'autre chargé des matières du fondage montait. En atteignant le niveau inférieur, la caisse d'eau de la première benne venait se loger dans une fosse où un butoir servait à soulever la soupape d'évacuation de l'eau. Pour la descente enfin, l'accélération de la vitesse était freinée par une roue en bois agissant sur le câble des deux poulies. De la sorte les charges arrivaient également au niveau de la plate forme du gueulard à vitesse réduite.

Ce dispositif exigeait nécessairement sur cette plate forme un bac à eau. A Savignac, son originalité consistait à être alimenté au moyen d'une pompe plongée dans le coursier d'eau et amorcée par le mouvement alternatif des pistons de la soufflerie. Pour éviter les gelées, on avait entouré les tuyaux de paille.



(B.RIGNAULT)

Relevé architectural de l'étage de chargement du haut fourneau Mission 1981 –



(B.RIGNAULT)

Coupe sur l'étage de chargement du haut fourneau Mission d'inventaire 1981 -

<u>La soufflerie à vapeur</u>

Après le monte charge, un deuxième effet de l'élévation du fourneau porta sur les transformations du système général de la soufflerie. Dans la décennie 1850, il est probable que les caisses carrées en bois avec leurs pistons grossiers suffisaient à peu près à l'allure du fourneau.

Mais eu égard à la plus grande pression de vent exigée, à la régularité de fonctionnement souhaitée, les soufflets en bois s'avéraient inadaptés : l'inexactitude de leurs modes d'assemblage, le flêchissement de leurs pièces "tourmentées par leurs propres poids" obligeaient à des réparations fréquentes et à des arrêts répétés provoquant le refroidissement du fourneau.

C'est pourquoi dans le courant de l'année 1874, pour achever les perfectionnements successifs qui améliorèrent le travail du fer à Savignac, on substitua à la vieille soufflerie, une machine soufflante à balancier en fonte moulée avec volant d'inertie, bielle, manivelle et dont les cylindres à pistons supposaient précision des assemblages, exactitude du mouvement des pièces. Cette machine était mue par chaudière à vapeur. Ainsi, 12 ans après l'installation du premier appareil à vapeur pour mettre en mouvement le marteau-pilon (1862), l'énergie thermique faisait une nouvelle apparition à Savignac, esquissant, en apparence au moins, un début d'indépendance à l'égard de l'énergie hydraulique.

Les responsables de l'usine à cette époque, en particulier l'ingénieur de Langlade, voulaient désormais "la durée d'une marche régulière". En palliant le manque chronique d'eau, ils tentèrent, comme les courbes de production le montrent, d'inscrire le travail du fer dans la continuité, de le rendre indépendant des rythmes saisonniers !

L'énergie hydraulique

Et cependant, les maîtres de forges, avec une certaine prudence ou par manque d'audace, conservèrent à côté de ces deux machines "modernes", toutes les installations traditionnelles à l'énergie hydraulique : le vieux marteau à drôme, la soufflerie hydraulique avec ses deux cylindres à pistons d'une capacité globale de 2 cm.3 d'air, et dont la roue à augets comportait trois flasques faisant une largeur de 2,60 m., un diamètre de 3,40 m., et fixées sur un arbre de rotation de 5 m. de long.

Cette coexistence de deux sources énergétiques pouvait paraître pittoresque au regard de la grande industrie cherchant à homogénéiser ses moyens de production. A Savignac, elle correspondait à une expérience industrielle tout à fait différente.

Les maîtres de forges n'ont pas remplacé l'hydraulique par la vapeur mais, en quelque sorte, annexé la vapeur à l'hydraulique. On peut alléguer plusieurs raisons : cherté de la houille en-

core accrue par le prix du transport jusqu'à Savignac, rendement comparatif des deux énergies peu favorable à la vapeur. De 1871 à 1875, l'usine réorganisée et perfectionnée, où de nombreux ouvriers puddleurs et forgerons avaient été engagés, ne chôma qu'occasionnellement et pour des raisons moins saisonnières que techniques. En 1871 : 1 mois de chômage. En 1872 : 3 mois. En 1873 : 1 mois. En 1874 : 2 mois. En 1875 : 1 mois. Ces laps de temps étaient relativement modestes par rapport aux longues périodes d'arrêt des hauts fourneaux périgourdins dans les décennies précédentes.

Au cours de ces quatre années fastes pour l'entreprise, l'énergie thermique apparut à la fois comme appoint non négligeable et comme incapable, cependant, d'assurer une totale continuité du travail du fer en raison des conditions socio économiques dans lesquelles elle.était placée. Un de ses principaux avantages était de fait annulé. Avec l'année 1876, les anciennes habitudes reprendront le dessus : 7 mois de chômage ! Dans la décennie 1880, la fabrication va s'orienter vers les objets taillants (socs, versoirs de charrue...). Le recours à la vapeur est de moins en moins important. C'est l'énergie hydro électrique qui mettra en mouvement les martinets installés en 1885.

Le régulateur d'air et le récupérateur des gaz du fourneau

En outre, la soufflerie à pistons, quelle que soit l'énergie utilisée, nécessitait la construction d'un régulateur de pression destiné à remédier aux irrégularités de débit du vent inévitables dans le mouvement de va et vient. Les maîtres de forges ont probablement vu dans l'emmagasinage de "travail mécanique" une réserve d'air très économique et n'exigeant que l'amortissement du grand collecteur de vent (6 m. de long/ 2 m. de diamètre / 3 m. de circonférence / 38 m.3 de capacité, soit environ 18 fois le volume des deux cylindres à pistons).

Les possibilités de ce réservoir furent particulièrement bien exploitées par les maîtres de forges de Savignac :

- Possibilité de stopper l'admission d'air à la tuyère du fourneau et de "débrayer" ainsi tout le système alors que l'engrenage de la roue hydraulique ne le permettait pas.

- Prise de vent pour le mélange avec les gaz du haut fourneau dans les régénérateurs "Siémens" des fours à puddler.

- Prise de vent pour l'alimentation du récupérateur de chaleur installé en juillet 1903 à la suite de la "conversion" de l'administration de Ruelle aux fontes au bois à air chaud.

En somme autour du fourneau, interféraient deux circuits bien différenciés, absolument nécessaires l'un à l'autre, dépendant de la force motrice hydraulique :

- Le circuit de l'air :

Sa source c'était la machine soufflante.

Son centre de distribution c'était le régulateur, grand volant d'air disponible pour le fourneau, pour le four à puddler, pour le récupérateur de chaleur. - Le circuit des gaz :

Sa source c'était le haut fourneau.

Son centre de distribution c'était l'appareil de récupération des gaz au gueulard avant tout contact avec l'air. Dans les régénérateurs des fours à puddler, on les brûlait avec de l'air venant du régulateur.

Dans le récupérateur de chaleur, les gaz servaient à chauffer les briques réfractaires et élevaient la température des tubulures en fonte dans lesquelles passait l'air destiné à la deuxième tuyère du fourneau. Au cours d'un fondage, cet appareil n'était mis en fonctionnement que par intermittences selon la qualité de fonte que l'on voulait obtenir : la fonte "aiguillée" N° 4, selon la terminologie de Ruelle.

L'utilisation des gaz récupérés : les fours à puddler.

L'ingénieur de l'usine de Langlade avait marqué de son empreinte l'ensemble de ce dispositif. Il présenta devant le bureau des brevets des Etats Unis d'Amérique son "système de gaz perdus des hauts fourneaux" et le <u>19</u> mars 1972, le droit lui fut accordé "d'utiliser et de vendre la dite invention à travers les Etats Unis et ses territoires". Cependant c'est à Savignac qu'elle fut pour la première fois expérimentée et après quelques retouches définitivement installée.

Le dispositif avait essentiellement pour fonction de puddler la fonte aux gaz du haut fourneau et d'en retirer un double avantage :

- Produire des fers au bois, "à nerf" (malléable) et "à grains" (dur et cassant) supérieurs à ceux des foyers d'affinage. Un tel résultat était possible parce que les gaz des hauts fourneaux au charbon de bois formaient un combustible aussi pur que les charbons employés dans les affineries, mais également parce que avec les régénérateurs "Siémens" on disposait d'une température très forte, "notablement plus élevée que dans les fours ordinaires de puddlage", créant une "atmosphère tout à fait oxydante OU entièrement réductrice, favorable à la fabrication de produit entre le fer et l'acier".

- Economiser tout le charbon de bois utilisé jadis pour l'affinage, réduire les déchets de fonte et faire baisser en général les coûts de production.

Quant à la nature du dispositif, elle consistait en quelques opérations simples décrites dans le brevet sur croquis et sur plan. Nous en indiquons les étapes :

- Lavage complet des gaz par ruissellement d'eau pour éliminer les poussières. Refroidissement et suppression de la vapeur d'eau qu'ils contiennent. Obtention d'une composition constante des gaz, sans soufre. - Entraînement par jet d'eau (système de "la trompe à eau" utilisé dans d'autres appareils.

- Chauffage préalable de l'air et des gaz dans les régénérateurs des fours à puddler.

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HISTOIRE GENERALE DES TECHNIQUES

&

EVOLUTION PARTICULIERE D'UNE USINE

Il arrive souvent que l'histoire des techniques mesure les progrès de l'Industrie en termes de capacité productive des machines et de fabrication de masse.

A Savignac, la genèse des techniques qui s'est inscrite dans l'évolution du haut fourneau et dans le remodelage de la forge ne peut en aucune manière s'apprécier dans les mêmes termes et selon les mêmes critères.

La pensée technologique s'y est appliquée à concilier les économies de matières premières, de combustible, de main d'oeuvre avec les améliorations de la qualité des fontes et des fers, avec la production d'aciers cémentés en très petite quantité. Et cela au moment où en Europe le progrès de la sidérurgie était conçu comme une réalisation massive d'économies peu soucieuse d'amélioration qualitative, impliquant au contraire une production à grande échelle.

C'est pourquoi il n'existe pas de modèle auquel nous pourrions nous référer pour comprendre l'histoire d'une entreprise telle que Savignac.

- Aucun modèle pour la suppression de l'énergie thermique et le retour au "tout hydraulique". Car ce retour n'évacue pas tout progrès. A l'intérieur de ses propres limites, il est l'occasion d'une nouvelle impulsion technologique dans une direction particulière. Et c'est la construction en 1885 d'une turbine de 20 cheveaux, en bout de barrage, pour mouvoir les martinets nouvellement montés et le futur atelier de fabrication de clés de conserve.

- Aucun modèle non plus pour cette installation tardive d'une batterie de martinets provenant de l'usine Jackson de Sireuil en Charente. Car en 1885 à Savignac, les "innovations" obéissent moins à une vision idéale du progrès technologique dans la métallurgie qu'à la conquête de marchés localisés, ponctuels, fussent-ils limités dans le temps. Et par exemple tout ce marché "paysan" des objets taillants travaillés au four à souder, cinglés et platinés aux martinets.

- Aucun modèle égalementpour la séparation temporelle -33 ans d'écart- de l'installation du récupérateur des gaz du haut fourneau en 1870/71 et de celle, en 1903, du récupérateur de chaleur, alors que ces deux installations sont économiquement complémentaires et techniquement solidaires.

En octobre 1902, les maîtres de forges de Savignac sont avertis par la fonderie de la Maine de Ruelle qu' "ils ne pourront pas arriver à contenter la fonderie pour les projectiles sans air chaud ou sans artifice particulier parce que la chaleur ne peut pas, dans l'état actuel, être assez forte dans le creuset de Savignac pour réduire en assez grande quantité le silicium". Dans un premier temps pour satisfaire cette exigence, les maîtres de forges adoptèrent l'artifice particulier, c'est à dire "ajouter sous forme de ferro silicium disponible dans le commerce en chargeant au gueulard en même temps que le minerai. Ce procédé doit réussir car pendant la descente dans le fourneau le métal ne s'oxyde pas. Et la quantité de ferro silicium à ajouter dépendra de sa teneur en silicium et de la quantité de silicium que contiendra la fonte sans cet appoint".

L'artifice ne put dispenser d'installer un appareil à air chaud en 1903, bien que les maîtres de forges de Savignac aient expliqué au colonel directeur de Ruelle qu'avec le ferro silicium "il aurait l'avantage d'avoir de la fonte plus pure comme étant faite toujours à vent froid".

Et le 2 février 1903, l'ingénieur associé de Langlade écrivait au maître de forges local, "après de longs tâtonnements, j'ai fini par loger notre appareil à air chaud dans l'espace compris entre le haut fourneau, le monte charge et la cheminée du four à cémenter. Il y a tout juste l'espace voulu. La maçonnerie de cet appareil aurait 5,70 m. de haut et environ 1,30 m. de large avec 2,40 m. de long. C'est un peu étroit vu la hauteur mais en l'amarrant au haut fourneau on peut le maintenir solide".

- Enfin, quel modèle pourrait appréhender le paradoxe de ce double phénomène relatif au haut fourneau : des transformations techniques importantes, une quasi stagnation de la production de fonte ?

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A CANADIAN PERSPECTIVE ON ARCHIVES AND INDUSTRIAL ARCHAEOLOGY

1 NORMAN R. BALL

SUMMARY

The paper presents an overview of the Canadian archives system with particular emphasis on its relationship with the state and the impact that this has on the ability to change to meet the needs of emerging research disciplines. The concept of total archives is discussed in terms of its aims, organizational structures and their impact on the ability to meet new research needs. It is argued that the Canadian organizational model is one which does not lend itself to effective change and demonstrates how archival aims and organization may hamper the growth of certain types of industrial archaeology research. The view is presented that for continuing healthy growth of the field, industrial archaeologists should take an increasingly critical and active view of archival aims, procedures and organization.

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The professional concerns of the industrial archaeologists transcend structure and design to encompass interests such as materials, fabrication, meaning and context. As a result, the field needs highly trained professionals with a wide range of knowledge, skills and interests. It is a demanding profession but this is obvious. Less obvious is the fact that the birth and growth of industrial archaeology are making heavy demands on other professions. Archivists are one such profession and it is the intent of this paper to examine some aspects of the relationship between archivists and industrial archaeologists with particular emphasis on what is happening in Canada. The paper will begin with a selective overview of the archival system in Canada followed by a brief examination of some of the consequences for types of archival records needed by industrial archaeologists and an impressionistic evaluation of the extent to which Canadian archives are meeting the needs of industrial archaeologists. The final part will consist of recommendations for future action in order to make archivists more aware of and more responsive to the needs of industrial archaeologists.

The Canadian Archival System

There is no one body or central authority which controls or governs Canadian archives. They are sponsored by, governed by, and accountable to a wide range of bodies, institutions or individuals. Nonetheless, certain generalizations may be made which paint a picture of the nature, characteristics and concerns of most Canadian archives.

Although Canada has a variety of private and public archives, most of the major archival collections are run by the state. There are various religious, university, hospital and corporate archives but most of the major archives are run by various departments and agencies of the Federal Government of Canada, its provinces and territories. Cultural activities in Canada tend to be much more heavily supported and dominated by the state than in many industrial nations of the non-socialist Western world. One result is that although usually one is not told what kind of research to do, or what to collect in, it can be very hard to find money for areas which are not considered important by the state and its servants. Archival activities are not immune to these problems. There are not forbidden areas of collecting but there are areas in which money is easy to find, sometimes even thrust upon institutions, and areas in which it is nearly impossible to find money. When Canada officially transformed itself from a bicultural to a multicultural society large quantities of money quickly materialized from various state departments and agencies to establish, staff and run what are called Ethnic Archives Programmes. Similarly, money was made available for museum exhibits, private scholarship, preparation of teaching materials and creation of university and other teaching positions. As a result of government initiative, an entire area of scholarship--both teaching and research -- and archival activity was more or less born, legitimized, mythologized, and thrust into prominence.

Archives vary considerably in terms of what they collect. In some countries state archives concentrate solely or primarily on state papers. However, in Canada the provincial, territorial and federal archives collect both private and state papers. This reflects an enlightened view of what constitutes the raw material of history as well as a strong tradition in Canada of state participation in cultural activities of all kinds. However, private papers do not fare as well as some would like to imagine. Government funded and run archives seem to place the highest priority on government papers and some of the programmes for collecting private papers, particularly in certain subject areas, are monumentally unimpressive. The collecting activities of Canadian archives are most unbalanced not only in terms of government as opposed to private papers but also in terms of heavy concentration on certain types of activities in both spheres and almost total neglect of others. Unfortunately, science and technology, particularly private science and technology as opposed to state activity, is very poorly represented. There are understandable reasons for this neglect.

To understand the archives of Canada, or any other nation, one must explore its self-image. Canada is a geographically large but not very populous country; New York City alone has over half as many people as Canada. When one considers the population of Canada, it has a very impressive history of science, technology, industry and engineering. Unlike its stand on bilingualism or multiculturalism, Canada has never passed an act or issued an order in council which declares it to be a scientific or technological nation. But what nation has? Awareness of scientific and technological status is made known by the fact of achievement plus the work of the culture business. By the latter is meant that rather complex and amorphous conglomeration which tells a nation what it has achieved, what it should be proud of, or ashamed of, where it should be heading and how it should be seen by itself and others. Culture business practicioners include scholars, journalists in print, radio and television, filmakers, teachers at all levels and a variety of workers in museums, galleries, science centres and archives. They play a major collective role in the creation of the national mythology, that is to say the self-image of a nation and its citizens, their visions of what they have achieved, who are its heroes, its areas of strength and pockets of national excellence and pride as well as a large part of its hopes for the future.

Canada is a most curious case study in cultural self-image. It has a record of considerable achievement in science, technology, engineering and industry; rather curiously there is very little recognition of this in the national consciousness, mythology and cultural institutions. The reasons for this state of affairs are very complex but in part stem from Canada having as its closest neighbour-both culturally and geographically--a leading industrial and cultural power with a population roughly ten times that of Canada. Whatever the reasons, Canadians have not come to terms with their own achievement and spend far more time admiring their neighbours achievements instead of trying to put their own into proper perspective. By way of example, Canadian universities offer more courses on the history of technology in any of the United States, Britain, or Mediaeval and Renaissance Europe than Canada. As a result there has not been a significant research demand for archival material in the history of Canadian science, technology and engineering. Similarly, Canadians have not eulogized their scientists and engineers and used them as models of historic achievement and excellence as do many other nations. In brief, the national self-image of Canada, particularly in government cultural institutions, has little place for Canadian achievement in science and technology. Therefore, in Canada, to spend anything but token sums of

money on documenting and emphasizing Canadian achievement in science and technology is to go against the unwritten but exceedingly influential vision of Canadian culture and history.

When one couples the fact that most Canadian archivists are state employees with the fact that Canadian self-image at the state level does not really embrace a historical vision of scientific and technological achievement it is not surprising to find that these areas are poorly represented in archives. One might ask if the same situation prevails in private archives. That assumes that there is a strong tradition of private archives in Canada which there is not. A major differences between Canadian and American cultural environments is that the former has a very weak tradition of private initiative. With rare exception, one simply does not find high quality private archives which offer the potential to express a vision of society which is not necessarily that promulgated by the state. So once again, one's analysis is thrown back to the state perception of the past.

One of the refreshing areas of Canadian historical and cultural scholarship is a growing, but not well organized or well articulated, awareness that historically science, technology and engineering have been central to Canadian development. There are two reasons why it is likely that this vision of the past will be slow to influence archives. First, unlike some European countries, Canada does not have a strong tradition of the archivist as scholar who plays a leading role in formulating a nation's self-image. Canadian archivists tend to be much more passive, less scholarly inclined and more involved in following than setting trends. Educational requirements to become archivists are more comparable to those of elementary and secondary school teachers rather than university professors. The second reason revolves around the more complex question of the way in which leading Canadian archives are organized as administrative and collecting institutions.

Canadian archives tend to be what are called multi-media or total archives. The total archives, a concept in which Canada is a recognized leader, aims at the documentation of culture through all communications media rather than through the traditional manuscript or unpublished sources which have been the mainstay of archives for centuries. The Public Archives of Canada, a leader in this field, has gone beyond manuscripts to collect photographs, films, television and radio broadcasts as well as other sound recordings, videotapes, computer tapes and discs, maps, architectural drawings, sketches and paintings, medals and a wide range of printed material.

The total archives concept in Canada has bestowed undeniable benefits in terms of variety of media covered and produced collections of immense research value much loved by journalists and documentary film producers as well as many historians. But has it made archives better places for industrial archaeology research. The answer is both yes and no. Before explaining this ambiguous answer it is best to look briefly at some of the types of total archival records of potential use to industrial archaeologists.

Total archival records of potential use to industrial archaeologists

Given the breadth of interest of the better sort of industrial archaeologists, one can see that all of the record types enumerated above are of potential use. It is also possible that almost all of them in a given archives will be of little or no use. Archival records may be collected with any of a multitude of aims. To serve the needs of the industrial archaeologist well, one must try to pursue information of interest to that profession and its vision of the past rather than hoping that what is collected with other things in mind will, by the way, contain something which helps the industrial archaeologist. The Prince of Serendip is not necessarily our best servant and yet in many Canadian archives industrial archaeologists are served serendipitously, if at all.

Total archives include photographs and most industrial archaeologists know that engineering structures, technological processes and the workplace have fascinated photographers almost since the invention of photography. But so have portraits and the use of the camera to imitate various schools of artistic representation. The archivist who sets out solely to document the photograph in portraiture, pastoral landscape and sports will do precious litle to meet the needs of the industrial archaeologist. Similarly, the archival librarian who concentrates on political tomes and treatises and is uninterested in technical literature and trade catalogues will probably be doing you few favours with his or her expanded mandate and increased budget. The business records archivist who acquires the corporate and financial records of a mining company but turns down the engineering drawings and the technical library with maintenance manuals and trade information for mining equipment is not serving your interests. Canada has recently enjoyed a boom in architectural history and the activities of some archives reflect this growth. This boom is potentially useful to industrial archaeologists but some institutions appear to be insensitive to the need to preserve a record of mechanical and operational features of the building as well as the aesthetic or stylistic components. Again, the total archives has the potential to help or abandon you.

Industrial archaeologists are making increasing use of oral history. Canadian archives are putting significant amounts of money into building collections of a variety of reminiscences, interviews and other oral history sources. Will they be of any use to industrial archaeologists fifty years or one hundred years hence who want to know something about life on ocean drilling rigs, synthetic rubber production during World War II, pioneering efforts in cantilevered concrete bridge construction or the generation of nuclear power? It all depends on what is asked or what is collected? Large film collections are being amassed but are the archivists seeking out films of industrial processes and construction or is it situation comedies, escapist fantasy, political speeches and experimental ventures into exploring the limits and new directions of the artistic medium?

Clearly the collecting aims of archivists will have a profound influence upon the research success of present and future industrial archaeologists. The modern multi-media archives has enormous potential to serve the needs of industrial archaeologists but it has equal potential to deceive and lull the industrial archaeology community into quiet and uncritical complacency. For it is easy to assume that with the expansion

of media coverage goes an expansion of subject coverage; easy to assume that as the archives moves beyond manuscripts and books to photographs, sound recordings and computer tapes and discs that it has gone beyond the traditional emphasis on politics and the upper levels of society. Such assumptions are completely unwarranted. The activities of the archivist will to large extent reflect traditional prevailing cultural values unless told to do otherwise. The extent and pace of changes in archival emphasis will also depend on how the archives is organized and an understanding of archival bureaucracy is an excellent guide to the probability of rapid and effective changes in emphasis and direction. The industrial archaeologist who is interested in assuring continuing meaningful growth of the field should keep an eye on archives and not let a little of bit of change in one area give a false impression of total change in the total archives. The way in which total archives have been set up in Canada makes meaningful short term change exceedingly unlikely. Archives in other countries which have followed the same pattern are likely to be equally unresponsive to unlegislated change.

The total archives concept has two main tenets in terms of coverage. First, it is supposed to cover many fields of human endeavour, what one might call many different subject areas. Second, it is supposed to do the first by preserving records in many different formats or, to use the archival jargon, media such as manuscripts, films, photographs, medals and sound recordings. To achieve these ends one must choose one of two very different organizational formats. One is to organize in terms of subject area coverage. That is to say, a division, section or other administrative unit is assigned to cover a subject area such as political history, ethnic history, corporate history or history of engineering. Each subject division would pursue relevant archival material in all media. The other possibility is to organize the archives on media lines with separate divisions or administrative units for each of private manuscripts. government manuscripts, photographs, computer records with as many divisions as media types. Under this arrangement each media division would, or should, collect material related to all of the various historical areas such as ethnic history, corporate history, political history and history of engineering, which the archives is to cover. It is this latter pattern which the Public Archives of Canada and many other Canadian archives follow. After eight years of working within that system it is very difficult to see it as being at all responsive to requests for voluntary change to meet emerging research needs as opposed to politically imposed change. The basic, and virtually insoluble, flaw is that for a new area to be adequately covered one needs to convince a host of independent divisions or administrative units that they should embrace a new vision of the past and collect accordingly. Human nature and bureaucracy being what they are it appears to be virtually impossible to introduce a new area such as industrial archaeology to all media areas without externally imposed, that is to say politically imposed, change. Under the other possible organizational scheme, the one used less in Canada, one could recognize the growing activity of industrial archaeologists simply by creating an industrial archaeology division; it might be small and not have a very large budget but it would be able to pursue balanced media coverage aimed at meeting the needs of the field and could be staffed by people who understand and support industrial archaeology. Under the system of total archives generally adopted in Canada, to introduce industrial archaeology one would have to convince a large number of divisions to start work in the

area; because it is exceedingly unlikely that any one division would have the money for a full man-year in the area there would be no recognized authority working in any of the media areas. The work would be done by people trained and primarily interested in other disciplines and visions of culture and the past. Under these circumstances it is rather easy to visualize industrial archaeology always being what people will get to next, but next, like tomorrow never comes.

The total archives concept with administrative organiztion on media lines is becoming increasingly popular. It serves the interests of established research areas exceedingly well but has not shown itself to be responsive to changing research needs unless these needs are backed up by political power or strong lobby groups. With some rare but pleasant exceptions the Canadian archival community has not done either a fair or a balanced job of meeting the needs of newer research interests such as historians of science and technology or industrial archaeologists. For a number of reasons the author is not optimistic about the possibilities of short term change for the better within Canada but does believe that there are things to be learned from the situation which might be useful to industrial archaeologists and representatives of other emerging approaches to the past.

Recommendations and future needs

Clearly the most obvious message is that industrial archaeologists must pay more attention to what is happening in archives in their own countries. The archival systems, priorities, and procedures which gathered and preserved the records we now use for our research are changing radically, almost beyond recognition. There is a strong possibility that the needs of future industrial archaeologists will not be served as well as we have been by past generations of archivists and librarians. Canadian scholarship and Canadian archives are both poorer on account of the scholar's general disinterest in the latter. Industrial archaeologists should be asking very pointed questions about collecting and organization: both current and planned. Industrial archaeologists in some countries should take a long hard look at the question of whether or not they can ever expect existing archives to take their needs seriously and begin to ask whether they should be striving towards the establishment of separate specialist archives to meet their needs. It is a strong possibility that existing trends towards larger multi media archives will seriously hamper the growth potential of certain types of industrial archaeology research and with it growing acceptance of the field in other scholarly quarters.

Industrial archaeologists should pay considerable attention to cultural policy, planning and perceptions, alien as they might seen to your interests. In Canada one of the factors militating against the establishment of programmes to aim at meeting the needs of industrial archaeologists and historians of technology is a cultural climate which places little value on Canadian achievement in these areas. This is a rather unusual problem, most countries go the opposite direction and try to prove that they have done far more than the evidence would suggest, rather than following the Canadian path of denying or trying to hide achievement. However, it does point out the need to communicate with other disciplines which are important in determining a nation's self-image; an emerging discipline, no matter how strong and confident it might feel, can only go so far beyond existing cultural visions and perceptions before it runs aground. If the discipline is to continue to grow it must be strong within but also must spend a certain amount of energy communicating with other approaches to the past.

The views expressed in this paper are based primarily on experience in one country. Other speakers on the programme represent countries which generally have been somewhat broader, wiser and openminded on the question of what constitutes culture and a suitable vision of the past. It is therefore with rather mixed feelings that the author spreads before you some of his own country's inadequacies and problems. Are they relevant to the concerns and experiences of other participants in this conference? Perhaps they will help to shed some light on problems that you face; perhaps they will help you discern some trend which you might re-examine and try to forestall; perhaps they will remind you of problems now solved in your own country and you will share the benefits of your experience. In preparing this paper the author considered giving an outline of what he did in his eight years as an archivist in a fringe area in Canada's largest archives. Instead he decided to try to analyze some of the things that seemed to be wrong and were not working. The hope behind this decision was that in doing so my colleagues and I in Canada, a country where industrial archaeology and associated disciplines are struggling very hard against cultural prejudice and indifference, might solicit advice from those who are more experienced and successful than we. When one takes such an approach the most interesting part of the paper should be the responses from the audience and I now look forward to what should be the best part of this paper, namely that which I hope to learn from others.

IRON-MAKING IN THE NETHERLANDS

Dirk J. DE VRIES *

SUMMARY

The paper is a brief synopsis of the history of iron making in the Netherlands, from the late Bronze Age upto modern times.

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Iron-making on a larger than a local scale began only in 1924 at the "Hoogovens" (blast-furnaces) plant, which produced steel for the first time. These Hoogovens are situated at the North Sea port of IJmuiden, 30 kilometers north-west of Amsterdam. The ironworks have all of the features that belong to a modern factory. There is no geographical relation between the site where the blast-furnace was founded and the places where the ore, fuel and power originate. The ore is imported from Sweden, Spain, Africa, Canada, Brazil and Australia, coal for the necessary coke comes from the U.S.A., Germany, Poland and Australia.

This all is entirely opposite to the oldest situation of wrought iron production in the Netherlands which was initiated in the late Bronze age, about 1200 B.C. Traces of small production centres (slag, furnaces, forges, etc.) were found throughout the iron age, Roman period, and Middle Ages in an area that is rich in bog-ore and wood for charcoal: the eastern part of Holland.

Examples of primitive bloomery hearths are found there and seem to have been worked for local needs rather than for export. During the Middle Ages, or even possibly earlier, this primitive ambulant wrought iron industry seems to have been pushed aside by specialized industrial centres, for example in Germany which applied water-driven bellows and hammers and which produced at one location in a continuous process.

During the Middle Ages specialisation in certain iron products had gone far, Liège for example was famous for its nails. Since the seventeenth century wealthy Amsterdam merchants (of Belgium origin) exploited international production (Sweden, Russia) and ironmongery, especially weapons. Before 1400 cast iron was hardly ever made, not only because the temperatures in the funaces were too low, but also because cast iron is a product with a totally different character. During the fifteenth century several applications had been found for this new material. Some patents for iron casting were taken out in Dordrecht and the Hague during the first half of the seventeenth century, but we do not know whether they resulted in real industries. Probably the initiatives in the eastern part of the country were more effective during the late seventeenth and the eighteenth centuries, which resulted in iron foundries near the Oude IJssel river (for water-power). The natural sources of bog-iron were used here until 1870-1880 when the area changed over to the use of cheaper imported pig iron that could be smelted in cupola furnaces.

Due to the high cost of fuel and the ineffective power supply of waterpower, the Dutch foundries chose coke starting from the first half of the nineteenth century and steam-driven bellows since 1836. The real Industrial Revolution could break through after 1815, especially in the Southern Netherlands where new and gigantic works were constructed on the advice of John Cockerill.

Important innovations were carried out by Ulrich Huguenin who was director of the "Rijksgeschutsgieterij" (State Cannon Foundry) in Liège. His theoretical treatises (1826 and 1834) were of great importance for example in Japan, as professor Shuji Ohashi wrote to his Dutch colleague Wessel Reinink: "This book is estimated as a first book published on iron casting method in Netherlands. Japanease engineers transported this book during about 1847-1850 (three groups) and published it. This book was the only guide-book to make iron canon and iron making by blast-furnace 1850-1870 in Japan. Man builded about twenty Reverberier-ofen (air furnace) placed all over the country during 1850-1860. And about ten blast-furnace was built three places during 1825-1863. This is the beginning of the modern industrialization in Japan. So Huguenin is recognized in Japan (as) the father of the Japanease modern industry".

When the Southern and Northern Netherlands split up in 1830, the northern part was - especially for wrought iron - largely dependent on foreign wrought iron and steel, but the number of foundries in the Northern Netherlands (also in the west) increased from 10 in 1830 to 56 in 1877. Actually these foundries were hardly capable of export, which they did only to some colonies thanks to a certain financial protectionism.

Nowadays the lively nineteenth century iron foundries have almost all disappeared, but the modern steel-works Hoogovens produces more than 20,000 tons of iron per day, 75% for export.

THE BLAST FURNACES OF CAPALBIO AND CANINO

IN THE ITALIAN MAREMMA

Daniela Ferragni*, Jef Malliet*, Giorgio Torraca*

SUMMARY

The blast furnaces of Maremma used ore from the island of Elba and charcoal made from the shrubbery of the coastal hills. They were operated on a seasonal cycle (November to June) and not every year because of a chronic shortage of wood.

Ironmasters from the region near Bergamo were hired for each season and most of the technology was also imported from that area.

The furnaces of Capalbio and Canino, located at the border between Tuscany and Latium, operated from the 17th to the 19th century and are well preserved thanks to their conversion to olive mills and other agricultural activities after the unification of Italy.

The paper summarizes the results of a study aimed at the documentation and structural stabilization of the buildings prior to their restoration. The Possible future use of the two factories is discussed.

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Fig. 1 - Map of the Italian Maremma, with indication of the historical border lines and locations of blast furnaces.

1. The Maremma region and the iron industry.

Maremma is the Tuscan name for the coastal region of Italy on the Tyrrhenian sea, roughly between the Arno and the Tiber rivers (Figure 1).

Maremma was a rich agricultural region in the Etruscan and early Roman periods, up to the second century A.D., but later its lowlands became marshy and unhealthy due to malaria. Large areas of land remained uncultivated and sparsely populated up to the modern era; cattle and horse breeding are the surviving farming activities.

The abundance of wood and water and proximity to the rich iron mines of the island of Elba determined, however, from the Etruscan era up to modern times, the importance of the region as an iron smelting area.

We still know very little of the smelting technology used in the region until the 16th century, even if the existence of ironworks is indicated by several documents and evident traces; nevertheless the direct reduction of the mineral in relatively small furnaces ("basso fuoco") may be inferred by comparison with other Italian regions, such as Liguria (Calegari, 1977).

Although the construction of large furnaces for the production of pig iron began in northern Italy probably around the end of the 15th century, their introduction in Maremma must have started somewhat later. We can date to the second half of the 16th century some of the furnaces, which survived for a long time, on the basis of documentary evidence: Follonica 1577, Valpiana 1578, Cecina 1594 (Mori, 1966, p.17). Figure 1 shows the location in central Italy of all the blast furnaces that have been identified at present.

A somewhat earlier date (1543) is documented (Morelli, 1980, p.502-503) for the building by specialists from Brescia of a furnace in Pracchia, which is in the Apennines; this may hint at a settlement of the first blast furnaces of Tuscany in the mountains, in a setting similar to that of the alpine valleys from which the technology was imported, followed by a move towards the unhealthy shore area where the mineral could be easily carried across the sea (land transportation was very difficult in central Italy up to the 19th century).

As the construction and operation of blast furnaces was deeply influenced by political events in the area, we think that a short account of them is required here.

The island of Elba and its mines were controlled by the Principate of Piombino for most of the period in which we are interested. This very small state had been separated in 1399 from the Pisa territory; it included the island and a piece of mainland, the Piombino promontory, where the blast furnaces of Follonica and Campiglia (frequently mentioned as Cornia) were later built.

Piombino was most of the time under the influence of Florence and Spain, with occasional intrusions of France (1646-1650) and attempts by the Turkish Empire and Barbaresque pirates to conquer it (16th century). The principate was held by the Appiani family up to 1634, then passed by marriage to the Ludovisi, up to about 1700, and finally, again by marriage, to the Boncompagni Ludovisi until it was swept away in the Napoleonic wars; it was merged with the rest of Tuscany by the Vienna Congress in 1815.

The Medici family tried, since the 15th century, to control the Elba mineral and the iron trade in the region (Goldthwaite, 1980); this aim was achieved, in part, by securing exclusive contracts for the ore in 1535 and by conquering all the central part of Maremma in the war of 1554-1555 that brought the destruction of the independent power of Siena, which had controlled the area since 1410. In this war Florence had the powerful help of Spain, while Siena was supported by the French and, indirectly, by the Turks.

The Medici also occupied Piombino and Elba for few years (1548-1557) but were not allowed to hold it, so their control of the iron production and trade could not be complete. They built their own iron furnaces: Cecina, Valpiana, Massa Marittima, Accesa (Mori, 1966,p.17) all around the border of the Piombino state to exploit the proximity to Elba and managed them through a separate administrative entity named "la Magona" which also controlled several bloomeries and forges.



Fig. 2 - The Capalbio ironworks seen from the side of the aqueduct (east).

Only one blast furnace in Tuscany belonged neither to the Prince of Piombino nor to the Medici family; it was the Capalbio furnace (Casini, 1982) which still survives to-day and is the object of the present study (Figure 2). It was built apparently by the local community near the border between Latium and Tuscany but fell under Medici control after some time, as we shall see.

After the Siena war, Spain kept possession of a strategic strip of land, on and around Cape Argentario, which was called the "Stato dei Presidi" (i.e. "the garrisons") which much later (1707) passed under the control of the Viceroy of Naples, depending from Austria, and then (1734) of the Kings of Two Sicilies of the Spanish Bourbon family. This anomaly on the Tuscan coast was also swept away in the Napoleonic period and re-united with the rest of Tuscany afterwards.

South of the Chiarone river, which is the traditional border line between Tuscany and Latium, another small independent state had an influence on the development of the iron industry in the area: it was the Duchy of Castro, created in 1537 by the Farnese Pope Paul III for his family which also held the Duchy of Parma. The Castro state was governed by the Duke of Parma who most of the time would rent the entire state to some wealthy business man for an adequate sum of money; the state also included the town of Ronciglione where the most renowned ironworks of Latium were located. The Ronciglione works never included a blast furnace, however, nor was any available in the whole Castro state up to 1670, and so they depended upon various sources for the supply of pig iron.

When the debts of the Duke of Parma grew so great that all the rent from the state was insufficient to pay the interests, the pope moved to take back Castro, but it took two wars, bitterly fought in 1641-1643 and 1649, to achieve this result.

After the Castro war a blast furnace was built in Canino (in 1670) with the task of providing pig iron for the Ronciglione works. Also this furnace survives and is included in our study.

South of Castro and north of Rome we are still in the Maremma proper, and the land is always suitable for iron smelting; aristocratic Roman families governed here in the pope's name and some of them built their own furnaces. The Odescalchi had one in Bracciano that was active in the 18th and 19th centuries (ASR Camerale III 501/a, par.21 and ASR Camerale III 501/b, par.24,29) while another one was located in Ruspoli territory, in Cerveteri, but in 1650 it appears to be controlled by a branch of the Ludovisi family (ASR Camerale III 652/a).

A l6th-century document mentions the blast furnace in Monterano (not far from Bracciano), noting that it was too far from the sea, so shipping of mineral would be rather costly (Morelli, 1980, p.500 footnote 82).

South of Rome, out of Maremma, but in a marshy region very similar to it, the papal government built its first large furnace in Conca, in 1587 (ASR Camerale III 966).

Another furnace was built in Monteleone, near Spoleto, under Pope Urbano VIII (1622-1644) (Morelli, 1980, p.498 footnote 77), but this one is completely out of Maremma and, being deeply inland, did not use Elba mineral but a local ore.

From the 16th to the 18th century the iron-smelting region was involved in the struggle between Spain and France for the dominion of the Tyrrhenian sea and the control of the Catholic Church. The Spanish influence prevailed in the 16th and 17th centuries, but the French kept coming back and in the 18th century both the pope and Tuscany inaugurated a policy of equilibrium between the two great European powers.

The whole region fell under French dominion during the Napoleonic era (1799-1814); this deeply affected iron technology as from then on French methods and French experts appear to have had a prevailing influence, replacing the technology imported from Northern Italy over 200 years before.

The French influence was maintained in Tuscany even though the pre-Napoleonic political organization was re-instated, with minor modifications, after the fall of Napoleon. When Tuscany (1859) and Latium (1860) were unified with Îtaly the asset of iron production in the nation was deeply modified, because the charcoal furnaces of central Italy were unable to compete with the coke-operated furnaces of the north.

The Follonica works were modified and able to survive thanks to their proximity to the main source of iron ore; new blast furnaces were also built later in Piombino. All the other furnaces were instead swept away in a few years and frequently other activities were started to exploit the hydraulic power that had been harnessed. In some cases this entailed a complete transformation of the buildings (e.g. Valpiana, Conca) but in others which were used as olive mills (Capalbio, Canino) the new operations were adapted to the old structures without introducing excessive modifications, although obviously all the movable equipment was dispersed.

2. The management of the ironworks.

As the operation of the blast furnaces required a considerable investment and had political implications (cannon balls were one of the main uses of pig iron) we normally find that only governments, or very rich individuals well connected with their government, undertook it in the 16th and 17th century. The case of Capalbio, built by a community of bourgeois, is rather an exception (and we do not know the actual circumstances of its construction).

In central Italy, the owner seldom appears to be also the manager of his factory (just as the owner of a farm seldom cultivated it); the normal practice was that of renting it for a number of years (most frequently 9) to somebody wishing to take over and produce iron to make money. Frequently the lease would be awarded to the person who made the highest bid at a public auction.

The auction for the furnaces of the Prince of Piombino had often an international character, the Rome and Naples governments or the merchants of Genoa bidding through their delegates (ASF Magona 1629).

The contract engaged the tenant to return the works in the same condition as received ("andanti e lavoranti", that is, literally: going and working) and it was obviously to his interest to effect no investment and to keep any maintenance to a minimum. As major repairs and the consequences of catastrophic events were the owner's responsibility, the best policy for the manager was to keep the factories in a condition of utter disrepair and try to pay as little as possible when they were handed back, or hope for, and occasionally foster (ASR Camerale II 501/a par.36), a providential disaster.

The system obviously did not encourage improvement of either equipment or technique, so these remained remarkably stable for a long time (about 200 years), which is perhaps a good thing for industrial archaeology but on the whole a very bad one for the local industry, contributing probably to its general crisis in the 19th century.

The managers themselves do not appear to have been particularly competent in iron smelting; small aristocrats or rich bourgeois, frequently with a group of shareholders behind them, they were mostly adept at working as much money as possible out of all types of governmental concessions (grain crops, alum mining, tax levies etc.) and in avoiding bankruptcy (a fact which was not uncommon, however).

For the actual direction of the works the managers would hire a specialist, or a company of specialists. As the technology was almost completely imported and operations were seasonal, from November to June, for climatic and health reasons (ASR Camerale III 654/a), the hiring was done year by year; the iron workers would travel to Maremma in the fall and go back to their homes in time for the harvest period. Not only the blast furnaces but also several forges were conducted in this way.

The management would provide raw materials and food, detracting their value from that of the iron produced. Good masters had to be found in their country towns near Brescia and Bergamo and hired even 9 months in advance by payment of half the estimated value of their work in silver or gold (ASR Camerale III 495/a). The Venetian ambassadors appear to have taken an interest in this traffic (ASF Magona 2445/a). Unscrupulous managers tried occasionally to get part of their money back by cheating the iron master on the weight (ASF Finanze Vecchie 453).

The coalmakers would be mostly Tuscan, instead, coming from the mountains above Pistoia, but they would follow the same cycle, with the difference that they travelled some two weeks ahead of the furnace specialists to prepare the charcoal.

3. Iron smelting in Maremma.

As mentioned above, most of the technology used in Tuscany to smelt iron in the 16th, 17th and 18th centuries was imported from the alpine area around the cities of Bergamo and Brescia (Morelli, 1980, p.500).

Charcoal for the operation of the blast furnaces was made from small oaks growing as shrubbery ("macchia") in the coastal regions of Maremma (chestnut wood from the hills or mountains of inland areas would be preferred for the forges). Because of a chronic insufficiency of wood the blast furnaces were not operated every year.

Another reason for interruptions in the yearly cycles were the frequent breakdowns. Between 1700 and 1750 the furnace of Canino operated on average four times in each 9-year rental period; but with three breakdown periods of about five years each, we have a global record of 15 working seasons in 50 years (ASR Camerale III 655/a and ASR Camerale III 501/a par.22,28 and ASR Camerale III 501/c).

Transportation of mineral and pig iron was one of the main problems in the iron industry; transportation of the ore was one of the main components of the cost of the product, 15% in Canino in 1751 (ASR Camerale III 655/b).

Shipping by sea was frequently disturbed by political events (pirates, wars) and high insurance costs were involved, e.g. 40% of the value during the Napoleonic wars and the English blockade (ASR Camerale III 501/d).

The distances to be covered by sea were not great, so the ore was mainly transported by barges which could unload it directly on the sandy shores; among the few harbours available in the region, only Piombino and Nettuno were conveniently located near the blast furnaces.

On land, horses or horse-drawn wagons appear to have been the main transportation system from the 16th to the 19th century; mules were used to carry charcoal over shorter distances. A lot of horses were thus required to serve the iron industry and ample stables were provided near the furnaces and the forges. Most frequently horses and drivers were not owned by the factories but were hired for each job (ASR Camerale III 670). A strike of wagon drivers is mentioned by a document of 1771 (ASR Camerale III/e).

The picture changed in a major way only in the 19th century; around 1840, for instance, the Capalbio furnace used an artificial canal entering about 1 km inland for loading and unloading the barges and perhaps a rail system connected the landing place to the factory, 6 km away.

To the eyes of the modern metallurgist, a very surprising feature of the Maremma blast furnaces is the ubiquitous presence of pre-roasting kilns for the ore (named "ringrane"); these were initially operated in a batch system but started running with a continuous feed of ore and charcoal in the 19th century. Being not provided with an air blast the "ringrane" would not allow reduction and melting of the iron although some amounts of spongy or powdery iron (called "ferrino") would be produced; the "ferrino" could have a market of its own or could be fed into the blast furnace at the start or when high quality casting metal was required. Pre-roasting also allowed sorting of mineral pieces of convenient size, like a goose egg (Santi, 1806), after washing.

What puzzles the expert is that pre-roasting should not be required for the rich Haematite mineral of Elba, which also contains very little sulphur. On the whole it looks as if the masters from the north (or "Bergamasque masters", as they were called at the time), who are known to have been very conservative from the technical point of view (Frumento, 1966), had imported the technology that was suitable for the mineral of their valleys (Siderite) without accepting any change in the running of the furnaces.

The Bergamasque furnace was also transplanted into Maremma without any change, as was the rather complicated process used to refine the pig iron and make it forgeable, called "cotticciatura" (Garella, 1839).

The furnace is an original model which appears to be the result of an independent development, not influenced by what was happening north of the Alps. Its characteristics are the rectangular (or better trapezoidal) cross-section and the fact that the changes in inclination of the side walls, which form the inverted conical and the conical part of the typical blast furnace, take place only on three of the four sides (see Figures 3 and 4). The front of the furnace is a simple straight wall (named the "presura" or "pressura") made of refractory stone cemented with clay and supported by a very elaborate system of metal ties (see Figures 5 and 6).

Another peculiarity in the Bergamasque furnace is that the crucible must be opened to extract the molten metal and the slags while in the



Fig. 3 - Vertical sections through a Bergamasque furnace (from SWEDENBORG, in G. de COURTIVRON & E.J. BOUCHU, Art des forges et fourneaux à fer, Paris, 1762).



Fig. 4 - Horizontal section through a Bergamasque furnace, presumably the Accesa furnace in 1774 (ASF, Fondo Magona, f.2745).



Fig. 5 - Typical Bergamasque furnace disposition with trompes, as in the South of France (from: SWEDENBORG, in G. de COURTIVRON & E.J. BOUCHU, Art des forges et fourneaux à fer, Paris, 1762).



Fig. 6 - The Accesa furnace in 1774 (ASF, Fondo Magona, f.2745).



Fig. 7 - The Accesa furnace, presumably 17th century (ASF, Fondo Magona, f.2745).



Fig. 8 - The Accesa furnace in 1774 (ASF, Fondo Magona, f.2745).

furnaces of France and Germany, since the 16th century, the bottom was always open and allowed periodical extraction. The air blast was injected through the "presura" passing through a short hollow pier standing in front of the furnace ("portavento") which supported the tuyere (see Figures 5-6).

With this arrangement it must have been much easier to open the furnace and to carry out the repair or the substitution of the refractory lining, but, on the other hand, the relatively thin and ample front wall must have caused far greater energy losses than in the case of round furnaces.

The iconographic record (see Figure 7) relative to the 17th and early 18th centuries shows blast furnaces that stand isolated in the country. The drawings made around 1778 to illustrate the Accesa factory show, instead, a blast furnace inserted in a built context (see Figure 8). The same arrangement exists in Capalbio (see Figure 9) where we suppose that the furnace, which was originally isolated (1570?-1645), was later surrounded by arches and vaulted rooms, which increased its structural stability, when the factory was re-structured around 1810.

For convenience of construction and ease of operation, the blast furnaces were normally built against a natural escarpment (see Figure 5). The height of a Bergamasque furnace must have been in the 5-6 meter range.

In the 18th century a corridor was normally excavated around the furnace to isolate it from moisture creeping in from the soil (ASF Magona 2809 and ASR Camerale III 638/b); when the round furnaces replaced the Bergamasque ones in the 19th century, this corridor was used to inject the air blast from the back of the furnace, leaving more space free in front of it.

From the 16th century up to 1860 the internal structure of the blast furnaces of Maremma was built with a special schist, silvery-grey in colour, which was quarried in Pietrasanta, near Carrara, and for that reason was called "la Pietra Santa" (i.e. the holy stone); two qualities are mentioned in a document (ASR Camerale III 638/a).

For the re-building of the furnace in Canino in 1770, we have the list of the stones that were purchased and their size; we also know that the Bergamasque masters superintended the cutting of the stones by a local stone mason. We also have a list of the cutting tools, because according to tradition they had to be provided by the owner (ASR Computisteria e Depositeria della RCA).

Another puzzling feature of Bergamasque technology in Maremma is that no mention of use of lime or limestone additions to the ore are found in inventories (ASR Camerale III 638/b) or in a description of the process published in 1809 (Santi, 1806). Also no lime kilns have been found up to now near the pre-roasting kilns.

A progressive intrusion of French technical influence in the region appears to take place starting from the end of the 18th century. In 1786 some documents mention for instance the attempted construction, in Ronciglione, by Louis Boichot of a blast furnace which should have produced steel (ASR 638/a) and, around the turn of the century, an engineer named Boury built a small round furnace in Follonica (ASF Magona 2408). The process must have been accelerated by the French occupation (1799-1814) but, nevertheless, the introduction of new technology was slow. The Capalbio furnace around 1810 was built still with the Bergamasque model and the passage to a round cross-section took place only in 1836 (Garella, 1839). In the furnaces of northern Maremma the introduction of the round furnace and the pre-heated blast happened a few years earlier. Experiments on pre-heating of the air were conducted in Tuscany by a French engineer named Brasseur in 1833 (ASF Segreteria Finanze 1155).

Aside from the carving and mounting of the furnace lining, which was carried out under the direction of the iron masters, the men who built all the rest of the structure do not appear to have been specialized in this type of work. Filippo Prada, who was the contractor for a major reconstruction of the Canino factory and personally looked after the forging of the metal ties of the furnace walls (ASR Camerale III 501/f), was at the same time restoring a church and building another one for the government (and Caring for the paintings to be put inside them); five years later he built an entire new town (San Lorenzo Nuovo) for Pope Pius VI, who, as a cardinal in charge of the treasury, had signed his contract for Canino.

The pig iron tapped from the furnace ("scea" in the language of the time) would be picked up with the help of a hoist and thrown into a shallow water tank, called, surprisingly enough, "l'asciuga" (that is the drying place); this would make the material quite brittle so it could be broken into conveniently small pieces by hammer blows.

One part of the iron smelting technology appears to be peculiar to Maremma and not imported from elsewhere, and this is the production of the air blast.

All Tuscan furnaces used the trompe ("tromba a vento"); it consists of a water chute, 5 to 9 meters high, driving a flow of water into a sealed chamber ("bottino") where the falling water hits a large stone situated at a short distance from the outlet of the chute and then flows out from the bottom. A vent on the top of the chamber allows the compressed air to be taken out (see Figure 5).

Around 1640 the trompes had already been working a few years in various locations in central Italy (Calegari, 1977) and learned travelers were arguing about the reason why they worked. Apparently a key point is the correct position of the outlets of water and air and the distance between the stone and the chute end.

The chutes were normally built in wood; the ones in Canino in 1733 (ASR Camerale III 638/b) and those in Ronciglione in 1771 (ASR Camerale III 641/a) appear to have been made of hollowed chestnut trunks encircled by iron rings (17 in Canino). The "bottino" could also be in wood but all the remains we see now are of brick or stone masonry. One entire chamber with stone and all, survived in Capalbio while an entire system is still operating in a forge in Maresca (near Pistoia).

As in the alpine region the trompes are reported to have appeared in 1745 (Tucci, 1970 guoting Brocchi, 1807) and, even then, to have met with some criticism because the blast they produced was considered too damp, it is quite probable that they are a Tuscan invention as, after all, hydraulic science had undergone great progress in Florence in the second half of the 16th century. The water trompes are well illustrated in Diderot's Encyclopédie (Diderot, 1969), as they spread into southern France (as did also the Bergamasque furnace, see Figure 5).

Exceptions to the general use of trompes in Maremma are the furnaces of Conca and Cecina, probably due to the small difference of level which was exploitable for the waterfall. Conca used the traditional waterwheel and bellows arrangement while in Cecina (Garella, 1839) a device called "argagno" provided an air blow from two chambers which were alternately filled with water.

4. History of the Capalbio furnace.

The exact location of the blast furnace is Pescia Fiorentina, a hamlet in the territory of the Tuscan city of Capalbio, about 100 m from the bed of the Chiarone river which, besides providing the hydraulic power for the works, was always a border between different states.

Near the works an ancient road named "Francigena" was the transit point to Latium which was closest to the sea up to the 19th century.

Ironworking in the area is mentioned in 1527 by Rasi (Casini, 1982, p.18) who writes that the free community of Capalbio had started the works in 1420, that is immediately after the Republic of Siena took over the region from the previous feudal rulers (the Aldobrandeschi and Orsini families).

We have no idea, however, of the size of the works nor of the smelting process employed. The quotation (Casini, 1982, p.29,30,45) of a report by a "Provveditore" from Siena who visited the place in 1615 (ASS Carte del Magistrato dei Quattro Conservatori) does not help much from the technical point of view.

An indirect reference to the works appears in 1618 when, following a dispute about the border line, it is reported that the bed of the Chiarone is dry because the Tuscans diverted all the waters into their ironworks in Capalbio (ASR Camerale III 614/a). The fact that a blast furnace was operating there is proved by a later report in which the question is posed as to why the Medici Magona decided to stop operating it as soon as it took over the factory in 1649 (ASF Finanze 464). It also may be be inferred from the reference to the unloading of ore on the shore appearing in a 1651 document and referring to earlier times (ASF Magona 2446 p.26).

In some documents dated between 1615 and 1651 (ASS Carte del Magistrato etc., ASF Magona 2445 p.32 and ASF Magona 2446 p.26), managers who had rented the ironworks from the community are mentioned and we can conclude that the community did not operate its factory directly but rented it, as every other owner used to do.

On the basis of its geographic location, and of the date of the shutdown some time before 1649 (ASF Magona 2445), we are led to think that perhaps the main purpose of the first Capalbio blast furnace was to produce pig iron for the forges of Ronciglione in the Duchy of Castro. Another point in favour of close business relations with Castro is that the landing place for the mineral was on the shore called "la Graticciana" near Montalto, that is in the territory of the Duchy, rather than on the Tuscan shore in front of Capalbio which was controlled mostly by the Stato dei Presidi (ASF Magona 2446 p.26).

We also know that when the storerooms of Ronciglione were inspected in 1651 a batch of pig iron lying there was declared to have come from Tuscany by way of Capodimonte (ASR Camerale III 652b).

By analogy with the other blast furnaces of Maremma, the Capalbio furnace should have been built towards the end of the 16th century and, at that date, it is unlikely that it could have used the water trompes for the blast and it is probable that the usual arrangement of waterwheel and bellows was in operation.

The remains of what looks like a race fall, on the west of the present blast furnace, suggest that a wheel house might have been located there (but there is no proof of this, as yet).

If our hypotheses are correct, when the trade with Ronciglione was disrupted by the political events of 1641-1650 (war of Castro and its destruction, French occupation of Piombino), this isolated enterprise could not hold its own and was taken over by the Florence Magona, created by the Medici. We know that the Magona rented the works from the Capalbio Community from 1649 to 1776 (ASF Segreteria Finanze 1155 and ASF Magona 2368).

The period of Magona management started in an ominous way because the first manager appointed from Florence was killed by a harguebus shot almost immediately (ASF Magona 2446 p.5); what came after was not very successful either.

The Magona had no interest in producing pig iron so far south, as the Latium market was not so promising now that furnaces were built in Cerveteri (around 1651), in Canino (1671-73) and, somewhat later, in Bracciano. Furthermore the papal government obtained occasionally the management of the Follonica works from the Prince of Piombino. As a consequence the Capalbio furnace was shut down and only the forges were kept in operation, with pig iron sent from northern Maremma.

While the Graticciana shore was still used up to the end of the 17th century as a landing place, this was moved out of Latium in the beginning of the 18th century, probably as a consequence of an argument about the tax to be paid on iron in Montalto which arose in 1696 (ASR Camerale III/c). The new landing place was at "la Tagliata" (ASF Magona 16), that is near the present Ansedonia, in the territory of the Stato dei Presidi (then under the control of Naples); a storeroom was also installed there.

It is not easy to imagine how the buildings of the forges might have looked in this period, but the misalignment and the massive thickness of some walls allow at least a tentative identification of their possible position, which should be at the southern end of the present building. The complex might have been composed of two buildings as sketches in maps of the 18th century normally show two buildings and use a plural name: "Ferriere della Pescia" (Camerale III 499/a); the race might have run between them on the same path of the present aqueduct, whose level at the time was probably lower than the present one.

The eastern building would be the one enlarged and transformed into an olive mill in the 19th century, while the western one would have been in part demolished and in part incorporated into the rebuilt ironworks of around 1810.

The coal stores would have been a little uphill, more or less in the same place as now, but smaller (they were probably completely rebuilt around 1810) while the isolated remains of the idle blast furnace remained in between. All the buildings must have been surrounded by heaps of slags which were occasionally sold for re-use in the Canino blast furnace (ASF Finanze Vecchie 453).

From a document of 1702 (ASF Finanze Vecchie 722), it appears that the beginning of the 18th century was a phase of relative prosperity for the Capalbio factory which was selling its product as far as Florence; the shipping would be by sea to Livorno and by river to Signa. One budget of this period shows a profit.

Inventories and budgets are abundant in the Florence archive for the 1720-67 period, which unfortunately is the least interesting one for the ironworks because only two hearths and one drop hammer are working and, furthermore, the overall impression is one of progressive decay because the equipment and facilities for the workers appear to be in miserable condition (ASF Magona 13, 20, 26, 29, 2818 and others). Agricultural tools and nails are the main products. The budgets are normally in the red and the situation is made worse in 1765-67 by a dishonest manager (ASF Finanze Vecchie 453).

For about 35 years after the end of the Magona rental we have no news of the Capalbio works. Indirect information, though, may be gathered from the fact that a very detailed map of the Chiarone river drawn after another dispute about the border line in 1796 shows no water diversion for the ironworks (ASR Camerale III 614/b), although the toponym "lasco della ferriera" (marshes of the ironworks) survives in the annexed report as a reminder of the existence of the factory which one might suppose was not active at that moment.

In the years of the French occupation a family of private entrepreneurs from Pistoia, the Vivarelli Colonna, who had become rich in the charcoal trade (Mori, 1966, p.15 footnote 1) and are mentioned as caterers for the Massa and Accesa works in 1760 (ASF Magona 2518), somehow obtained the ownership of the factory (ASF Magona 1847). In 1813 Antonio Vivarelli Colonna declared to the prefect of France, installed in Siena, that the ironworks of Pescia were the property of his father Francesco and asked the permission to operate a blast furnace, as required by a recent French law (ASS Governo Francese 253).

With the advent of the Vivarelli family in Capalbio, the figure of the entrepreneur, owner of the capital and manager of the works, appears for the first time in the iron industry of the region. Antonio Vivarelli, the senior of four brothers, was the driving force in the first 40 years. After his death in 1852 (Contrucci, 1852) his place was taken by his nephew Francesco who in turn died of a carriage accident in 1865 (Casini, p.57); more or less at the same time the ironworks ceased to operate.

Under the impetus of the Vivarellis the Capalbio ironworks underwent continuous development and technical innovation. At the start of their ownership, that is approximately around 1810 (as also shown by the style of the portal built for the furnace room), the whole structure of the complex was substantially modified and rationalized.

A vaulted room was built in front of the furnace and this was connected to the forges re-built in the end of the building incorporating part of the previous ones; new rooms for the masters and their helpers were realized in the upper storey. As mentioned above, the charcoal storage was probably re-built and connected to the furnace building, thus realizing the unified, regular building which, with some modifications, is the one we see now.

We know for sure that the factory was modified in 1836 and in 1842 but, looking at the traces left on the surfaces of the walls, we may suppose that this must have happened even more frequently. In 1836 a French engineer visited northern Maremma, but did not reach Capalbio; he reports, however, a description obtained from the Magona experts he met, thus providing us with the only technical description of the works available at present (Garella, 1839).

A new round furnace was being built that year, to supplant the old rectangular one. We see now that the old supporting structure of the Bergamasque furnace was preserved, while a new round furnace was inserted, rather awkwardly, into it. The new furnace being about 7 m high (an increase in height of about 1.5 m), this entailed raising the floor of the working space at the upper mouth so that it became higher than the level of the upper courtyard, where the mineral was washed and sorted after pre-roasting; also the communication of the top of the furnace with the charcoal stores became more difficult.

The flow of materials to be fed to the furnace thus became less rational, but the imperative to increase production must have been the first priority at the time. Another symptom of this drive for greater production is the modification of the charcoal storage in order to obtain larger capacity and easier access for the wagons (or mules).

The continuous increase of production was also a consequence of the improvement of the air blast. In 1836, or before that date, the aqueduct was raised and prolonged; this made it possible to feed four high (8.95 m) water trompes. Pre-heating of the blast was also introduced around 1836.

In 1842 the Vivarellis took over a Swiss hydraulic pump which had been bought for a new private blast furnace enterprise (with the exception of Capalbio, all the Tuscan blast furnaces were now the property of the government) set in Gavorrano (Mori, 1966, p.386-389); this one had gone immediately bankrupt because the government would not sell the Elba ore to it (and we suspect that the mainland ore they tried to exploit had an unsuitable composition for the technology of the time).

The very large pump must have been similar to the one shown by Karsten in his book (Karsten, 1830); it was powered by a large waterwheel and required the complete modification of the south end of the building in order to accommodate it. The southern access door was sacrificed and the floor was raised by 1.80 m; a hollow arch carried the aqueduct water to the center of a large room where the wheel was set in a deep trench, supported by a series of stone blocks.

The story of the progressive rise of the blast temperature in the Capalbio furnace lies written in the ground all around the buildings because the colour of the vitreous slag changed from black to bottle-green, blue, and finally turguoise as the temperature grew, because of the diminishing iron content, as we know from a report on the experiments of M. Brasseur (ASF Segreteria Finanze 1155).

As a consequence of the introduction of the hydraulic pump, the buildings around the furnace were almost completely occupied by its services and not enough space was available for the forges. Land survey maps (ASG Mappa Catastale Orbetello) show that in 1847 a new building was built some 500 m downstream, so it could use the same stream of water for power. This building still exists and shows evident traces of its previous use (e.g. the water reservoir) but it has been converted into a farm and not available for study at the present moment.

The Vivarellis apparently were able to keep good relations with the government, so the Elba ore was always available to them; but when in 1826 they bid to take over the entire Magona which was not running so well (Mori, 1966, p.267-268) the government was frightened by the prospect of a private monopoly of pig iron in Tuscany and refused.

The letters and reports of the Vivarelli firm to the Magona are the only source of information for this period because the family archive for the siderurgical activities, which included some forges in the Pistoia area, is unfortunately lost.

The date of construction of the 1 km canal which allowed easy unloading of the ore is not known, but in 1836 it was already in existence (Garella, 1839). The road to the ironworks must have followed the same path of the present road from Pescia Fiorentina to the sea, because that road is built on foundations made with blue slag; slag also permits identification of the landing place where an unpaved path leaves the present road and, over an old bridge, reaches the course of the Chiarone at 100 m distance.

The energy of the private entrepreneurs made the Capalbio factory quite prosperous; in 1850 the number of workers had increased to 140 and the production to 6 million Tuscan pounds (about 2,000 tons) of pig iron per year.

A book printed in 1864 lists the Capalbio factory as still in operation (Giordano, 1864) but it must not have survived for long the unification of Tuscany to Italy (1859).

The dates of the period of activity of the olive mill that was set at the south-east end of the building and exploited the aqueduct of the ironworks for power, are not yet known; in the 18th century the Magona budgets show that olive oil for the workers was bought in Canino, so the mill must have started in the Vivarelli period or after the ironworks were closed. Later the buildings were used as stables and, for a time, they were occupied by the Italian army; in the Second World War and immediately after they were used as dwellings by refugees. This kind of use caused the disappearance of every movable piece of material and let the buildings fall into a state of utter disrepair, but respected the structures and the traces left by the equipment on the walls.

These lucky circumstances make the Capalbio ironworks an interesting field for archaeological studies, all the more so because even the modifi-Cations of the processes which were introduced in the past respected in general the traces of the previous systems; the new equipment was inserted without bothering to erase the remains of the previous one, unless it was strictly necessary. It is possible, therefore, that even some traces of the earliest activities may be preserved, hidden somewhere in the walls or under the ground.

In any case the evolution traced here must be considered only as a tentative scheme, to be used as a working tool, more than a reliable historical sequence; much more archaeological and documentary evidence is needed to establish on a firm basis the history of the development of the buildings.

5. Capalbio. Study of the building and of the deterioration processes.

The reader is referred to a simplified sketch of the existing building (Figure 9) and to a hypothetical reconstruction of the working cycle around 1835-1840 when the Bergamasque furnace had just been replaced, but the water trompes were still in operation (Figure 10).

Upper court and pre-roasting kilns.

Entering the complex from the north, the visitor normally has access to the upper court on which the draw holes of the four pre-roasting kilns open, two on the north side and two on the east (see Figure 11). The kilns were loaded from the top level, which is now the garden of the villa the Vivarellis built for themselves, now the villa Pietromarchi.

The body of the kilns is buried in the garden, under some trees, while the front is visible and shows some signs of deterioration. The front of kiln N°2 collapsed, probably due to seepage of water through the garden soil, and the brick or stone masonry of the other ones shows signs of erosion caused by moisture. Two slender arches that supported a shed, intended to shelter the workers ("picchiavena") who extracted the roasted ore from kilns N°3 and N°4, are badly weathered and urgently require stabilization.

In the center of the upper court archaeological research is planned in order to identify the traces left by ore washing and sorting activities.

To the east the court is flanked by the main building; the first room is a vaulted space extending, in part, behind kiln N°4 and lying under the passage that allowed the charcoal loads to reach the store at the upper level. This room is of rather late construction (successive to a raising of the windows into which the coal was discharged) and its original use is still unclear (stable? blacksmith shop?).



Fig. 9 - Axonometric sketch of the Capalbio ironworks.



Fig. 10 - Reconstruction of the production cycle in Capalbio around 1840.



Fig. 11 - Capalbio. The upper court and the pre-roasting kilns.



Fig. 12 - Capalbio. Blast furnace, front view. The charcoal store is in good condition thanks to a good roof built recently by the new owner. A particular feature of its ashlar stone masonry is the fact that in some wall surfaces ancient slags (incompletely vitrified and black) are infixed in the mortar joints in what appears to be an attempt to reinforce a repointing carried out on some deteriorated surfaces.

Crushed slag appears to have been intentionally added to some mortars used in the building; a petrographic study carried out on some 30 samples, using the presence of slag as a criterion of classification, allowed us to reach the conclusion that the use of slag could be connected to masonry that belonged to the well-aligned walls, built in a general re-structuration of the building, and so it must have been relatively recent.

The upper court terminates against a small construction protruding from the main building; this is situated exactly above the natural escarpment against which the furnace was built. As shown by the fragment of a water chute included in the wall at court level, this might be the site of a shed(?) housing the wheel and bellows in the first blast furnace building. Currently it is adapted for residential use at the upper court level while one of the two rooms at the lower court level appears to have been used by a blacksmith and the other for storage, but it is unclear at what date.

The blast furnace.

The last door (south) in the upper court leads to the top of the furnace. The blast furnace is well preserved but full of debris; it is surrounded by two heavy towers ending in small pyramidal structures, analogous to those which are visible in the 1778 drawing of the Accesa furnace (Figure 6), where they are adorned on the top by two cast iron sculptures of the Arabian Phoenix (a symbol of iron, re-born on fire). Besides the towers, the furnace is supported by a system of vaults and arches, built all around it, which also had the function of supporting the roof covering most of the working area in the 19th century.

The front of the furnace is bulging slightly and much of the iron reinforcement has disappeared or is rusting away, as the furnace was never sheltered from the rain; furthermore some part of the lower front collapsed and the forehearth, if it exists at all, is buried under the debris (see Figure 12). It is not possible, however, to clean and excavate the furnace free of all the rubbish until the whole structure is stabilized.

The underground passage behind the furnace is also preserved and the area on the rear of the furnace where the blast was injected through the tuyere is visible. A hole immediately above this point allows a direct communication with the top of the furnace; it was through this passage that the air pre-heated by the hot fumes could reach the injection point at the back of the furnace. A small section of the vaults in front of the furnace collapsed and a larger one is in danger; this is obviously due to the disastrous condition of the roofs above and the consequent penetration of rainwater.

Important remains of various phases of the air blast transmission systems used in various times are visible on the walls under the vaults; their archaeological study is important, as is that of the unpaved floor of the entire room, but it is impossible in the present conditions of stability of the roofs.



Fig. 14 - Capalbio. Present state of the roof of the south wing near the race.





Fig. 15-16 - Crack movement diagrams for monitoring points FEC1 and FEC4 (Capalbio ironworks).
The south wing and the wheel room.

The large room in the south section of the building which housed the hydraulic pump after 1842 is now completely empty (see Figure 13), with the exception of the stone blocks which supported the machine and were later precipitated into the trench of the wheel; the trench in this phase Was covered by a wood floor, now missing, to allow a different use of the space. On the walls some remains of metal brackets and other support Systems show how the large pump was mounted in the room and may allow an approximate reconstruction of its structure.

The floors of the workers' rooms, in the upper storey, collapsed almost entirely due to the progressive destruction of the roof above, whose condition is shown in Figure 14.

All the southern part of the building shows a series of cracks, some of them quite large, mainly on the transverse (E-W) walls, showing that the western facade and some adjoining walls tend to separate from the rest of the structure; this is probably the consequence of some differential settlement caused by the change of the water regime in the soil when the waterworks stopped carrying, and leaking, water.

We have been studying the movement of these cracks by means of a Demec gauge since January 1981 in order to assess the risks involved for the stability of the building. The data read on the instrument (the distance between three measuring points attached to the wall surface in such a way that a crack passes between two of them and the third) are fed into a computer programme prepared by J. Malliet which calculates the horizontal and vertical displacement of masonry across the crack and displays the results in a graphical or tabular way.

A three-year survey diagram (Figure 15) shows that two cracks, measured at 1.50 m above grade, open in summer (up to 0.6 mm) and close again in winter, but not completely (average increment in width 0.15 mm per year). A larger displacement (1.0 mm summer increase, 0.25 mm yearly increment) was measured, as is logical, in the third point which is situated in the upper storey.

In summer, two cracks out of three also show a daily cycle (a fluctuation in width of about 0.1 mm), pointing to the fact that both the yearly and daily cycles, in the horizontal displacement data, would be due to the thermal expansion of the surviving roof structure; the loss of many of the horizontal connections (floors) and the cracking of other ones (arches) help to explain the magnitude of the movements measured.

The fact that the cracks do not go back to the initial width when the yearly cycle is concluded might be due to the displacement of minute particles of detritus or dust which inhibit the re-establishment of the previous fit of the two sides. The yearly increment of the vertical displacement being very small, it is not likely that differential settlement in the soil is a cause of disturbance at this time.

A fourth measuring point was set across a thin crack on the (N-S) longitudinal spine wall of the south wing. This crack shows (Figure 16) almost no thermal cycle but only a slow drift in both the horizontal and

vertical displacement (0.1 mm per year) indicating that the southern end of the building is sinking very slowly.

On the whole we are unable to draw a definite conclusion as to any immediate danger that such movements might indicate. The expert we consulted (Prof. A. Gallo Curcio, who teaches Construction Science at Rome University) suggested that horizontal connections should be re-established as soon as possible in the building in order to face possible future catastrophic events (e.g. earthquakes) with a coherent structure.

The waterworks.

The whole factory is flanked on the east side by the water race (see Figure 2), built in stone masonry and supported in the northern sections by some arches of variable shape which look quite old; it shows evident signs of having been raised by about 1 m at some stage of its existence.

More or less at the side of the blast furnace a diversion stems from the main channel and descends to an underground channel and, from this, to the horizontal wheel lodged below grade which provided power for the olive mill (part of the wheel mechanism still exists).

The final part of the race, south of the furnace, appears to have been modified several times and shows traces of various operations which still need study to allow a plausible interpretation. For instance a small chute dropping directly into the furnace room was probably meant to feed a small masonry chamber whose purpose is unclear since it does not look like a trompe.

Farther south, three elongated arches housed the first three trompes, while the fourth trompe is hidden under a later prolongation of the canal and its chamber ("bottino") is completely preserved inside a longitudinal gallery, created under the prolonged aqueduct. Into this gallery, at the end of the aqueduct, was funneled all the residual flow of the main race and, through an underground passage, also the water which powered the wheel of the hydraulic pump.

The walls of the final prolongation of the aqueduct form a slight angle with those of the earlier section; this allowed the insertion and the anchorage to the old structure of 4 longitudinal metal ties, whose purpose was to increase the resistance of the terminal wall to the pressure of the water stream. The structure of the aqueduct is also reinforced by a number of transverse metal ties connecting both side walls to the structure of the factory.

All the waterworks are remarkably preserved and constitute one of the most interesting parts of the building.

The olive mill.

The mill is situated beyond the aqueduct at the south-east end of the building. When we first inspected it, all the roofs had disappeared but the floors and the grinding wheel were in good condition. The wall of the aqueduct, which forms a side wall of the grinding room, shows the trace of a fired clay tube feeding water to a small fountain in the room; an area below grade lodged the presses.

The second room of the mill, with its floor sloping toward a central hole, was obviously built later than the first one, as is the expansion of the first room in which the crushing equipment is lodged. All this shows that the first room was pre-existent to the olive mill; as it is very large, with thick side walls, and adjacent to the water race it is natural to think that it was part of the earlier forges.

In support of this interpretation there is also the fact that this building is surrounded on all sides by heaps of what appear to be bloomery or forge cinders with a depth of some meters (still to be exactly determined). Unfortunately the mill was completely restored in 1983 and transformed into a holiday residence, so further study is not possible at this time, even if the main features have been respected in the restoration.

Stables.

The stables were also recently converted into a residence. This building, which is a separate structure on the west side of the lower court, must be relatively recent as it lies on top of a heap of cinders and slags and its foundation masonry includes blocks of blue blast furnace slags (which was produced after the introduction of pre-heating of the air blast in 1836).

Building survey.

Our team carried out a complete survey of the factory and the olive mill, from which plans on 1:50 scale were drafted. In addition photogrammetric views of the furnace front, of all the west facades (upper and lower court) and of the aqueduct from the east allowed an accurate recording of the most important vertical surfaces. A 1:20 photoplan of the furnace front was printed out of one of the photogrammetric negatives as a documentary basis for the future restoration work to be carried out on the furnace.

The survey is supported by an extensive photographic documentation of all walls, in both black-and-white and colour; this should allow us to keep a record of all traces of previous equipment which might disappear in the course of future restorations (although our project proposes to leave such surfaces in their present condition, even in the final use as a museum).

In June 1983 a preliminary archaeological examination was carried out, at the request of ICCROM, by B. Trinder (Ironbridge Gorge Museum) and D. Crossley (Sheffield University) with the assistance of J. Malliet. This confirmed the importance of the potential information enclosed in the factory building and allowed us to prepare a plan for further archaeological study.

6. Capalbio. Conservation and adaptive use.

The basic concept in our project is that conservation of the Capalbio ironworks should be carried out phasing the various stages of the work in such a way that the maximum possible amount of information be preserved. The first phase, therefore, is a preliminary study, permitting identification of the areas of archaeological interest and the causes of deterioration; this is followed by drafting and implementation of an emergency stabilization plan which should arrest the continuing decay of materials and structures.

A second study phase should be started after relative stabilization is achieved, while restoration, aimed at a satisfactory re-use of the building, should start only when such a study is in an advanced state.

This sequence should avoid the danger of great damage being inflicted on the informative patrimony of the building by a hasty intervention on its surfaces and structures.

As we have seen in paragraph 5, the preliminary phase of study is now complete and it has allowed us to identify the penetration of rainwater through the damaged roofs and the wide-open windows as the main cause of deterioration. Also the potential risk arising from the lack of horizontal connections in the south section of the building was put in evidence.

As a consequence our team prepared an emergency stabilization plan including:

- a. construction of temporary roofing, not only where the original roofs collapsed or are badly deteriorated, but also over the furnace where there was no roof in the past:
- b. provisional bracing and strutting to insure the stability of all endangered vaults and floors;
- c. temporary boarding up of all windows;
- d. insertion of 24 east-west metal ties, crossing the entire building, in the south section.

The temporary stabilization work should also allow easy access to all parts of the building and the prosecution of the archaeological research in satisfactory conditions insofar as safety is concerned.

After the emergency stabilization plan was approved by the competent technical authority (the Superintendent of Monuments for Siena), the town of Capalbio allocated about US\$22,000 for its realization. The works, which have already been contracted to a local firm, are scheduled to start in November 1984 under ICCROM direction.

Unfortunately, due to inflation and some delays, the budget now available is no longer sufficient to carry out all the work envisaged in the plan; therefore the structural reinforcement with metal ties will not be included in the first group of works (as it was estimated that roofing and supporting the endangered parts were the top priorities). It is hoped that the plan will be completed soon, when another allocation from the town's, or the province's, budget will be possible.

As for the long range programme of conservation and restoration, the financial manoeuver is based on the creation of a foundation in which the former owner, the town of Capalbio and the regional government of Tuscany are partners; this foundation should then receive funds from various sources to carry out a programme aimed to install a small museum and a library in the Capalbio ironworks. The legal machinery for the foundation was completed in July 1984 with the formal accession of the Tuscan Region (an important fact because the regional governments are well provided with funds for stimulation and administration of cultural resources) and with the donation, by the owner, of the central part of the building (including the furnace, the wheel room and the waterworks) to constitute the patrimony of the foundation itself.

In addition to the remains of the works, kept as much as possible in their present condition, the museum will display illustrative material on iron smelting and forging in the 18th and 19th centuries. The display panels will be placed more or less in the same position where the various Operations depicted were carried out in the Capalbio works. The progressive evolution of the technique would also be illustrated, in good part by means of the evidence offered by the walls themselves.

Figures 17-20 illustrate the plans for the consolidation, protection and use of the building.

Another section of the museum, in the wheel room, might deal with some ancillary processes (coal making, transportation) and with the life of the migrant workers who operated the Maremman factories. The museum visit would also include a tour of the waterworks and of the underground passage surrounding the furnace.

The library will be based on a donation by a prominent figure in recent Italian cultural and political life, Prof. Carlo Muscetta, who lived many years near Capalbio. It is mainly historical and literary in character, but there are plans to build up progressively a technical section on the industrial activities of Maremma.

In the present project several parts of the factory remain out of the foundation property; some of them (the olive mill, the stables, the house between the upper and the lower court) have already been restored and sold or rented for residence while others (the coal stores, the rooms at the southern end) are earmarked for a similar conversion.

This is an unfortunate fact which will pose serious limits to the future activities of the foundation, as one may easily forecast future contrasts between the tenants of the residential flats and the public activities of the foundation, should these be successful.

On the other hand this sacrifice was probably necessary to provide the project with a realistic base for operations; by cutting down the area allocated for public use it is possible to bring down the cost of restoration (estimated in the range of US\$400,000) and of operation of the future foundation within limits that could be acceptable to the community in the present condition of public finances.

As the whole building is now listed as a national monument, all restoration, both in the private and the public section, must be approved in advance by the local Superintendent, and this should avoid excessive damage in the process of conversion. Later it is hoped that a prosperous foundation will be able to buy other parts of the building and convert them to public use.



Fig. 17 - Capalbio. Axonometric view showing the proposed arrangement of the museum.



Fig. 18 - Capalbio. Plan at ±0.00 level.



Fig. 19 - Capalbio. Project of consolidation of vaults and floors in the south wing.



Fig. 20 - Capalbio. Project for a protective shed for the furnace area.

7. History of the Canino blast furnace.

In 1670 the Marguis Nerli of Florence and his two brothers, who had rented (1670-1679) the State of Castro, obtained from the papal government the authorization to build a furnace in Canino for the production of pig iron (ASR Camerale III 628/a).

A partial transcription of Nerli's accounts (ASR Camerale III 638/c) informs us that, besides the furnace, the factory that was built included the water race and trompes, rooms for the workers, pre-roasting kilns, charcoal stores and a church. A total cost of 4065 scudi, for buildings and equipment, was evaluated by the author of the transcript; it also included the road to Canino and a bridge.

The largest payment for the construction of the buildings (1442 scudi) goes to a "maestro Antonio Rinaldi muratore".

The furnace was fired for the first time in April 1672, as we know from the payment to the priests who performed the religious ceremony.

In the following years the furnace was seldom managed directly by the persons who rented the State of Castro; most frequently it was sub-leased for the usual nine-year period. The sub-lease would often include the forges of Ronciglione, although there are also cases of separate rentals.

On the whole the activities of the furnace are well documented thanks to a series of law suits which accompanied its life in the 18th and 19th century and left abundant traces in the State Archive of Rome. Other useful data on the import of iron ore are also produced by litigation on the payment of the tax on imported iron.

Early in the 18th century, a first law suit concerns the ownership of the furnace (ASR Camerale III 654/b); apparently Nerli had gone bankrupt (not because of the furnace which, in all estimates we have found, appears to have produced a profit any time it was run) and his creditors were trying to recuperate some money from those who had sub-leased it from the tenant of the Castro State.

The court judged that Nerli was in effect the owner but then the government must have bought the furnace around 1740 because in the following years it is always mentioned as the property of the "Camera Apostolica" (treasury department) which cashes the rentals and pays for major repairs.

The ore always came to Canino from Elba, through the Montalto shore, where the furnace owned an open air storage place and a small two-room house. A 20 km road, which was occasionally repaired (ASR Camerale III 641/b), connected the furnace to the shore; a far longer stretch, about 60 km over hilly country was required to send the pig iron to Ronciglione.

The furnace, therefore, had to be well-provided with stables; the inventory of 1770 lists 4 caves, dug in the tuff of the overhanging cliff, which could accommodate 200 horses (ASR Camerale III 623).

Among many names of people who rented the furnace it is worth mentioning that of Girolamo Mariani who, with the support of some partners, took the sub-rental of Canino for 18 years (1715-33) and that of Ronciglione for an even longer period (1708-33). Mariani operated the furnace through 7 seasons with an average profit of 6456 scudi per season (maximum 9263, minimum 3529) (ASR Camerale III 501/a par.28).

Mariani also managed the Follonica works from 1733 to 1754 when he could no longer obtain the rental of Canino and Ronciglione. At the time he was accused of introducing large amounts of pig iron into the Papal State, which was illegal (ASR Camerale III 501/b par.8,9,10,16,17). Mariani claimed that he had to do so because, otherwise, the forges of Northern Latium would have remained without any pig iron to work.

Two sons of Girolamo Mariani (Cristoforo and Domenico Antonio) obtained the sub-rental of Ronciglione later.

An inventory of the Canino factory written in 1733, at the end of the Mariani period, provides an approximate description of the buildings and a list of equipment (ASR Camerale III 638/b). The air blast at that date was provided by three trompes fed by a race carried over a wood structure, so the blast furnace might have looked like the one shown in Figure 5, except for the fact that the output of the trompes was collected in a masonry chamber, reinforced with metal, before being injected in the furnace.

In 1742 the tenant of the Castro State (a Mr Degola) delivered the blast furnace to the sub-tenant (a Mr Perti) in such a condition of disrepair that it was impossible to operate it (ASR Camerale III 501/b par.19). In the law suit that followed, some experts were called by the court to examine the accounts of the previous seasons at Canino in the 18th century; they also compared those data with others obtained from Bracciano and Conca (ASR Camerale III 501/a various paragraphs). The purpose of the study was to establish how much profit Perti might have made out of two seasons he should have worked in the time of inactivity (ASR Camerale III 501/b par.19).

The acts of the Perti vs. Degola suit thus constitute an interesting document on iron smelting in Latium in the 18th century.

The blast furnace resumed operations on Christmas eve in 1747 and also in this case a religious ceremony solemnized the occasion (ASR Camerale III 501/b par. 15).

There must have been another spell of inactivity in the sixties but after that another manager worthy of notice, Filippo Stampa, took up the rental in 1770 and convinced the Camera Apostolica to carry out a major renovation.

Stampa also managed the Follonica works for some time (around 1759, that is before coming to Canino) and although he certainly knew about ironworks he must have been more a business man than a technologist. Boichot, who went to Canino in 1786 to have some metal parts cast for his experiments, reports a quarrel there with a "Maestro Bergamo", that is a Bergamasque who conducted the works (ASR Camerale III 638/a).

Besides also renting Ronciglione, Stampa took over the entire State of Castro and this simplified his transportation problems because the ship owners would appreciate the advantage of coming to Montalto with the ore and going back with wheat produced in Castro (ASR Camerale III 495/a).

The complete renewal of the factory, under the direction of Filippo Prada, was terminated in 1771 and is illustrated by an accurate description of each single piece of work (with individual prices) signed by the architect of the Camera Apostolica Francesco Navone (ASR Computisteria e Depositoria della RCA); we also have found, in another file (ASR Camerale III 495/b), the plan which, most probably, accompanied the project (see Figure 21).

The total cost of the restoration was 3987 scudi, that is almost equal to the cost of construction, one hundred years before. The work included a complete re-building of the structure supporting the furnace and of the lodgings for the masters and the helpers.

The terminal part of the aqueduct was completely reconstructed in brick masonry; the new race splits in the end into two canals, diverging at 90 degrees, carried by two great arches in each of which two trompes were lodged.

The width of the bridge on the access road was doubled and an underground drainage system was constructed to protect several areas from periodical flooding. Better internal communications were insured by the creation of two internal staircases and two small vaults were built in front of the pre-roasting kilns.

The church had the roof completely redone while the charcoal stores (whose roofs had been remade a few years before) were not touched.

On the whole the extensive renovation carried out by Prada succeeded in imparting to the complex some architectural dignity and should have been technically effective because the general organization of the factory was not further changed in the following years.

Stampa also asked for government permission to operate a forge (ASR Camerale 497), something that Nerli had already done; the forge was in another building downstream, not far from the furnace, but it has not been identified yet. Its activity must not have been very important because it is hardly mentioned in successive documents.

Starting from 1772, Stampa inaugurated a practice of running the furnace every year, with the usual winter and spring schedule (ASR Camerale III 628/b); apparently he was making smaller profits than Mariani (six seasons show an average profit of 3842 scudi, minimum 2246 maximum 4888) or hiding them better. Anyway he was using a lot of wood so he asked the authorization to cut some woods of tall trees and not only the usual shrubbery.

This inspired a general protest from the citizens of Canino who started a legal action in Rome claiming that the cutting of the woods would allow bad air (in Italian "mala aria") to seep in from the marshy low lands and bring malaria into Canino which, so far, had been immune.



Fig. 21 - Plan and project for the Canino ironworks around 1770 (ASR, as quoted in the text).



Fig. 22 - Canino. A general view of the ironworks.

The government sent a commission of experts (ASR Camerale III 499 and ASR Camerale III 500) who produced several reports which included statistics on birth and mortality rates, wood cutting, atmospheric conditions (the anopheles was not yet known but we have a good description of a thermal inversion); it may well be that this is the first environmental impact inquiry on record.

Troubled times were coming, however, and the iron was needed; Stampa won and the city of Canino was condemned to pay the cost of the inquiry (1614 scudi) (ASR Camerale III 691).

Filippo Stampa obtained in 1778 a permanent lease, inheritable by his successors, for the Canino furnace and the Ronciglione forges. Life, however, was much tougher for his successors; the son Angelo took over in 1791 and renounced the Castro rental (ASR Camerale III 495/c) and then also the Ronciglione forges (ASR Camerale III 498/b) which, later, he had to sub-lease from the new tenant to find an outlet for the pig iron produced in Canino.

The French invasion had an important influence on the Canino furnace. In 1799 the Jacobin Republic of Rome seized the furnace and had it evaluated (ASR Camerale III 495/d), then sold it to the French Republic (ASR Camerale III 495/e). The estimation was 35,500 scudi: obviously some inflation had been going on.

Angelo Stampa got the furnace back from the Austrians who occupied Latium immediately after, but died almost at the same time; his son Piero claims in a memorial (ASR Camerale III 495/f) that he was able to operate it for several seasons notwithstanding the difficulties created by the English blockade. Apparently Canino was the only furnace in Latium that operated in those days.

In 1808, however, Piero Stampa was more or less forced to sell out to Luciano Bonaparte (ASR Camerale III 501/d), the brother of Napoleon, who decided to settle in Canino after a decisive guarrel with the emperor. Besides the furnace he bought other property in the area and obtained also the sub-rental of Ronciglione; in 1812 he was nominated Prince of Canino by the pope.

As the Bonaparte archive was dispersed in the 19th century, we have no direct information on the successive activities of the ironworks; for instance we do not know the date at which the Bergamasque furnace was replaced by a round one. It is logical to think that the new owner's good connections with France would have favoured this development at a rather early date.

Today around the furnace we found no trace of blue vitrified slag and we wonder whether it was removed for re-use elsewhere; as we know that Capalbio sold its slag to Canino around 1765 (ASF Finanze Vecchie 453) the reverse might have happened another time. It is possible also that the blue slag was never produced because the pre-heating of the air blast had never been introduced.

The furnace appears in the inheritance of Carlo Bonaparte, son of Luciano, in 1842 and then in the sale to the Torlonia family in 1853 (ASR

Camerale III 498/c). We were not able to consult the Torlonia archive to see if some information on the iron furnace is available there; we are left therefore without any information on the final phase of activity of the ironworks.

An Italian geographic dictionary, published in 1866, mentions the Canino furnace as still in operation (Amati, 1866) but this might be the automatic transcription of information from an earlier text.

As in Capalbio, also in the Canino factory an olive mill was active for some time; in this case, however, we are sure that this happened after the end of operation of the ironworks, as the top of the furnace was covered with a floor and the olive crushers were set on top of it.

This olive mill is rather peculiar because it exploited the hydraulic power of the aqueduct by means of an iron chute (still existing at the side of the furnace) which very likely powered a mechanism whose movement was transmitted to the top of the furnace through a series of shafts and gears that no longer exist but left evident traces on the walls.

The mill's dates of operation are not yet known; it is worth noting that the olive oil of Canino enjoys a considerable reputation in the region and that two firms produce oil on a large scale in the town today.

8. Canino. Study of the buildings and of their deterioration.

The study of the Canino furnace started in 1982, when our group discovered that most of its structures had survived, under the cover of abundant vegetation, in a small valley not much affected by recent development even though very close (less than 2 km) to the town of Canino.

The dam on the Timone river is still efficient but, as water is no longer diverted into the ironworks, the stream overflows the dam and pours into an abandoned guarry forming an attractive waterfall near the ruins of the furnace.

The aqueduct is well preserved for most of its length, showing an elaborate system of water distribution at its end, where two channels diverge and then both are further separated into two branches to feed each trompe separately. Two of the chambers of the four trompes may have survived buried in the soil.

The present condition of the ironworks is illustrated by the general view in Figure 22. The visit to the factory normally starts at the lower level where, near the main door, a memorial stone is infixed in the wall commemorating the 1770 renovation, under Pope Clemens XIV and the direct authority of Cardinal Braschi. Immediately above this stone, another one carries the Torlonia arms and the "ferriera" inscription.

The lower level includes, from west to east, the great room in front of the furnace ("barca del forno"), the workers' living quarters and, in a separate building, the director's house. The front of the furnace is shown in Figure 23. From the "barca" a covered stone staircase leads in two ramps to the top of the furnace.



Fig. 23 - Canino. Two pre-roasting kilns (foreground) and the church.

Fig. 24 - Canino. Blast furnace, front view.



At the higher level, with a west-to-east direction roughly parallel to the buildings in the lower level, we find the room at the furnace mouth ("barca superiore"), the charcoal stores, the church and the pre-roasting kilns (see Figure 24).

From the room over the furnace a ruined staircase leads to the top of the aqueduct, about 10 m above the lower furnace room and 4.5 m above the upper one; it is interesting to note that the trompes use the same difference of level as in Capalbio. The main race flows approximately in the north-south direction, with a branch diverging in the end to the east.

A still higher level is that of the top of the natural escarpment against which the furnace was built; we know that it was accessible through a path coming up from the Canino road and also through an outdoor stairway (almost invisible now) rising between the charcoal stores and the preroasting kilns. It was at this level that the charcoal was carried to be unloaded into windows opening in the top of the charcoal stores.

On the whole the existing structures correspond strikingly to the plan related to the restoration of 1770. Some details are different because they must have been realized not exactly as planned (e.g. the staircase connecting the room in front of the furnace with the upper level), others because of modifications introduced for various purposes.

The workers' living quarters appear to have been completely modified in the interior because they were adapted to a completely different use; a series of shallow tanks was built at various levels allowing perhaps the flow through them of a liquid, from the upper to the lower level. Our interpretation is that these tanks might be the remains of a process of purification of the olive oil.

It is more difficult to interpret the use of two large tanks installed in the underground passage behind the furnace, that is in total darkness; further information on late uses of the premises will be needed for this.

The charcoal stores do not appear to have suffered a great change because of their use as cattle pens besides the blocking of some doors with stone blocks which appear to be cut as furnace lining stones, but are not made of the usual schist or show traces of use.

A modification introduced by nature, rather than by man, is the disappearance of the pig iron store which is shown in the 1770 plan and now is completely ruined; this happened probably because of soil erosion during floods of the Timone river. Also, as a consequence of the natural decay of all wood beams, all the buildings lost their roofs, with the exception of the church and the director's house which shows signs of recent occupation.

The walls look dilapidated as the growth of vegetation on them has caused much superficial damage (loss of plaster, penetration of roots etc.), although probably it has avoided more serious damage from other sources (vandalism, direct impact of rain). No hint of immediate danger of collapse is noticeable, although we shall be able to assess this in a more reliable way only when the results of the architectural survey (which is now almost complete) are examined in detail. The blast furnace interior is accessible, through the underground corridor, thanks to a hole somebody opened in its back; it looks completely preserved under the protective ceiling formed by the new floor built on top of it but, unfortunately, it is not a Bergamasque furnace but a round one, rather wide and about 5.5 m high.

The front of the furnace lost almost all its metal armature, although the infixed bars to which the iron ties were hooked, are preserved. Contrary to what was found in Capalbio, the forehearth of the furnace appears in good condition.

Both pre-roasting kilns appearing in the 1770 plan are preserved and remarkably complete; the small porch in front of them shows important signs of erosion in the brick plinths; this is probably caused by the capillary rise of moisture in the masonry and the action of soluble salts. The presence in Canino of these well-preserved specimens of "ringrane" will probably make the excavation of the Capalbio ones unnecessary.

A third kiln, not appearing in the 1770 plan, is found a few meters east of the other two; it is smaller than the older ones and oriented W-E rather than S-N. Its date and use are still unclear (an added "ringrana" or a lime kiln?).

The study carried out by our group up to the present was aimed at documenting the remains as accurately as possible by means of measured plans and cross-sections accompanied by an extensive photographic survey. Archival research, which was guite fortunate because abundant documentation was available in the Rome State Archive, completed the initial phase of operation.

The materials collected are currently being used to convince the local community of the importance of the furnace and of its preservation.

For the future our plan is to follow a sequence of operations analogous to that attempted in Capalbio, that is: drafting of an emergency stabilization plan, continuation of study, drafting of a conservation plan.

9. Canino. Conservation and adaptive use.

In the Canino furnace a complete production unit of the late 18th century has survived, with most of its ancillary services (houses, stables, stores, bridge and road, waterworks); we are convinced that it has a considerable documentary and spectacular interest.

The conservation project should be rather different from that of Capalbio, however. The Canino furnace is a fascinating ruin to which it would be difficult, and probably disfiguring, to provide a roof; only the director's house can be easily reclaimed and used to lodge a warden and some informative material.

In our opinion the best use of the factory would be as an archaeological park which would take advantage of the rich and attractive vegetation and of the secluded character of the site. Obviously the realization of this programme would pose serious problems of maintenance in order to avoid excessive damage caused by vegetation and the progressive decay of the roofless masonry under the action of rain and temperature variations.

We think that by a proper choice of the plant species allowed to grow among the ruins and by periodical treatment of the walls, in particular of their tops, accompanied by a selective use of unobtrusive sheds, a satisfactory result could be achieved.

As the distance from Capalbio is rather short (about 30 km) a visitor could easily see both factories in the same day and could draw from the Capalbio museum the additional information required for a more complete interpretation of the Canino furnace and of the iron industry of Maremma in general.

We also think that in the future interpretive schemes besides the blast furnace also the olive mill must find adequate illustration, considering the peculiarities of the machinery employed and the fact that olive oil appears to have always been an important feature in the economic history of Canino.

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LA FONDATION D'ETUDES ET RECHERCHES SUR LA MAREMMA TOSCANE DE CAPALBIO

Isabella CASINI

SUMMARY

Thanks to the concern of the owner and the collaboration of the public authorities and some enthusiastic individuals, it has been possible to preserve such an important archaeological site as the Capalbio blast furnace. The creation of the "Foundation for Study and Research on the Tuscan Maremma of Capalbio" has improved greatly the effectiveness of their involvement. The statutory goals of the foundation are the administration of the blast furnace building and of a donated private library and the promotion of cultural activities and of research and studies on the territory and its history. This means that the foundation should exploit the fortunate presence of such an important monument of the history of the area, in order to improve the cultural self-awareness of the inhabitants of this small country town, Capalbio.

Octobre 1984

Quand, au printemps 1980, j'eus la chance d'accompagner un groupe de fonctionnaires de la Region Toscanne qui venait visiter ce qui par la suite résulta être le four de fusion Vivarelli-Colonna de Pescia Fiorentina, aucun des présents n'aurait imagine à combien et à quels développements imprévus, cette connaisance des lieux aurait conduit.

Le premier et le plus important desquels fut l'élan donné depuis lors à la recherche historique, qui, grâce aux sources bibliographiques et des archives, a servi pour tracer un premier cadre de récits où placer les nouvelles que nous possédons déjà aujourd'hui, soit celles qui seront les fruits de recherches futures.

Un travail pareil a naturellement besoin d'un approfondissement et d'une mise à point, qui j'en suis sûre, ne manqueront pas d'entraîner pendant les annés suivantes, des savants spécialistes d'autres disciplines, étant nécessaire de procéder évidemment toujours avec une vision pluridisciplinaire du problème.

Le second résultat atteint, fut représenté par la collaboration des organismes publics pour ce qui se rapporte à la question de la présence sur le territoire de pièces archéologiques d'une aussi grande importance, grâce à la libéralité des propriétaires, messieurs Pietromarchi, et à la clairvoyance des administrateurs de la Commune de Capalbio et en tout premier lieu, du maire, Mr Massimo Abbate: les premiers déclaraient être disposés à donner une partie considérable de l'immeuble, à condition d'être restaurée et ouverte au public; les seconds, ayant compris son importance historique, garantissaient l'appui nécessaire à toute l'opération en chargeant en outre, l'administration, des premières et plus pressantas dépenses, et d'appliquer une politique prévoyante promotionnelle, à l'égard de l'Administration Provinciale de Grosseto, de l'Association intercommunale des Collines de l'Albegna, Organismes auxquels la plus récente législation italienne a délégué à peu près tous les pouvoirs et la jurisdiction à l'égard des biens du milieu et des iniciatives culturelles. Le troisième, mais non pas pour son importance, des buts rejoints est le suivant: l'intérêt soulevé auprès des studieux de l'Institut Central de la Restauration de Rome, le Professeur Giovanni Urbani, qui était à ce moment-là, son directeur, le Docteur Giorgio Torraca et les architectes Daniela Ferragni et Joseph Malliet, qui, dès le début, ont prêté leur précieuse collaboration à des niveaux différents, par des recherches, des relèvements, des projets et de restauration et de la récupération des bâtiments, grâce auxquels on a déjà pu, aujourd'hui, arriver à une première partielle terminaison des travaux (financée, elle aussi, par la mairie de Capalbio), en arrêtant son délabrement et en transmettant les structures au futur. "aintenant je voudrais illustrer avec plus de détails, l'itinéraire au moyen duquel on a pu obtenir ces résultats. Étant donné la disponibilité des propriétaires à faire une donation, et, du moment qu'auparavant, un autre legs avait déjà été offert à la Commune de Capalbio, (legs représenté par le considérable patrimoine libraire de la bibliothèque du Professeur Carlo "uscetta, éminent italianiste et critique littéraire), sur le conseil de la Pégion Toscanne et d'accord avec la Province Grosseto, l'Administration capalbienne devenait la promotrice de l'institution d'une Pondation ouverte à la participation d'Organismes publics et privés, dans le patrimoine duquel les legs susdits convergeraient.

Dans ce but, le 15 novembre 1981, naissait avec un acte notarié le Centre d'Etudes et de Recherches sur la Civilisation de la Marenma, un Commité promoteur de la Fondation qui le constiait, et qui, après avoir achevé tous les accomplissements des lois relatifs aux problème juridique des donations et de la participation des Pouvoirs locaux à l'organisation naissante, se transformait en Fondation d'Etudes et de Recherches sur la Marenna toscanne, avec un acte notarié du 19 Juin 1983. Le cheminement buracratique que j'ai synthétisé ci-dessus, a été en réalité, complexe et non dépourvu de difficultés cue l'on a dû vaincre l'une après l'autre. Et ceci, parce que, même en Toscanne, après le passage de maints pouvoirs de l'Etat aux administrations régionales et d'une partie de ceux-ci, des Régions aux Organismes locaux, on est en train de passer par une compréhensible phase de transition et d'adaptation, et souvent des questions d'interprétation surgissent à cause des sphères respectives d'action, ou bien encore, parce que les différentes régions n'ontpas, jusqu'à présent, réussi à résoudre leur propre législation, qui puisse remplacer l'antérieure.

Il suffit de penser au rôle des différentes surintendances, organismes ministériaux qui continuent à se conduire dans un contexte aù, comme je le disais ci-dessus, les soins des biens culturels et de l'entourage, sont délégués désormais complètement, aux régions.

En outre, chaque décision prise par les Organismes locaux, sur la délibération des Conseils respectifs, est soumise à l'Organisme de contrôle régional, le Tar, (Tribunal Administratif Régional), dont dépend le consentement pour l'exécution de ces mêmes délibérations.

Aussi, la concession de la personnalité juridique des Organismes, comme celle des Pondations autrefois accordées par un Décret Présidentiel, dépend aujourd'hui, des Organes Régionaux.

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"aintenant que le long chemin a été parcouru dans sa plus grande partie, on ne peut moins que constater, en continuant sur ce chemin, toute une sérié de précédents qui ont été créés et qui ont, d'une certaine façon, ouvert une voie, signalant les étapes obligatoires et indiquant les solutions.

Pendant les années qui vont de 1979 à1984, le Centre d'Etudés et de Recherches sur la Civilisation Maremmatique et, en second lieu, la Pondation des Etudes et Recherches sur la Maremma Toscanne, n'ont pas manqué d'obtempérer aux devoirs institutionaux, selon un statut qui repropose des buts différents dans ses intentions relatives à un programme. Permettez-moi de citer entièrement le deuxième article:

Article nº II

La Fondation a pour but:

- a) De gérer les biens immobiliers, de conduire et d'administrer et de ranger les biens afin que l'on puisse jouir des biens mobiles qui ont convergé vers le patrinoine.
- b) Pouvoir aux interventions opportunes de restauration et mettre à exécution de ce qui est nécessaire à la conservation en général de l'ensemble sidérurgique de Pescia Fiorentina, afin d'en empêcher la dégradation et d'en permettre l'usage public.
- c) Accomplir toute activité de recherche scientifique et de diffusion culturelle et éducative, pour l'étude des civilisations de la Maremma toscanne.
- d) Organiser des études et des recherches sur le territoire dans le domaine de l'archéologie industrielle.
- e) Constituer une bibliothèque dont le noyau fondamental soit représenté par la donation du patrimoine libraire effectué par le professeur Carlo Muscetta.

- f) Encourager les études et réaliser des structures muséographiques de caractèere ethnoanthropologique sur les coutumes et sur le travail de la Maremma toscanne
- g) D'accord avec les organismes dépositaires de la gestio à développer, en se servant des instruments dont on dispose, nommé précédemment, et au moyens de tout genres d'iniciatives, le développement culturel de la population de la Maremma toscanne, et diffuser la connaissance de son histoire et de ses traditions folcloristiques, littéraires et artistiques.
- h) Favoriser la divulgation de recherches, les conférences, les débats, les spectacles, l'activité de formation professionelle;
- i) Promouvoir au moyen d'initiatives appropriées, l'étude, la connaissance et la divulgation d la production de Giacomo Puccini liée à son séjour à Capalbio et dans la Maremma;
- j) Défendre les biens ambientaux de la Maremma et favoriser la diffusion d'une conscience écologique, en particulier auprès des jeunes générations.

Avec le travail de coordination et de recherche, on n'a pas négligé celui qui est lié à la promotion culturelle sur le territoire, d'accord avec les organismes locaux, et, en particulier avec l'assessorat pour l'Instruction Publique et la Culture de la Commune et la Bibliothèque Communale de Capalbio. Ceci a eu lieu grâce à des débats et des conférences, dont l'une, relative au "Ironbridge Gorge "useum", qui fut donnée par les Drs Crossley et Trinder, à l'occasion de leur visite aux implantations de fusion de la Pescia Fiorentina, en 1982. En outre, la Pondation a promu et organisé des concerts, des spectacles théatraux et musicaux, des présentations de livres, en permettant de la sorte à la population résidente, de jouir de vive voix, de moments culturels d'un niveua élevé, réservés habituellement aux seuls habitants de grands centres. En ceci, on a agi avec la conviction que la formation culturelle des petits centres citadins de la province, et , encore plus, des populations éparpillées, est aujourd'hui dépendante presque exclusivement des mass-média, étant donnée l'incomplète préparation que l'école fournie. Si cela d'un côté, semble offrir un plus ample bagage d'informations, de l'autre, à cause du manque d'essor, et de l'uniformité dûs au milieu (surtout à celui de la TV et de la presse de genre), tend à effacer le substrat autoctone, lié à la culture locale qui nous a été transmise. On est, en outre, en train de perdre le goût et le sens de l'expréssivité artistique qui dérive de la puissance directe du vif. Si aujourd'hui, dans presque toutes les maisons de la Commune l'on trouve un appareil pour reproduire de la musique, qui va du plus simple magnétophone à cassetes, à la plus sophistiquées installation de haute fidélité, très peu d'entre elles ont eu ou auront, la possibilité ou le désir (ce qui est équivalent sur le plan du développement culturel), d'entrer une seule fois au moins dans leur vie, dans une salle de concert, ou, tout au moins, dans un musée.

De 1979 à nos jours, par exemple, toute une génération d'enfants capalbienne a grandi, en fréquentant, autrefois les premières classes élémentaires, et aujourd'hui,celles supérieures, ou acheminés déjà vers un travail; toute cette géneration, qui n'aurait vu que d'exécrables cartoons japonais ou de pitoyables sérials télévisés, a pu, au contraire, acceder

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à un patrimoine riche d'expressions différentes, allant du théatre d'animation à la musique pòlýphonique, du mime à la danse classique et moderne. Je ne crois pas que nous soyons loin de la vérité en affirmant que, sans doute, ces enfants aient grandi mieux, avec des informations plus complètes et pleines de vie.

Je dis ceci pour faire comprendre combien un organisme comme la Fondation doit s'adapter aux exigences du très particulier contexte social dont il est sorti, s'il ne veut pas se transformer en un organisme culturellement actif, même à un très haut niveau, mais détaché de la vie du milieu qui l'héberge, réservé à un petit groupe d'élus, et donc en dernière analyse, insensible aux problèmes des personnes; fermé et attentif seulement à la sphère du savoir dans ses formes les plus élevées et de recherche pure. Ilen dérive un problème éthique, qui n'a pas une moindre importance, du moment que notre Fondation survit seulement au moven de l'argent public, ou surtout, jusqu'à aujourd'hui, au moyen des financements de l'administration communale, avec l'argent de la population capalbienne. Seulement à travers un travail de ce genre, même l'agriculteur venu d'es profondeurs du sud italien et le berger sarde (une grande partie des plus au moins 4000 habitants épars sur un territoire d'environ 80km sont des inmigrés), de même que le citoyen qui est né et qui a vécu à l'intérieur du centre historique entre les murs de Capalbio, pourra comprendre l'importance de conserver et d'étudier les biens culturels et du milieu de son territoire, y compris les inatallations pour fondre, de la Pescia Fiorentina, qui ont joué un rôle si important dans l'istoire du village où il habite et où il travaille. C'est uniquement de la sorte, que l'équipe universitaire, les restaurateurs, le studieux solitaire, les fonctionnaires de la Surintendance, envoyés pour notifier un lien necessaire à la préservation d'une ancienne structure, cesseront d'être observés o omme des intrus ou des velleitaires ennuyeux.

INDUSTRIAL RELICS IN THE WALBRZYCH COKERIES REGION

PIOTR GERBER*

SUMPARY

Against the historical background of Lower Silesian coke engineering /German as well as Polish/, the lecture gives the number and describes the present state of monuments of coke engineering: machines, technical fittings, buildings and industrial structures with some of them still in use.

These objects form the cultural scenery of this mining regior. A place where this heritage of industrial civilization could be maintained a preserved should be found.

The postulate for protection and maintenance of cokemaking technology is the main concern of the author.

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Over the last few years a growing interest in industrial relios can be observed. Systematic studies of all material sources concerning the history of industry are sometimes refered to as industrial archeology. This specific branch of archeology aims at describing the history of civilization in terms of its technical and industrial relios, regarding them as manifestations of human work and erdeavour, as the synthesis of cultural and environmertal effects.

The artifacts of technical civilization are virtually everywhere. Some of them are of true historical value. Many of them which will be of interest to us in this paper are still in use although as technical devices they have actually become or are becoming obsolete. Unfortunately, all too often, they escape the notice of historians and maintenance technicians. Complexes of industrial buildings which are inherently present in the landscape are sometimes considered as its most interesting elements.

Let us consider the region of Wałbrzych, where the traditions of coke-making date back as early as the 1820s. The Wałbrzych Coal Basin was among the leading mining regions in Europe. No wonder then, that, following the example of Ergland, coke-making was started. At first it was performed in charcoal kiln. This type of device was extensively used in copper and steel mills. In 1789, the first coke sinter furnances were put to use in Boguszów and charcoal kiln although beginning with the'90s of the 18th century, coke-making in the region of Lower Silesia underwent many technological changes and innovations both in the devices used and in the methods of coke-making itself. New technologies came into use, production was increased, and the quality of the final product was improved. Beehive overs were replaced with sinter furnaces, and in the first half of the 19th century the Appolttype chamber furnace was introduced, for the first time using coke-oven gas produced during coke-making, for heating. Simultaneously, the production of carbor derivatives grew.

Chamber furnaces were improved: chambers were lengthened, the number of heating flues increased, walls got thinner. Such banks of coke-ovens were commonly operated in Wałbrzych Coal Basin in the 1820s. Gustaw Hoffman greatly improved the heat balance of coke-ovens by building his regenerative furnace in Gorce, in 1882. An improved version of this furnace is still in use today, known as the Otto-Hoffman furnace.

In 1900, in the Wakbrzych region there were 948 active furnaces, 313 of which produced carbon derivatives. They yielded 540,000 tons of coke, 7,000 tons of tar, and 2,000 tons of ammonium sulfate. Afurther advancement was the Heinrch Coppers furnace which improved the heat balance and yielded more carbon derivatives.

In the Lower Silesia region, furnaces of this type were built as early as 1904 in the Bahnsohacht cokery, in 1906 in the Fuchs cokery and Glückgilf. These furnaces greatly increased the gas-yield and, thanks to this, the Wałbrzych cokeries could provide even further regions with fuel and illuminating gas. In the '20s, coke-making plants were concentrated in particular regions. As a result, four cokeries were left in Wałbrzych /still in operation today/.

The scenery of Wałbrzych is inseparable from banks of coke-ovens, cooling beds, trestle bridges and other structures connected with the production of cokes and carbons derovatives. Nights are aglow with poisonous, colourful smokes

The "Bolesław Chrobry", "Victoria", "Biały Kamień" and "Mieszko" cokeries, which are still in operation, date back in their greater part to the 1920s. Certainly, such structures of fundamental importance to the functioning of the whole plant as banks of coke-ovens, sorting plants or coal towers have not been retained in their original shape, and have been subject to many reconstructions and repairs. Every now and again, the chambers are demolished and then again reconstructed - this is required by the specific character of coke-making technology.

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Each of the existing cokeries includes some objects of historical value. The "Bolesław Chrobry" and "Victoria" are the two cokeries which have been nodernized most, and thus the objects of interst there are few. The former utilizes three batteries of ovens of pour system: two of them are the Otto type, dating from 1928 and one is the Coppers type, 1924. The most interesting complex is the condensation plant, which has been retained in close to its original form /1929/. This unit includes such original technical equipment as a steam-driven turbo-exhaust fan, electro-exhaust fans /electricity-driven/, final and pre-cooling beds of gas, benzene scrubbers, and a steam-driven impeller pump. This part of the plant should be preserved as it is, since it is the only one which is fully equipped with its original devices, and thus constitutes one inseparable whole.

Besides, in the tar-working plant of the same cokery there are electricity-driven vacuum pumps wiht belt transmission, dated from 1921 /3 pieces/. They produce subatmospheric pressure during the periodic distillation of oils and tars.

Today, this model of a pump is a curiosity and should be specially protected, together with the unique cokers for the periodic distillation of oils and tars. This technology was given up in the 1950s, when two of the five existing cokers were closed down. To this day, only three of them have remained, thus providing an illustration of the development of the production of coke and carbon derivatives. That they should be protected is beyond question. The cokers in question skirt the premises of the plant and would be easy to separate from the rest of the factory in order to expose them properly.

Structures such as the coal house, sorting plart, and ammonium sulfate plant, combine to make up the characteristic shape of the whole plant. The agressive forms of these objects stand out against the clearly nistorical administrative buildings: the head office building in the style of a villa or palace, with a turret and frame wooden construction or the laboratory buildings, classic in form and architectural details.

The "Victoria" cokery has five Otto batteries of ovens. The first and the second date from 1928, the third from 1962 the fourth from 1954 and the fifth from 1959. The plant has many times been modernized, particularly its batteries. Most of the original devices have been replaced, and new ones installed. A modern ammonium sulfate plant was built. The historical industrial architecture of the production buildings is well illustrated by the "Wojciech" shaft or electrical work-shop building and woodworking shop from 1904. As regards architectonic decorations, the coke-making plant buildings are much simpler.

A very interesting object is the benzene scrubbers unit dating from 1921, which in its form resembles a fortified tower. Among the production buildings, the repair shop stands out with its large windows rimmed in steel frames of soft, secessional lines.

The "Biały Kamień" cokery was built in 1906. In the same year. two batteries with 60 chambers each were built. In 1929, two more batteries of Copper system were added. Those batteries built in 1906 were replaced with new ones in 1936/37. At present four batteries of vamming system are in use. In the years from 1950 to 1970 they were successively re-built in keeping with their original form. A unique feature of these four batteries is that both the sealing of the chamber doors and the damping of coke are still manual operations. These historical rarely met technological processes must be documented in the form of pictures, desoriptions or best. in a film. Among the antique machinery preserved to this day in close-to-original form, attention should be drawn to the charging larries from 1916 and 1920, where repair work was limited only to restoring their original structure and, if needed, replacing worn out units. The waterless gasholder of 20 000 m² capacity is very interesting.

The "Biały Kamień" cokery lies in between two hills and can be well seen from many points of the surrounding town. Its profile, made up of production buildings of squat heavy lines is a lasting element introduced into the town scenery.

The industrial objects of this cokery can be divided into two groups. The first group includes those production buildings which date from the 1920s, and which in respect to architectural details are rather simple, with their original form and large dimensions they create the overall scenery of the coke-making plant.

The characteristic element that immediately strikes a visitor and allows him to recognize the plant is the squat trestle bridged coal tower with an arched roof. The second group is made up of production buildings of historical, architectural outfit which date back to the beginnings of the plant.

Among the most interesting buildings here are: the condensation house, gas compressor, bath, and laboratory. All of them were built in keeping with traditional technology. Facades are sectioned with pilasters and extended cornices. and in between the pilasters, steel-rimmed windows are mounted. The most decorative elements of the facade are triangle-shaped, richly ornamented tops. These buildings should be put under legal protection. Most of the buildings are still in operation. Some of them, however, e.g., the former gas compressor, are not intended for further exploitation and therefore are threaten-ed with demolition. At the premises of the "Biały Kamień" cokery as well as in other coke-making plants, there are many buildings whose origin can be traced back to the times when the whole plant was constructed. Modernizations and repairs that they went through changed their appearance and, in most cases, made them look ugly.

The fourth and the smallest cokery, "Mieszko", built in 1905, has four batteries dating from the 1920s /two Copper and two Otto system/. The batteries were renovated in the
'30 s and '50s, and the architects tried to preserve their original form. The batteries are situated at the slope of a hill ard together with the accompanying structures clearly stand out from the town scenery.

They provide a very good illustration of the development and the state of the Lower Silesian coke-making industry - flat and slanting ramps are used and both manual and mechanical damping of coke are executed. Besides the batteries there are also such unique devices as gas exhaust fan /1920/, benzene scrubbers /1920/, ammonis water desorber /1925/, pre-cooling and final beds /1940/. A very interesting detail is the switchboard with controle for gas pressure in scrubbers which dates to before World War 1. Most of the old buildings in the cokery have been demolished or re-built. Among the remaining buildings attention should be drawr to the laboratory building with the shield placed at the top of its front wall and the condensation house. Also, the mass of the coal tower is very impressive. Another interesting architectural element is the water holder in the form of a flattered funnel made of riveted steel sheets and mounted on top of a hill. The cokery has also two apartment buildings not far from the premises and several singlefamily houses at the nearby housing estate "Szczęść Boże", formely belonging to the "Mieszko" coal mine.

The protection of artifacts of technical civilization is not limited only to individual buildings or devices but first of all to the protection of complete old technologies. Here, we are not concerned with typical industrial buildings like production halls, boiler houses or administrative buildings but rather with individual objects linked by technological installations. The necessity to keep the plant moving greatly complicates the problem of protection.

All too often, protection in situ is impossible or too expensive. The only possibility we are left with is to move the whole object in question to a new place, an operation which in practice destroys the true character and meaning of the object. For cokery production plants, such an operation

is practically impossible. Very often the only answer is to carry out a comprehensive documentation of the object. This applies not only to the batteries of ovens but also to a complete system of installations, and production buildings such as coal towers, sorting plants, coke-quenching towers. etc. Out of all Wałbrzych cokeries which are still operated it is the "Mieszko" cokery which will be the first to take a decision about the artifacts of technical civilization located on its premises. They are seriously devastated and mining works carried out in this region add to the waste. The "Mieszko" cokery is outstanding for its number of historical objects, its batteries with accompanying devices /loading machinery, quenching cars, unloading ramps/, large production buildings /condensation house, laboratory/, and, last but not least, still existing and operating archaic production process - all these should be carefully preserved. The artifacts on the premises of the "Mieszko" cokery do not only testify to a certain stage in the development of cokemaking technology but they also have become one with the Wałbrzych scenery and cannot be separated from it. The optimum solution would be to establish a sort of Skansen museum including all closed down departments of the plant. Room would also be provided for phased out objects coming from other plants.

In the case of the Wałbrzych cokeries, it is extremely difficult to say which individual objects should be taken out of service. It is not only particular buildings, machines or devices that are of historical value but rather whole, complete technologies. These technologies should be documented in the form of graphs, descriptions, photos or, best, in films. This work should be assigned to the present user of the factory. The collected material can be utilized as teaching materials for educating the workers of the plant. Therefore, I suggest:

- to document presently operated in Wałbrzych technologies of the production of coke and carbon derivatives in the form of descriptions, drawings, photos and films both educational and historical in character,
- to list all artifacts of technological civilization and in particular of the coke oven batteries,
- to carry out studies of the landscape of the Wałbrzych cokeries in order to list all elements that go to make the industrial scenery of the town and to choose those which should be preserved in situ if the present industrial scenery of the town is to be left untouched.

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1. General view of "Boles Zaw Chrobry" cokery.



2. "Mieszko" cokery - view of the department of carbon derivatives.



 "Bialy Kamień" cokery - view of batteries, sorting machine and waterless gasholder.



 "Bialy Kamień" cokery - view of battery with flat and slanting ramps.



5. "Bialy Kamień" cokery - view of battery with flat ramps.



 "Boles% aw Chrobry" cokery - view of cokers for the periodic distillation of oils and tars.



 "Bolesław Chrobry" cokery - view of electricity-driven vacuum pumps with belt transmission, dated from 1921.



8. "Victoria" cokery - the repair shop dated from 1912.



9. "Bialy Kamień" cokery - the gas compressor building.



10. "Mieszko" cokery - view of final and pre-cooling beds of gas.



CASTING ABOUT AND FORGING AHEAD: THE PRESERVATION AND RESTOR-ATION OF HISTORIC IRON-WORKING SITES IN THE UNITED STATES

ROBERT M. VOGEL

SUMMARY

Although the ferrous metals are the basis for the Industrial Revolution and all industrial activity that followed, historic preservation of iron-working sites and structures lags behind that of other cultural remains. A number of sites survive in the U.S., from minor to outstandingly important to iron and steel history. Blast furnaces predominate. The earliest represented is the 1647 Saugus Iron Works, actually a 1950s reconstruction based on excavated artifacts and Diderot's engravings. Pennsylvania's Cornwall Furnace is the most nearly intact from the 19th century, preserved with all its appurtenances, while the Sloss Furnace in Alabama, recently opened to the public, is the only 20th-century site formally preserved. As the cost of similar ventures may well be prohibitive, historians of iron and steel should begin assiduously to gather the paper records of the industry.

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THE BACKGROUND

Consider that if there is a single basis for the Industrial Revolution and all that it gave rise to, it is not the steam engine, as some historians assert, nor the systematized mining of coal, nor the development of the factory system, nor mass production, nor railroads, nor the various other phenomena that variously are put forward. It is, I maintain, quite simply, the ferrous metals. Without a ready supply of cast and wrought iron, there would have been none of the above. Even steel played a vital role in the industrialization of our culture well before the heroic age of Cort and Bessemer, in the low-volume but highly critical form of the edge tools and springs necessary to the fabrication, extraction, growing, and transport of literally all things that mankind uses and produces, from crops to buildings.

How ironic, then, that of the profusion of industrial remains that we examine, preserve, restore, and revere, fewer appear to relate to the production of iron than to nearly any other category. The reasons are obvious. Other than the single--but important--category of stone-built blast furnaces, these objects and structures were highly temporal. That is the physical reason. Superimposed on that are a myriad of cultural reasons. Blast furnaces, forges, iron mines, rolling mills, and later, steel works, invariably are large, and they tend to occupy vast tracts of valuable real estate in regions rarely attractive in the traditional scenic sense. So unlike canals, say, ironworking sites do not easily inspire their own preservation constituency. Furthermore, they cannot readily or practically be put back into any sort of operation to attract the public as in the case of operating railroads or certain factories, for example, further lessening their appeal to preservation groups. While--again--the stone blast furnace may constitute a picturesque element in the landscape, the same cannot be said for many other members of the family of ironworking structures, an even further impediment to their preservation. Covered timber bridges, for instance, are quaint looking, they scenically enhance their environment, they can be made practical use of, and in general they are easy to love. So are old grist mills, wind mills, canals, and even many factory buildings. But not old by-product coke ovens or rolling mills sheathed in rusting corrugated sheet iron.

The inevitable consequence of all this is that in the United States there is a dearth of surviving ironworking structures that could be construed to be historic, formally preserved on the basis of their historicity. The same is essentially true of the rest of the world, for the same reasons.

But there <u>are</u> some, of greater and lesser importance, covering most aspects of ferrous-metal production. These fall into two categories. First are those that survive by simple default or abandonment, remaining with us because they are both physically durable and the land they occupy is not in demand for some more rewarding purpose. It should be observed that historically, these sites and structures are not necessarily the least important of the survivors. Then there are those that survive because their significance has been recognized by a historical body or, rarely, by a firm willing to create and maintain a formal monument. Here, too, we find a range of historical significance, from the minor to the most important historic ironworking sites in the United States. I propose to describe a selection of sites representative of both groups, more or less in process order, from the ore banks to the coke ovens.

IRON MINES

Of the various elements in the process of producing the ferrous metals, the preservation of the mines and pits from which the ore itself is taken is the most problematical. So far as I know there is not a single formally preserved iron mine, which is hardly surprising in view of their very nature-essentially amorphous holes in the ground. This is all the more so in the case of the bog iron mined up to the middle of the 19th century. How to preserve a bog? . . . and, if in a particularly cynical frame of mind, we might ask, "why?" It is not that the process of ore extraction is not one of profound importance or even that it is uninteresting--it is merely that it is difficult to get hold of the story on the basis of its archeology. There are, of course, remains of mines in every part of America where iron was dug, but nothing that could be regarded as a formal "monument" to the winning of ore.

There are, however, a few recognizable sites that can be viewed as sufficiently important to be worth mentioning. The principal of these was, interestingly, until only ten years ago perhaps the oldest continuously worked iron mine in the Western Hemisphere. This is the Cornwall open-pit



Cornwall mine, largest open-pit mine in the eastern U.S., worked from 1742 until 1972 when nearly simultaneously the high-grade ore was almost worked out and the (later) underground section was flooded by tropical storm Agnes.

mine, first exploited in 1742 (with underground workings from 1921). The mine was worked--latterly by the Bethlehem Steel Corp.--until June, 1972. Bethlehem shut it down at that time since the high-grade ore had nearly been

exhausted and the underground shafts had been inundated by the torrential rains accompanying tropical storm Agnes. The mine also was--and remains--the largest open-pit mine east of the Mississippi, being some 3150 feet long by 1200 feet wide by 440 feet deep (960 x 366 x 135 m).

Apart from mine preservation, there are a few instances of deliberate historical attention to the ore itself. At least two furnace sites exhibit samples of bog ore. The first is Batsto in southern New Jersey, which was worked from 1766 to 1848. Batsto is billed as a historic, preserved, iron village but in fact the only remnant of this is the excavated portion of a "Durham" boat used to transport bog iron from the ore banks to the furnace, and a pile of the ore itself. This does at least provide the visitor with a glimpse of bog ore, which I suspect is believed by many--including many industrial archeologists--to be more mud-like than rock-like. The other site is the celebrated Saugus Iron Works near Boston (about which more later) where, too, are shown samples of the bog ore that was smelted there as early as the mid-17th century. Finally, the 20th-century Sloss Furnace site in Alabama will, when fully organized, devote full attention to the question of its former ore sources.

In the celebrated Missabe Iron Range of northern Minnesota there has been some effort at historical recognition of the great open pit mines, worked from 1893 until the present nearly total cessation of operations, but it cannot be said that any of the pits are in any sense "preserved". Like Cornwall, when abandoned they simply remain. On the other hand, there is little danger from the depredations of developers or vandals, so in that sense these huge voids are far safer than the most scrupulously preserved "built" historic site. One of these pits is, incidently, the great Hull-Rust mine, opened in 1893, and the largest open-pit mine, in the world: 3 miles by up to one mile in extent and 535 feet deep (4.8km x 1.6km x 164 meters). It has, in fact, been declared a National Historic Landmark.

THE MINOR BLAST FURNACES

It is the blast furnace--the very heart and soul of all ferrous metallurgy--that has received by far the greatest share of historians' and preservationists' attention. More blast furnaces survive than all other types of iron- and steel-working artifacts put together, probably by a ratio of ten or more to one. Aside from the symbolic importance of the furnace, this certainly is due to the fact that until sometime in the 1870s nearly all furnaces, in the U.S. as in the rest of the world, were built of masonry, the most durable of nature's or man's battery of building materials. Abandoned furnace stacks, if the land they occupy is not otherwise needed or their very stone has not been "quarried", endure. The only natural enemy of these nearly solid masses of stone or brick is the insidious expansive action of frost and vegetation. There probably are well over 200 lone furnace stacks surviving in the U.S. of the estimated 1000 built between 1622 and 1895. The majority are in Pennsylvania with appreciable numbers in Maryland, Ohio, and New York; and the odd stack in nearly every other state east of the Mississippi. Few exist in the American West as what little iron smelting was done there came well after the period of the masonry furnace.

As it is such an easy thing to do, many of these bare stacks have been



Nassawango Furnace showing hot-blast stove (above), and Scranton Furnace



"preserved," the preservation act frequently consisting of little more than cutting the grass, pointing up the stonework, and erecting a historical marker. The blood quickens hardly at all in the presence of these monuments, for only in rare cases is there anything to be seen but the stone heap itself, in total isolation from any other element of the ironmaking process, and thus there is little to be learned from it. Still, some of these are of interest, and I will mention a few as examples.

The Clove or Greenwood No. 2 Furnace at Arden, New York, in operation between 1853 and 1885, is a large anthracite furnace presently under restoration by the Orange County Historical Society, who expect also to rebuild a number of the ancillary structures.

Nassawango Furnace near Snow Hill on Maryland's Eastern Shore was built in 1830 to smelt bog iron, going out of blast in 1852. It is said to be the first American furnace to employ the hot blast, and in view of the surviving air heater on the stack and the early date of abandonment, that is entirely possible. The survival of the stove is remarkable and fortuitous. The site is owned and being developed by a local historical society.

The state-owned Katahdin Furnace site in Maine must be the remotest in the U.S., well inland and near nothing at all. Its principal point of interest is a preserved charcoal kiln, one of a battery.

The Scranton Furnace in Scranton, Pennsylvania (cal855) seems to be the only remaining ganged furnace and certainly is about the largest stone stack to survive, if not ever to have been built. It is instructive on that basis alone.

One of the most interesting preserved stacks is notable not of itself, for it is routine, but for association with a recent event. The Tannehill Furnace--first in the Birmingham, Alabama iron region deep in the American South--was built in 1855, figured importantly in the Civil War, and ultimately was shut down by the Union Army toward the war's end about 1864. It now is part of a state park. In the fall of 1976 it was ceremonially and experimentally reblown. The widely publicized event was under the supervision of a professor of metallurgy at the state university. It was a mixed success for despite bringing to bear a fair degree of modern technology, mainly in the form of liberally applied oxygen lances to help matters along, there never seemed to be quite enough heat, and what iron finally did emerge was not fluid enough to run into the prepared molds. The affair was not repeated as initially intended, and some write it off as a total failure -the result of "lost arts". That may be, but more likely was an incompatible combination of ores, fuels, blast-air supply, furnace dimensions, and perhaps other factors that did have to do with the "art" of 19th-century blastfurnace management.

BLAST ENGINES

As noted, frequently it is the sites <u>not</u> formally preserved or protected that contain the most important artifacts of this industry. I will mention three that have in common the fact that they contain the only known examples of 19th-century blast-furnace blowing engines of iron construction.



(above) The 1976 re-blowing of Tannehill Furnace, an event of mixed success. (below) Double-cylinder blast engine (1836?) at Principio Furnace, Maryland.



Remains of the water-powered four-tub blowing engine at Tahawus Furnace, NY.

The Principio Furnace in northeastern Maryland was a conventional charcoal furnace of the late 18th century. In 1836 it underwent a major rebuilding at which time, it is supposed, the iron double blast engine was installed (although it might have been later--but not much), driven by a water wheel. It, the water turbine that replaced the wheel, and an apparently unique hotblast stove adjacent to the furnace all remain, in fair condition although exposed to the weather and badly in need of protection. A somewhat similar horizontal machine, of four cylinders, remains unprotected at Tahawus Furnace in the Adirondack Mountains of northern New York State. Tahawus was active between about 1830 and 1855 but never very successfully because of its remoteness and ore problems. The present furnace and this machine were built in 1854, and were in use for a year only. The machine is, unfortunately, less complete than that at Principio.

The final, and in many ways most interesting of these machines stands starkly on a secondary road in southern Pennsylvania in the mini-hamlet of Metal, Franklin County. This was the Carrick Furnace, dates unknown. The conventional stack survives, and what surely is the earliest American steam-powered blast engine extant. It is signed and dated, having been built in 1879 by Weimer Bros. of Lebanon, Pennsylvania. While badly weathered, it is intact, as is its pair of furnace-gas boilers just behind. The site is said to be owned by a local historical society but inquiries over the years have turned up nothing concerning preservation plans, and it is extremely unlikely that any exist. This machine--as well as the other two mentioned---has raised a critical preservation issue that it would not be out of place to touch on briefly here: what ideally should be done? If left in place its eventual total loss from exposure is certain, for unless the state should acquire the site and at least roof it nothing is going to be done toward preservation in situ. (And there is little hope of the state doing anything of the kind.) If some historical body should acquire the engine itself and remove it elsewhere for protection and possible restoration, the important relationship between it and the site is lost, to the detriment of both. This is a not uncommon preservation dilemma.

SAUGUS IRON WORKS

This brings us to the four leading examples of what I will call the serious preservation of the American iron industry's archeology, although only two of these could be regarded as true preservation. What I mean by "serious" is that in only these few cases does there exist anything like a whole plant site, with both its major and its minor elements, capable of furnishing a reasonably complete historical view of the processes involved.

The first of these is important from a number of standpoints. The Saugus Iron Works, just north of Boston, is regarded as the first in the American colonies to have achieved commercial success, commencing operations as early as 1647 (going out of blast in 1675). It was an "integrated" ironworks, not merely a furnace, incorporating a bloomery where the pig was worked into wrought iron, and a rolling and slitting mill where iron plate and nail rod were produced. In the nearly 300 years following its demise the site's structures succumbed to cannibalism, weather, and topographic changes in the wake of suburban development. By the early 1950s nothing at all remained above ground. At that time the American Iron & Steel Institute--the industry's trade association--at a flush time in the history of both,



(above) Carrick Furnace steam-powered blast engine (1879), a unique survivor of the type and period. (below) Saugus Iron Works bloomery, showing water wheels for driving forge hammer (left) and bloomery-fire bellows (right). Beyond is the rolling and slitting mill.



Saugus Iron Works: bloomery tilt hammer with samples of wrought-iron bars.

undertook to sponsor a complete reconstruction of the works. It was a highly ambitious project, unique in historical annals. But while conducted with the very best of motives it has given rise to considerable controversy, especially in recent years.

Its basis was extensive underground archeology, which revealed the foundations of the major structures plus a large quantity of artifacts (ASME, 1975). All this was insufficient, however, to support any sort of meaningful reconstruction, and the project historians fell back on the illustrations in Diderot's encyclopedia as their principal guide. The result is an ancient ironworks, to be sure, and, as surely, one typical of mid-18thcentury France. But is it one typical of mid-17th-century New England; that is to say--England? That is what troubles everyone, for the records that would describe the practice of that time and place remain obscure.

Meanwhile the site exists, all in operable if not operating order, and the controversy swirls. The National Park Service now owns and manages the site and while NPS historians are well aware of the problems of chronological and geographical appropriateness, and from time to time make an effort to resolve them, the resolution is bound to result in a serious conflict: if it's all wrong, what to do about it? Leaving it would mean accepting and



Saugus Iron Works: rolling mill (right) and slitting mill (left) with part of the train of wooden gearing for driving the top and bottom rolls in unison.

giving governmental credence to a rather major historiographical error; while its correction would mean near if not total demolition of what must be acknowledged is an interesting group of structures and equipment, whatever it represents. One can hardly blame the Park Service for its hesitation to confront the issue.

HOPEWELL FURNACE

Somewhere between reconstruction and preservation lies the Hopewell Furnace site in southeastern Pennsylvania near Birdsboro. Hopewell had been a typical Pennsylvania iron "plantation"--a self-contained community organized in 1771 to produce pig iron and cast-iron products. All members lived on or near the site, from the ironmaster himself through the furnacemen, teamsters, colliers, miners, and laborers, down to the woodcutters, and including, of course, women and children as well. Hopewell survived booms and busts until the final blast in 1883, decades after it should have folded in the face of competition from the large centralized iron centers. The village fell into gradual but far from total decay. In 1930 the Franklin Institute purchased the blowing tubs, intending to transfer them to its new museum in Philadelphia. This didn't materialize, and in the mid-'30s the federal government bought 4,000 acres (1,620 hectares) of the site for a Civilian Conservation Corps camp and public parkland (NPS, 1983).

At this time a National Park Service historian surveying the site became impressed by its historical integrity and in due course the Park Service undertook restoration. The decision was made to restore everything to the period of the furnace's greatest prosperity, about 1820-40, when it absolutely typified an important stage in the evolution of the American iron industry. Work was disrupted by World War II but picked up immediately afterward, with 848 acres (344 hectares) dedicated to the Hopewell Village National Historic Site. The immediate machinery of the furnace was entirely rebuilt -principally the blowing tubs--as well as the various dam and raceways. Extensive historical research and archeology were carried out, and every effort made to create an accurate reconstruction-restoration. The site today is of extreme significance as the only one in the U.S. -- North America, for that matter -- reflecting the early 19th-century iron plantation to nearly its complete extent, from the furnace proper and the other components involved directly in iron production, to the ancillary elements such as those for supplying the charcoal, on down to the adjunct structures needed for the support of life.

CORNWALL FURNACE

If Saugus and Hopewell are full or near reconstructions, what then survives in the U.S. that can be construed as real preservation? Apart from the array of isolated furnace stacks and blowing engines previously mentioned, there are two sites of transcendent significance, noteworthy as a consequence of their being true survivals from important periods in American ironworking. These are the Cornwall and Sloss furnace sites.

Cornwall, in Lebanon County, southeastern Pennsylvania, also was organized as a self-sufficient iron plantation, in 1742, three decades before Hopewell. Its basis was the rich Cornwall iron bank referred to earlier. The furnace's history was conventional--supplying pig and cast wares, and, of course, cannon and shot during the American Revolution.

In 1856 a nearly complete rebuilding occurred, with the furnace enlarged, wood blowing tubs replacing the traditional leather bellows, and a horizontal steam engine replacing the waterwheel that drove the bellows. There were fairly extensive alterations to the various buildings on the site as well, which were rendered in a tasty rural Gothic style. There was little significant change from then until the last blow, in 1883. Thereafter Cornwall's history is atypical. The Coleman family that owned the site was well-off and not only had no financial need to liquidate land and structures (except for the mine), they had the sentimental incentive to maintain roofs and grounds, and the normal decay did not set in. This remained the state of affairs for half a century, until 1932, when the Colemans deeded the property to the Commonwealth (State) of Pennsylvania which with considerable



Cornwall Furnace. (above) The furnace with storage and charging building at left and casting house at right. At the top of the stack are the furnace-gas boilers that supplied the steam engine driving the blowing tubs. (below) The casting arch and pig bed, with interpretive figures and molding flasks.



historical wisdom--then certainly a rarity--accepted it and continued maintenance (Grandia, 1983).

With the exception of a mere handful of similar preservations in Sweden and Germany--and possibly a few in Eastern Europe--I doubt that elsewhere in the world there is a 19th-century iron furnace complex with the degree of historical integrity to be found at Cornwall, where it has been estimated that fully 95% of the fabric is original. Here we see a blast furnace of the period with its immediate ancillaries, all there to be examined, studied, and interpreted, with nothing having to be based on research, speculation, or inference. The Commonwealth has done a splendid job of interpreting the site by means of a museum and visitors' center established in the charcoal storage shed.

The Miners' Village nearby is a picturesque and rare survival as well, commonly compared to a Welsh village although there is no history of the iron miners being particularly Welsh, or Cornish for that matter.



Cornwall miners' village. Houses all are double, the later units of brick.

SLOSS FURNACES

The Sloss Furnace (or, properly, Furnaces) may well be seen as the most important historic ironworking site in the world today, not because it is inherently unique but because it is unique as a preservation project--so far. The twin furnaces, blown in in 1882, were major producers of merchant pig iron in the Birmingham, Alabama region, largest in the South. Between 1927 and 1931 the furnaces and most of their adjuncts were replaced, although blowing engines and several buildings of the late 19th and early 20th cen-

turies do survive. In 1970 operations ceased under increasingly stringent air pollution regulations. The story to that point is conventional, and it might have been anticipated that in short order the tons of steel on the site would have been reduced to scrap and sold by the ton. It is not clear who the initial preservation hero was, but someone had the notion--bordering at that time on the outlandish--of preserving the furnaces as symbolic of the city's industrial might. The owners were persuaded to donate the site to the state fair authority as the venue for a museum of Alabama industry. The fair authority, quickly developing cold feet, proposed demolishing at least the furnaces themselves and their immediate auxiliaries. Again nonorthodox views prevailed. In a region where theretofore historic preservation rarely went much beyond the defense of pre-Civil War cotton planters' houses, there arose a public outcry that resulted in formation of the Sloss Furnace Association, a citizens' group dedicated to the site's preservation. By 1976 their efforts had the happy effect of having the property deeded to the city and designated a National Historic Landmark, the first 20th-century and nonstone blast furnace to be so named. The astonishing saga continued to unfold. Also in 1976, the National Park Service's Historic American Engineering Record conducted a full-scale recording project at Sloss, producing measured drawings, photographs, and a thorough historical report. Each of these milestones in the site's recent history seemed to inspire the next as there grew both a local and national comprehension that the site represented a major element in the evolution of American industry, significant on the basis of its very typicality, and whose chances for preservation as an instructive symbol were as favorable probably nowhere else in the nation.

The recognition of this by various national historians undoubtedly bolstered local awareness. This resulted, under the advocacy of an enlightened mayor and city council, in the city's residents voting a \$3,000,000 bond issue in 1977 in support of the site's development as an industrial museum and public facility.

At that point the project came perilously close to total collapse in the form of a scheme that was put forward as its deliverance. A promoterfilmmaker was hired by the city to prepare a comprehensive development plan. His Disneylandish proposal proved so ambitious--and in the minds of many councilmen and citizens so overwhelming, so outrageous, and so wildly inappropriate--that matters approached a breakdown. What inevitably and mercifully scuttled the proposal was its estimated cost of \$77,000,000.

There was retrenchment and rethinking, with local architect Jim Waters taking the initiative in a scaled-down, fully rational scheme that in due course did see the light of day. With constant urging along by a dedicated cadre of adherents, the project has advanced to the extent that a full-time director and staff of five have been appointed, the array of massive equipment has been stabilized and painted, and the site has been landscaped and made accessible to the public. On Labor Day Weekend of 1983, just over a year ago, Sloss formally was opened. The furnaces and the process of pigiron production are the central themes, while a variety of regular and special events and exhibitions ensure that public enthusiasm and visitation remain at a high level.

The purists among us may recoil at a perceived dilution of the site's historical-industrial message by the vivid colors applied to some of the steelwork and such radical alterations to original function as conversion



Sloss Furnaces, 1983: rehabilitated, interpreted, and opened to the public.

of the casting shed to an amphitheater where are heard the likes of the Alabama Symphony. But it must be realized that the costs involved in preservation of a site of this scale and complexity are an order of magnitude greater than those incurred at sites like Hopewell or Cornwall. Sloss (and any other 20th-century furnace sites that it is contemplated preserving) succeeded, and can survive, only with the support of ancillary public activities, which inevitably will involve a certain degree of compromise to the site's integrity.

STEEL

There is more to iron and steel making than the blast furnace, of course, but the preservation of sites and structures representing the subsequent processes of converting pig iron to wrought iron and steel has been a campaign of less than rousing success in the United States.

There is nothing more symbolic of the age of steel than the Bessemer



The last Bessemer converter to work in the Pittsburgh area (making wrought iron!) and probably the last in the U.S. Preserved at Artifact Square, Pittsburgh. A replica "bottom" now has been fitted to replace that missing here.

converter, and fittingly one has been preserved, also fittingly, in Pittsburgh. It stands beside a converted railroad station with a collection of other antiquarian industrial and railroad objects in something called Artifact Square. It was the converter last in use in the Pittsburgh area and without much doubt was the last in service in America, operating until about 1970. Ironically, it was employed <u>not</u> in making steel, but in the socalled Aston process for producing wrought iron, used in corrosion-resistant water pipe.

A related survivor is the Kelly converter, one of the few artifacts of the American ferrous-metals industry preserved in a museum. In the late



Wm. Kelly's converter (cal862), at the National Museum of American History.

1840s William Kelly invented a process similar to Bessemer's, and after long experimentation had a few converters built--this one probably in 1862. It remains uncertain whether Kelly actually made steel, and if so, whether earlier than Bessemer, but regardless, this one testament to his efforts occupies a significant place in the National Museum of American History.

Although a significant amount of American steel now is produced in electric furnaces, only one early example has been formally preserved. It was built in France in 1906 and installed at a specialty steels firm in Syracuse, New York where it was placed on outdoor exhibit and designated a historic landmark by the American Society for Metals in 1973.

COKE

Here and there are other miscellaneous fragments of the industry that have survived by default, but I have described the principal ones. There is one group of secondary monuments of the iron industry that still is with us but which rapidly is disappearing in the absence of any formal program of preservation. Once it became evident that iron no longer could be smelted on a large scale with charcoal--for the same reasons of forest depletion that prevailed almost a century earlier in England--the production of metallurgical coke by the beehive process mushroomed. Thousands of beehive ovens fouled the landscape -- mainly in West Virginia and Pennsylvania -- making the atmosphere noxious with their fumes. The process survived, amazingly, until about 1980 when the last bank of these, in Alverton, Pennsylvania, southeast of Pittsburgh, was shut down, ending an era. Many abandoned ovens exist but their life expectancy is short in the face of frost action and the other incursions of natural decay. Most have been razed to reduce taxes and liability. There is a unique survival, however, in southeastern Ohio near the town of McArthur. In the late 1870s the managers of the Vinton Furnace, in an effort to coke the local coal, installed a battery of so-called Belgian coke ovens, these being a cross between the beehive and the later by-product oven. In these the coking took place in narrow rectangular cells open at each end for removing the coke by "pushing." The coal turned out to be too sulfurous for ironmaking, but the ovens were turned to ore roasting, and due to their innate stoutness and the site's remoteness they have survived, apparently unique in the U.S.

THE NON-PRESERVATION PICTURE

While much has been saved formally, and a bit more exists by simple abandonment, the whole evolutionary picture of iron and steel making in the United States never can be fully told on the basis of the industrial archeology for vital elements already have been lost beyond recall. There is not, for instance, a single surviving example of the first generation of metaljacketed, cylindrical, high-capacity blast furnaces of the 1870-90 period, which spelled the end of the small, isolated, rural stone furnace and the dawn of the centralized iron industry. We have seen that the preservation of the odd Bessemer converter is feasible. But even there it must be recognized that the converter is little more than a symbol of the process--a vital symbol to be sure--but far from an artifact that can, by itself, reveal much about Bessemer steelmaking. Missing are the blowing machinery, charging



What has not been saved and what probably cannot be saved. (above) Carnegie's Lucy Furnace, Pittsburgh (cal875), a typical iron-clad blast furnace of the generation following the stone-built furnace, not one of which survives. (below) Bethlehem Steel Corp's. Sparroes Point works near Baltimore, typical of the modern plant that has grown so large, and whose equipment is so massive, that the likelihood of preservation has just about vanished.



machinery, the ladles, tramcars, cranes, manipulators, and all the other organs of the Bessemer plant, each one as vital to its operation as the converter itself.

Symbolizing the Bessemer plant there is, at least, this separable, preservable entity that can stand for the whole. What of the open-hearth process that succeeded the Bessemer, and was as colossal a step beyond it in terms of capacity as the Bessemer had been over the crucible process? Here, too, the plant consisted of (for the open hearth, at least in the U.S., is dead--the more reason for concern over the preservation of its remains) a great array of ancillary organs, all vital. But the open-hearth furnace is not so neatly distinct an element as the Bessemer converter. In fact, in an open-hearth plant it isn't easy to say where the furnace itself begins and ends--it blends into the supporting iron and brick work and is interlaced with a ganglia of air ducts, regenerative stoves, and other secondary equipage. It is, in short, very solidly built in, and cannot readily be broken away from its surroundings (McGannon, 1964).

During the final years of American open-hearth steelmaking, in the late 1970s, as the number of furnaces was dwindling, there was considerable talk within both the steel and industrial preservation communities of the need to save at least one example of this vitally important industrial artifact. But unlike the Bessemer, there simply was no way neatly to unplug an open-hearth furnace and drop it into an appropriate preservation setting. This assumes, of course, the unlikelihood of an entire plant being preserved in situ.

The plant of wrought-iron making has disappeared in the U.S. almost without a tangible trace. Discounting Saugus there is not a single equivalent of the several 18th- and 19th-century hammer bloomeries intact in Germany and Sweden. There is no puddling furnace, although what must have been the last in the country was in production as recently as 1949. One large Nasmyth steam hammer of about 1855 and a single roll stand of the same period exist at the National Museum of American History, and that is about as close as we come to the survival of American wrought-iron production equipment.

It is not difficult to predict the ultimate total loss of the present day's iron- and steel-making plant, even as far back as the generation of furnaces and related equipment that immediately followed Sloss. These things simply have grown too colossally large for historic preservation schemes. Beside that, their inherent value as scrap metal and real estate is too great to permit their donation to or purchase by the typical preservation group. Sloss probably ought to be viewed as a happy but unique fluke, not likely to be duplicated. Not to belabor the point, consider, if you will, the scale of modern steel mills as a whole, or even of their components: massive rolling mills; blast furnaces towering twenty stories high; coke plants of endless length; blowing-engine plants a city block long; and all else in proportion. It is possible--probable--that we have come nearly to the end of the preservation road in this particular industry, and would be well advised to turn our attention more consciously to the systematic preservation of those of its paper and photographic records that still exist.

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11.5

THE ARCHITECTURE OF IRON IN FLORENCE AND EUROPE

FRANCO BORSI *

SUMMARY

The essay, which in particular gives a few examples on Tuscany, intends to propose as a research hypothesis the reconstruction of cultural matrices of the architecture of iron, which are obviously English and French, and how they are recognized, assimilated and diffused in Italy.

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When themes of industrial archaeology are being faced in the Italian area, warnings must be advanced constantly. Italy, it is well-known, did not experience the industrial revolution; indeed, at the period in which "a wave of mechanisms broke" over England, Italy didn't even exist, except in the Metternichian form of a "geographical expression", and instead there existed as many cultural worlds as there were States making up pre-unification Italy, each with its own precise identity with an extraordinary cultural level. It may be said that basically the very Italy that was politically divided, was unified from the point of view of culture, and in particular artistic and architectural culture, through the common references to the neoclassical world and the European matrices. This paper, which in particular gives a few examples on Tuscany, intends to propose as a research hypothesis the reconstruction of the cultural matrices of the architecture of iron, which are obviously English and French, and how they are recognized, assimilated, and diffused in Italy. This would require, or will require, an analysis of very precise contexts well beyond the schematic reconstructions, the optimistic syntheses of the historiography of modern architecture totally inspired from the usual point of view of the "pioneers", for which the architecture of iron has meaning and value only because it prepares the architecture of the Modern Movement. In reality, a common element that emerges in the milieux of the Italian "province" and is not only characteristic of the technical and artistic culture, is the extraordinary level of information, of being à la page, the capacity for knowledge, the curiosity that dominates the Italian environment and offers not irrelevant evidence of belonging to the European level. Then, immediately after, there come to light the differentiations deriving from the conditionings of the environment, the limits of the courts in which the events are taking place, the artisan rather than industrial dimensions, the political and economic conditionings. A noteworthy example that we might call paradigmatic is had right in the Papal States. Leafing through the pages of the treatise by Nicola Cavalieri di San Bertolo, "chief engineer in the Roads and Waters Corps and professor at the Archiginnasio Romano della Sapienza", entitled "Istituzioni di Architettura Statica e Idraulica", published in Florence in 1832 "at the expense of engineer Vittorio Bellini, architect in the royal employ"--a sort of technical-professional synthesis, a sort of home-grown Rondelet reduced to two volumes --, with regard to the architecture
of iron one will find the debt to the attics of which "use has been made frequently in Paris for about thirty-five years now" (1), or immediately thereafter, the trusses composing the cover of the "great hall destined for exhibitions of the paintings of the museum of the Louvre". Then going on to an ample and quite accurate description on English iron bridges, subdivided into "castle bridges, arch bridges, and hanging bridges", with precise reference to Payne, to the work of the English protagonists, as well as to the three fundamental French treatises, Cauthey, Rondelet, and Bruyère. Especially on the hanging bridges, on the advantages and disadvantages from the point of view of construction and statics, like the conditioning deriving from the market in relation to the iron-producing centres, the analysis of Cavalieri di San Bertolo is careful and precise. Then, however, when dealing with Italian matters and in particular the State of the Church, he concludes in a drastic way that "it seems to us that we may reasonably presume that, on the economic consideration, for now no reason will be had to adopt the system of hanging bridges in any part of Italy". But the motive for this skepticism of his--fortunately belied by the reality of the facts--is precisely the insecure Italy of brigandage: "the existence of a hanging bridge is continually in danger . . . principally the reason that for men of ill will prompted either by greed for the looting of metal or by the perverse spirit of injuring society, it is a small undertaking to remove the pins, the screw spikes, or other fittings destined to keep the system's parts connected, or even to cut the wires and chains with files, and it is obvious that any of these damages is sufficient to produce the total, instantaneous ruin of structures made in that way" (2).

In spite of the thesis of the professor from the Sapienza, in '64, six years before the arrival of the <u>bersaglieri</u> in the capital, but three years after the unification of Italy, a "Trattato elementare dei ponti tubolari ed a travi di ferro e descrizione particolare di quelli di Conway e di Britannia con un cenno storico dei ponti di ferro e illustrazione dell'applicazione del ferro malleabile alla costruzione dei ponti di Draysdale e Dempsey, traduzione italiana dall'inglese all'italiano del Cavalier Camillo Guglielmetti architetto professore dell'insigne e pontificia Accademia Romana denominata di San Luca, architetto rincontro della Basilica di San Paolo e socio di varie Accademie" was printed in Rome. This is a little

popularizing brochure relating precisely to the cost of the English works in connection with iron structures and in particular the bridges over the Conway rivers and the one over the Menai Strait, "which are the largest works of this kind carried out by the English". The translation is made necessary by the expediency of "generalizing the knowledge of such complicated works that may acquire a useful application in difficult cases, particularly in this era in which Italy too is carrying out magnificent works in iron". The pessimistic forecasts of the professor of the Sapienza are belied by the member of the Accademia di San Luca--not the least of the tests of the still progressive value of the Academies with respect to the ever recurring sclerosis of the Universities; but the debt to the great English works is acknowledged, and indeed becomes increasingly greater. Moreover, even in little Tuscany, and in the smaller world of the Grand Duchy of Lucca, it must not be forgotten how the architect who was the protagonist thereof, Nottolini, influenced by his friendship with Karl and Friedrich Wiedekind, royal architect of the Kingdom of Bavaria, went to London where he noted in his diary, "London Bridge. Greatest bridge I know. The tunnel of which it is made /sic/ more than 2/3. The railroad from London Bridge to Greenwich 5 miles long." Then he went to Wales purposely to gather direct documentation of the construction of bridges suspended by iron chains; he visited the bridge on the Avon, completed in '36, and the 1826 bridge over the Menai Strait joining England to the Island of Anglesey. Remembering these, in the neglected Marienbad of Lucca in Bagni di Lucca he built the so-called Bridge of the Chains, which was destroyed by the war and faithfully reconstructed by the founder of our Istituto fiorentino di restauro Sanpaolesi. But Florence too, that Florence that was also the centre of the English world, Victorian Florence, the Florence of Vernon Lee who rightly thundered against the demolitions of the old centre, had its viaticum of the architecture of iron, in two bridges: the bridges of San Niccold and the Cascine were two suspension bridges with truly extraordinary comprehension of urban value. The Ponte Vecchio--the traditional Arno passage from the Cassia romana to the centre--, the mediaeval bridges and the sixteenth-century Ammanati one of Santa Trinità corresponding to the old city, and on the edges where the Arno opens up a perspective towards the snows of the Consuma or broadens in its lazy course downstream from the park of the Cascine, there the two bridges were of iron. This was not



Fig. 1 - The bridge of the Cascine (Florence).



Fig. 2 - The bridge of San Niccolò (Florence).

understood in the postwar reconstruction which set in place two works that had no sensitivity of this fact.

The theme leads back to another problem, namely the relationship between iron and garden, iron and nature, which was likewise an English theme. In the grand duke's villa of Poggio a Caiano, that of Giuliano da Sangallo and Lorenzo the Magnificent, Alessandro Manetti in 1833 had planned an iron footbridge over the Ombrone, that passed through the villa's romantic park. Here the bridge becomes an element of décor linked to the taste and the fashion of the time, and not strictly responding to a functional need. Upon completion, Manetti thus comments on the work: "I had a bridge built, suspended by ropes of iron wire, over the Ombrone in the Poggio a Caiano Park, and remained not very happy with the work. These bridges should not be built except with very ample spans that allow their boldness to be conceived by the eye at first glance. The Ombrone is not wide enough for these to be applied. It was the first bridge of this sort to be made here among us, fit for the passage of carriages, and those for which it was destined were those of the sovereigns and of the court. Navier erred in the Bridge of the Invalides on account of scarcity; I erred on account of slenderness with respect to excessive strength of the Ombrone" (3).

Where, a posteriori, the relation between iron and proportions is ascertained; the former always justified, that is, when efforts of the intuitive knowledge that comes from the Renaissance enter into play; when those relationships between size and gracefulness, between form and nature, are given, that constitute a sort of continuation, accentuation of the Gothic search, hence difficult to ensure with classical equilibrium.

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- (2) Op. cit. Pag. 261.
- (3) A. Manetti, Mio Passatempo. Scritto postumo del Comm. A. Manetti già direttore generale delle acque e strade e delle fabbriche civili di Toscana, Firenze 1885, Pag. 113.

THE CULTURAL MATRICES OF THE ARCHITECTURE OF IRON AND UTILITY IN TUSCANY

PAOLA MARESCA

SUMMARY

The essay analyzes how XIXth-century Tuscan, and in particular Florentine, culture was indebted to English and French tradition in the matter of new experiments in the field of architecture, as far as the building of "industrial" structures was concerned, such as the iron suspension bridges, the Roster tepidarium, the railway network, the central market, the abattoirs, and Poggi's railway viaducts.

⁺Architect Tuscan Region Department of Culture Assistant to the Professor of History of Architecture II, University of Florence In the very poetry of the garden the appeals for a cultural renovation of English mould are realized, and in a possible reconciliation between art and industrial revolution the culture of utility in the city of Florence expresses itself in a series of architectural achievements characterized by the new technology of iron.

The culture of utility is reconciled with the expressly decorative, architectural culture in the Roster greenhouse of horticulture in Florence, the great tepidarium modeled on the most prestigious accomplishment of the century, the Crystal Palace by Paxton, the greenhouse builder whose work inspired numerous specific treatises such as "L'art de construire les serres" (Paris, 1846). In this important tepidarium still on the English and French model and in particular in the wake of the architectural achievements north of the Alps and the cultural-aesthetic problems developed by Boileau and Baltrand in France and Deane and Woodward in England, the Gothic style is reconciled with the metal structures where the properties of the new material come to be exalted.

Here we must point out how much Italian, and in particular Tuscan, culture was indebted to French and English culture in the field of new constructions in iron and cast iron.

As has already been noted previously, in 1837 Grand Duke Leopold applied to French technique for the building of two iron bridges, an undertaking entrusted to the Seguin brothers, "builders of twenty-eight iron bridges in the Kingdom of France", who at the end of their career counted more than 80 suspension bridges built all over the world. Then again, Marc Sequin was heir to a family tradition in the matter of new technological experiments. A nephew of Montgolfier, he had already invented a sort of tube-shaped boiler that enabled steam engines to run long distances. In this regard Gideon notes that American suspension bridges offered models for Sequin's work in Tourlon. "These bridges were suspended by hemp ropes or strips of leather. Seguin used metal cables instead. Metal cables were used for the first time in that application here, and Sequin made careful scientific checks before launching his project." On that occasion Alessandro Manetti, Director of the Corps of Roads and Water Engineers, was invited by the Grand Duke to express his opinion with regard to the project, and did not hesitate to affirm, "As for appearance, I believed I discerned no little elegance in the simplicity of the work both overall and in the individual parts." It is to be noted, at any rate, that for the Seguin brothers the new technique had already taken on the characteristics of a genuine industry. In effect, the Seguin undertaking tended to reproduce not only the profoundly structural components, but also the same architectural types, to the point of rendering the two Florentine bridges, even in the attribution of neoclassically inspired adjectives, quite similar to those built by the same brothers in Europe. The metal frameworks destined for the building of the two structures were in any case cast in France.

We must also note how frequently recourse had previously been had, in different forms and manners, to the new technologies from beyond the Alps. In 1833, after a series of informative trips to Paris, Alessandro Manetti had promoted the adoption in Tuscany of the French technique for building a machine capable of drilling the earth to construct artesian wells. Following Napoleon's request, it was believed that the age-old problem of supplying water to the city of Florence could be solved with the new machine.

Constant reference to the technical-scientific tradition of the new machine age was to be made by Corridi, director of the Florence technical schools in the mid XIXth century, who in that capacity took inspiration from the Parisian models of the Arts and Crafts Conservatory, and the "Lyonnaise" school and the "Martinique". Furthermore, Corridi provided the Institute with a substantial number of apparatuses manufactured in the Deluil and Rumkorff shops and purchased in Paris.

A few years later Dino Carini devoted a study to industrial and technical training in France, England, and Belgium (<u>Della Istruzione Tecnica e industriale considerata nelle sue</u> <u>realizzazioni colla pubblica economia</u>, Florence, 1869), holding up as an example for the Florentine Technological Museum under construction, the Museum of Kensington and other English museums, to which he assigned an undisputed primacy.

Again, it was under the Lorraine regency that the swift advances in mechanical and technical sciences gave rise to the first Tuscan railway network, second only to the Naples Portici one in Italy.

"La Toscane," affirmed Carducci in 1846, "est la contrée de l'Italie où l'exécution des chemins de fer est la plus avancée." Indeed, the studies for the building of the first railway system date from 1838, the very year in which the line connecting London to Birmingham was opened in England. The problem was entrusted to the father of the European railroad, Robert Stephenson, while, still on the French and English example, a company was formed for the purpose of "building and starting up at its own risk and expense the mentioned road on the established drawing, and collecting the price of carriage on that road for one hundred years". The need to improve transportation was accompanied by the desire to keep step with the other European nations. Thus, in 1846 Grand Duke Leopold decided, after the example of Paris, to replace the city's oil lighting with gas lighting. The contract was given to the French company, Montgolfier-Bodin & Company, and subsequently transferred in 1854 to the Lyonnaise Civil Company, which operated the gas lighting of other cities in Italy (Venice). This firm was responsible for the construction of the four big gasometers on the bank of the Arno near the populous San Frediano guarter. The largest of these, consisting of sixteen columns rising 15 meters high--an old fossil saved in extremis from a pitiless as well as senseless destruction --, with its unusual architecture still today overlooks the small area on the bank of the Arno.

Full maturity and mastery of metal structures was to be had, however, once the Lorraine administration ended, in the second half of the XIXth century when the decision to transfer the Italian capital to Florence rendered advisable, among other measures, the building of the new central market to replace the by now dilapidated Old Market. The latter moreover occupied a vast area that was extremely attractive for building speculations. Out of respect for the taste of the time, which Boldi described in his treatise on covered markets, asserting that the Halles of Paris by Baltard had been "built in a way that has not yet been excelled", metal structures were preferentially used for this type of construction. As regards the new Florentine Market, commissioned from Mengoni (1868) who was later to execute the even more celebrated iron and glass gallery in Milan, it must be noted how harmoniously the traditional architectural idiom of distinct neo-Renaissance mould joined with the new technology of iron, taking on a new character. New indeed was the particular operation of grafting





Fig. 2. Giuseppe Poggi. The plan for the railroad viaduct.



Fig. 3. Giuseppe Poggi. The plan for the railroad viaduct.

the new material, emblematic element of the new culture, onto a traditional plan. A module of transition and, in a certain sense, of synthesis between the use of the two different materials was traditional technique as well as the attribution of decorative adjectives derived from the classical repertory qualifying the structural parts in iron. Clearly drawn from the model of the Halles were, again, the internal layout and the furnishings consisting of the sales counters, as well as the use of door and window frames in panes of frosted glass, with which Mengoni had planned to close both the headpieces and all other vertical openings. Likewise, on Baltard's example, placed over the ground floor covered by a slanted roof was a higher central part, reproducing in all respects the profile of the Parisian Halles. Mengoni's double entry as French-style progressive and German-style traditionalist was not lacking in criticisms, however. The new structure, which moreover stirred a sense of innate distrust in the Florentines, had to be used for some years as an exhibition hall, due to the objective impossibility of transferring the sellers there.

The distrust in the new materials in any case was not to find corroboration in the works that characterized the face of Florence the capital. Mention may be made here of the Cattle Market built on the outskirts of the city by Francolini, sonin-law of Giuseppe Poggi: here the use of iron structures was associated with the then nascent technique of cast iron, and previously in the plans for the railroad viaducts designed by Giuseppe Poggi to solve the problem of crossing the city of Florence by rail. Here the metal structure is camouflaged by Volute stuccowork in plaster and masonry. The different designs, although in fact of the same common technological mould, essentially reflected the styles that characterized the building scene of the 1800's. One project even offers the bridge in a severe neo-Egyptian style. It is to be noted, in fact, that the connection between neo-Egyptian and iron was quite frequent for bridges and railroad stations in France and England. An example is the iron bridge of St. Petersburg with neo-Egyptian piers, published in the Rondelet, or the station designed by J.J. Short, again in Egyptian style. As it is seen, the influence of transalpine cultural forms on post-unification Tuscany, even though in minor keys, mediated by the rising and strengthened local culture, was more than ever evident.

If it is possible to delineate a conclusion, there are two aspects that count in the Tuscan experience. First: the presence of an advanced European culture, in the proper and suitable sources that have a reasonable but not excessive <u>décalage</u>, and in professional preparation and public purchasing. Second: how the iron idiom was accepted as compatible with tradition in an area with an accentuated, essentially conservative stylistic connotation, linked, that is, to the Renaissance image to such an extent as to have been impervious to the heated, rhetorical calls of the baroque. It is no small motive for reflection today just as yesterday. THE FLORENCE MUSEUM OF CONTEMPORARY ART IN THE OLD "GALILEO" FACTORY. THE REUSE PROJECT.

Marco MATTEI *

SUMMARY

The transfer of the industrial activities having been effected, and the old workshops abandoned, in February 1981 began the difficult battle against demolition of the ex-Galileo factory in Florence.

The main target of this singular debate around a question of urban renewal was the central pavilion of "Textile-machinery" which is one of the most important pieces of industrial archaeology in the city.

The City of Florence has now decided to locate the new Centre of Contemporary Art in the area of the ex-workshops. This decision, which constitutes a clear intention as to policy with regard to historic workplaces - and which is emblematic if compared with the FIAT Lingotto question sets down a firm reference point for a problem which had been dragging along in Florence for more than thirty years.

* Architect

Translation from Italian by Thomas Muirhead.

October 1984.



1. The Galileo works in the "Le Cure" area (1870).



 The construction of the Galileo works in the "Rifredi" area (1908).

This report is the result of the first phase of work carried out by a design group (Battisti, Dezzi Bardeschi, Gregotti, Mattei) commissioned by the Florence City Administration to prepare a feasibility study for realisation of the Museum of Contemporary Art in the area occupied by the ex-Galileo workshops in Florence.

The City of Florence has now decided to locate the new Centre of Contemporary Art in the area of the ex-workshops. This decision, which constitutes a clear intention as to policy with regard to historic workplaces - and which is emblematic if compared with the FIAT Lingotto question sets down a firm reference point for a problem which had been dragging along in Florence for more than thirty years.

Being as yet unable to present the results of Phase Two, regarding the outline project, I would like to take this opportunity to describe the work done up to now, and to explain the difficulties - which are of primary importance which we have so far only been partly able to overcome (1).

1. Historical profile of the Galileo workshops.

The Galileo question is explosive for Florence, and in past years has been the object of bitter squabbling, which has never completely ceased even today, and it is to be expected that the issue will continue to be controversial in the future. It is not easy to sum up the issue, in view of the social and historical importance which the ex-Galileo workshops have in Florence's history, although it is only in recent years that the site has become the object of a very unique urban recuperation question, after transferral of the factory to another site. It is therefore necessary briefly to describe the history of this place, and how it has evolved.

The Galileo factory was founded at the beginning of the last century as a mechanical precision engineering workshop. The first official document is dated 2 August 1870; in that year, the firm bought several lots in the Cure area of Florence, and transferred its activity to that area. The new headquarters and machinery permitted an increase in production, which traditionally is concentrated on high-quality precision machinery. The production system was of artisanal quality and the means of production - at least at the end of the last century - were at a low technological level, which was compensated for by the presence of a highly skilled work force (2).

At the beginning of this century, whilst Florence generally was undergoing a new phase of intense building activity tending to saturate the remaining unbuilt areas in the Poggi Plan, the first industrial plants were set up in one of these areas, Rifredi. In this period, the new Galileo Workshops experienced a relaunching of their activity, and a specialisation in the field of precision instruments and firearms. In 1907 the new area at Rifredi was bought and work began on the new factory.

The factory's growing activity, favoured by Italian involvement in war operations, accelerated the move to Rifredi, and regular functioning in this new location began in 1909. The first production nucleus - which was to become a part of the future textile machinery workshop - covered an It was constructed in cast iron columns area of 2500 m^2 . and north-lit roofs, on a grid of 6.60 by 8.00 m. The iron columns permitted rational use of the available space and maximum flexibility for future changes. The roof is one of the first continental examples of its kind, and is based on English examples. As the World War approached, military contracts became increasingly important, and Italy's entry into the conflict was the decisive step forward for the Galileo firm.

After the war, a reconversion crisis deriving from the necessity of modifying production from war use into other uses led to a series of layoffs and sackings which culminated - in September 1920 - in occupation of the factory and definitive closure in March 1921.

The later course of events involving growth and development of the firm was dependent on external historical events, on war and peace, on various processes of reconversion. At the end of the thirties, at the culmination of an intense period of building, the original area at Rifredi was saturated. Growth of the surrounding area had swallowed up the factory and made further expansion impossible except towards a nearby steep incline.

The Second World War was the occasion for another phase of intense production ; the enormous amount of military contracts led to a massive increase in the work force, and led to a record figure of 5000 employees (3).

When the factory reopened at the end of the war, Galileo put a programme into operation for the production of textile machinery; however, traditional work in the precision instrument field was not abandoned.

Following a period of grave tension and trade union activity in defence of jobs, 530 employees were dismissed in 1959, most of them skilled.

The evolution of this state of permanent crisis and restructuring, which had a very great influence on transformation of the surrounding Rifredi area, conditioned relationships within the firm for the whole period leading up to the crisis in the 1970s (4).



 Expansion of the machine tool section, presently the textile machinery department "meccanotessile" (1914-1915).



 Hardware section (1917) in the present "meccanotessile" department.



5. Turret lathe section (1917) in the present "meccanotessile" department.



 The "meccanotessile" department of the Galileo works (1950). The process of reconversion of the production process, which above all concerned the occupational patterns and the composition of the workforce, culminated, in 1965, in transferral of the Galileo firm into the Montedison Group, whose failure coincided with the beginning of decentralization.

In 1970, as part of a restructuring programme, Montedison decided that the existing factory buildings were inadequate and that the whole concern should be moved to Campi Bisenzio, a new site on the outskirts of Florence.

This transfer having been effected, and the old factory abandoned, in February 1981 began the difficult battle to prevent demolition of the buildings. The main target of this singular debate around a question of urban renewal was the central pavilion which had been used to produce textile machinery and which is one of the most important pieces of industrial archaeology in the city.

The textile machinery building is now nothing more than one fragment of a historically meaningful area, menaced by the threat of elimination of memory, of cancellation of history.

For its large size - about 10,000 m² of covered area this building is in any case a landmark, especially with regard to the relationship between the pavilion and the surrounding urban landscape. From its role as factory, i.e. as a simple shed to house machinery, the building has gradually taken on a more significant role as a public interest-building, an architectural element on an urban scale, to which the city has made continuous reference in the past.

The area and the pavilion, which have managed to survive demolition, can thus become a focal point of great importance within a plan of re-connotation, in a cultural sense, of urban spaces.

A suggestion arose that the buildings could be utilised as the proposed Centre for Contemporary Art. The space is full of exhilarating potential as a museum ; it has all the necessary characteristics of constant uniform lighting and refined technology. Furthermore, the vast quantity of space available and the great flexibility which the structure permits, make this deserted factory, fossil of human labour, into an ideal setting for the functions of a Contemporary Art Centre.

In the wake of a unanimous consensus around this idea, and of local mobilisation, on the 14th of July 1981 (ironically, on the anniversary of the taking of the Bastille) the City of Florence voted to safeguard the pavilion and to undertake a global redesign of the buildings, commissioning the feasibility study for the new museum. The project (Battisti, Dezzi Bardeschi, Gregotti, and Mattei) was submitted to the City in February 1982. The general plan for the area, previous decisions taken, and the stringent conditions imposed by the landowners, all heavily conditioned development of the project.

The range of proposals that the designers presented is in any case the result of numerous attempts to re-equilibrate the relationship between public and private space, in those cases - frequent - where the public spaces do not succeed in carrying out their function of controlling the city's transformation processes, which they should do. In brief, the project foresees a containment of the site boundaries within which private speculative development should be permitted, thus consenting recuperation of the industrial pavilion, to be destined for use as the Contemporary Art Centre, and its projection towards the hillside lying east, which should be reorganised as a public park connected to the museum.

But the architects' problem was not only that of how to reuse the industrial pavilion ; the question facing designers, local politicians, and the population was : given its intermediate position between the nineteenth-century city and the later expansion, the Galileo area constitutes a fundamental node for the entire reorganisation of the whole of the Florence area towards the west, along the Florence -Prato - Pisa axis. This is why the case of the Galileo goes far beyond the simple recuperation of an important archaeological container and impinges directly on the city planning proposal for the entire urban zone. The very scale of the intervention - for the history of the city, the Galileo is as important for Florence as the Lingotto factory is for Turin - makes it necessary to consider the reorganisation of the whole Galileo area as part of a wider territorial planning operation.

2. The character of the new museum.

The City of Florence's decision to create the new Contemporary Art Centre in the ex-Galileo factory and therefore to provide itself with a museum structure destined to conserve the heritage of contemporary art already in its possession, as well as fostering new trends, constitutes a complex programme within which the architectural realisation of the building represents only a small part of a wide-scale decisional process. In fact, the architectural object, destined to contain artworks, services, administrative functions, and so on, can only be viewed as the synthesis and the spatial verification of choices (made at a technical and political level) which programming of the initiative must inevitably consider ; only in this way will it be possible to arrive at a projectual definition which is not abstract and detached from the real objectives of the programme.

In particular, the validity of the project and the concrete verification of its functionality can only take place taking account of the overall objectives identified by the city administration ; in relationship to the functions carried out by the network of cultural services and in particular by the museum structures ; in relation to the exigencies of conservation and enhancement of the heritage acquired and finally, considering the policy of information which the new structure must satisfy within the specific sector in which it is destined to operate.

There are at least three valid reasons why this new Florentine cultural institution should have a characterisation in a productive sense.

The first consists in the fact that having to measure itself against other international-level institutions which have already been on the scene for many years and which as a result are equipped with a chosen and meaningful collection, the Florence venture would end up as a second-rate affair for a long time to come ; in any case an acceptable degree of upgrading to bring it to the same level as other existing international-level organisations would involve an intolerable use of large amounts of public funds.

The second question regards the relationship with the rest of Florence's museum system, which obviously has a historical bias tending mainly towards conservation. It seems opportune to say that the new institution should not function in the same way, but should offer a real diversification of experiences for the user which in any case would not be represented by a purely perceptive relationship with the work of art, but which would consent forms of acquaintance with the artists going deeper, of knowledge of the environments in which they operated, of their techniques.

Finally, a third reason has certainly a more particular character, but certainly not less important ; it regards the relationship between the new Contemporary Art Centre and the pre-existing Galileo pavilion.

We maintain that this reference cannot and must not be a simple pretext, dictated by essentially emotional motives, to justify introduction of a mere superstructure into a part of the city - the working-class area of Rifredi - unique in Florence, historically designated by the production and by the active presence of workers.

Also from the viewpoint of definition of the character of this institution and still more from a design viewpoint, this reference must have a determining importance and play a fundamental role in the characterisation of its contents, of its functioning, and of its spatial aspect. From this circumstance derive some design presuppositions which concern the general necessity of conserving the building, which represents the biggest and most unified spatial element of the ex-workshops.

The fundamental activities of the new Modern Art Centre of Florence must be :

The <u>expositive function</u> based on temporary exhibitions of both thematic and monographic character and along the lines of large exhibitions such as the ones held in Venice, Kassel, and so on.

For obvious reasons of convenience, the space reserved for this type of large show must be easily convertible to allow every artist to act in the spatial, acoustic, and lighting conditions preferred. All the same, it should be noted that from a design viewpoint, an easily-convertible space, unless one resorts to technically complex systems which are very costly, usually does not have much character.

The large pavilion undoubtedly presents conditions of great flexibility, which are however the result of an indeterminate space which makes it a problem to insert any work of art. It is therefore necessary to develop design of the areas dedicated to temporary exhibitions in such a way that the necessary flexibility is accompanied by requisites of clear dimensional individuality and formal character for the available spaces which correspond to spaces of varied plan shape, of different height, of regulated intensity of lighting and acoustic insulation.

Study of the large pavilion, which is top-lit, must therefore be conducted not only at the level of the most accurate restitution possible of the general environmental conditions ideal for showing works of art (lighting, temperature, humidity, flooring materials, ceiling and wall finishes) but also put into effect a system of spaces connected by coherent routes, partially convertible and adaptable to different needs.

The <u>conservation function</u> is based on the collection which can be set up beginning from the roughly 2000 works, of various interest and value, already belonging to the City and at the moment dispersed in all sorts of places.

The <u>function of dramatising or animation</u> which regards that part - by now determining - of artistic manifestations of a spectacular nature and also all sorts of teaching activity which in a modern art centre cannot be absent.

The relationship between these functions, all essential, but which can evidently be dosed in different ways, determines the formula of the institution and contributes to delineating the image and to conditioning, in an irreversible way, the functional and the spatial asset. Prescinding, for now, from the specific modality of functioning of each of these fundamental activities, we propose to evaluate, in a totally preliminary way, some criteria which lie at the base of the design intervention.

3. Basic data and requisites for the design intervention.

The present-day surface area of the pavilion is 9,400 m^2 corresponding to a single volume calculated from the base of the supporting structure of the roof, of 61,000 m^3 , equal to 6.5 m^3 for each square metre of covered surface area. This total volume can be divided in two parts ; one of thirteen spans, realised in cast iron columns and iron roof structure with a surface area of 5600 m^2 and the second contiguous, realised in a structure in reinforced concrete of nine spans equal to 3800 m^2 .

For the first part (the historic part in iron) the bearing structure of the roof consists of cast iron columns having an external diameter at their base of 25 cm and terminating at their upper extremity in a flat plate on which two I-section beams rest. Between these there is a rainwater channel which conveys the water into the core of the bearing columns, which act as downpipes.

On the beams rests a network structure of L and U beams which support the roof.

Two structures are also visible, adjacent to the external walls and delimited by load-bearing internal walls; one of these is at the east, and is of 1350 m², the other, at the west, is of 770 m²; there are internal partition walls. These parts appear to be components of the physical and spatial structure of the pavilion, and also represent some significant phases of its development.

From the technical reports in our possession, which we obtained from some metal formworking companies and restoration firms, regarding the actual state of degradation of the iron bearing structures, we deduce that the general state is good, although both of the examining firms have found some small areas of damage which are only partly the result of wear and tear (for example, rusted cross-beams and some bolts which will have to be replaced) but especially caused by irresponsible manouvering carried out by the people who disassembled the factory machinery and the furnishings which were left behind (cutting and ripping of some of the elements of the reticular roof structure, etc.).

However, these are forms of damage which cannot be attributed to degradation of the structure itself, and which above all do not compromise the general stability. In checking the resistance of the existing structures in iron, we considered a uniform distributed load of 385 kg/m^2 divided as follows :

self-weight in kg/m ² :		
beams	50	
roof tiles	40	
concrete roof slab	90	
prefabricated roof elements	35	
insulation	20	
added snow and wind loading	90	
human traffic	60	
total	385	kq/m^2

Furthermore, the beams were considered as having an imposed linear load of 100 kg/m, including the self-weight of the structure and of the overloading. Calculation of the forces acting on the structure was effected using a computer and gave the maximum moment at the intermediate bearing-points as M=705195 kg.cm.

Since the beams consist of an IPE 280 type I-beam, with a resistance modulus of W=541 cm³, we thus have a tension of G=M/W=1303 kg/cm² (at the present moment, these beams, if made in steel, have a breaking tension of 5000 to 6000 kg/cm²).

The cast iron columns are essentially subjected to compression because torsion is extremely limited thanks to the absence of overhead cranes. The normal loading of about 11200 kg is easily borne by the columns, with a compression tension of 83.58 kg/cm^2 . (At the present day, in cast iron, the breaking strength caused by compression is about 8000 to 10000 kg/cm²).

An element that is certainly important is to respect this structure of the pavilion which has been saved from demolition and, by means of opportune stratagems, to conserve as a unit the remaining parts of the Galileo factory, which constituted a coordinate and unitary spatial system.

Naturally, this can be done by using rocedures of a metaphorical or illusive type, and without resorting to literal re-creations.

So far as the actual workshop is concerned, its value as a true and proper remnant of industrial archaeology is evident.

The question of conservation must be one of the elements of the brief, to be examined in relation to the various solutions which are proposed. A decision which is anything but linear, be it from the architectural viewpoint, or from the cultural viewpoint; summing up, we are dealing with transformation of the old industrial outskirts of the city into a new centre of activity, and, finally, this is a choice which represents a kind of cultural continuity between a period characterised by industrialisation and architectural use of iron, to an age which reaps the fruits of its inheritance of technological transformation.

Notes :

1) E. Battisti, M. Dezzi Bardeschi, V.Gregotti, M. Mattei : <u>Il Museo d'Arte Contemporanea di Firenze nell'area delle</u> <u>ex-Officine Galileo</u>, Progetto di fattibilità, Comune di Firenze, Firenze 1982.

2) F. Foggi : <u>Le Officine Galileo di Firenze</u>, Alinea Editrice, Firenze 1984. and AA.VV. : <u>Industrie fiorentine tra '800 e '900</u>, Alinari, Firenze 1982.

3) AA.VV. : <u>Fabbrica e territorio</u>, Edizioni Clusf, Firenze 1973.

4) AA.VV. : La ristrutturazione delle Officine Galileo di Firenze, Edizioni Clusf, Firenze 1973. a) should for an antich of a conventing for a life of the second such that the second such that the second such that the second such that the second summing up, we are dealing with transformation of the second second

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ion on of the elements excland in election to the various STRUCTURAL APPRAISAL OF EXISTING IRON & STEEL CONSTRUCTION

Michael N. BUSSELL *

SUMMARY

The investigation of structures built since the late 18th century will often demand the appraisal of loadbearing members of cast iron, wrought iron, or steel. The paper considers the various aspects of such an appraisal, and in particular emphasises the need for an understanding of the original materials and their characteristics, construction methods, and design standards.

The article is reprinted from the final report of the IABSE-symposium, Venice 1983 on Strengthening of Building Structures - Diagnosis and Therapy, by kind permission of IABSE (the International Association for Bridge and Structural Engineering), ETH-Hönggerberg, CH-8093 ZÜRICH, Switzerland.

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1. INTRODUCTION

There is at present a growing tendency for old buildings to be renovated or adapted for re-use. In itself this is not a novel situation, but it is significant that many of these were constructed during the last two centuries, in the period which has seen the introduction and widespread use of first cast iron, then wrought iron, and ultimately steel as structural materials. Consequently the engineer is likely nowadays to be faced more often with the appraisal of structures containing one or more of these ferrous metals.

The aim of the appraisal will be to show whether the structure can be retained for the future intended use of the building, whether it needs to be strengthened, or whether total renewal is the only practical course of action. Factors other than purely structural considerations will of course also need to be taken into account: these include for example adequacy of storey heights, and legal requirements for preserving architecturally important facades.

It is worth stressing here the contrast between design and appraisal, which is particularly relevant in regard to ferrous metal structures. In a design, the engineer can prescribe through drawings and specifications the material properties, member sizes, and construction details to ensure that his (usually simplified) assumptions of strength and behaviour are achieved in the built structure. An appraisal however is concerned with a structure that has already been built: its characteristics exist but are initially unknown and must be defined by investigation of the structure itself, coupled with an awareness of the original materials, and design and construction practice of that time.

2. GENERAL APPRAISAL PROCEDURE

The appraisal process generally involves investigation and assessment in two stages, broadly analogous to the 'scheme' (or preliminary) and 'detailed' (or final) stages in the design process.

The aim of the preliminary appraisal is to establish in principle whether it is feasible to retain the existing structure for the future. (If the answer to this is 'no' there is clearly no point in making any further study.) This stage involves:

- search for available drawings and other documentary evidence
- identification of the metal(s)
- outline structural survey to establish existing construction thickness and spans, member sizes, and major defects
- preliminary assessment
- decision in principle on feasibility of retention

The timescale for this preliminary appraisal is often very short, being imposed by the building owner or client. This can paradoxically be of benefit in helping to focus attention on generalities rather than particulars of the structure, in encouraging the minimum and simplest of calculations, and in postponing the commissioning of slow and expensive detailed surveys and testing programmes. (In this stage it is suggested that any testing of materials is done only to confirm the identification of the metal(s).)

The final appraisal, once the feasibility of retention has been established in principle, will be a more thorough exercise involving:

- detailed structural survey of all construction that is required to remain (especially connection details)
- detailed definition of renovation and re-use needs as they affect the structure
- testing of materials
- comprehensive assessment of members and connections
- decisions in detail on strengthening and other alterations to structure

Following this, the necessary work can be specified.

It should not need saying that the early involvement of the building control authority is essential in any appraisal for alterations or re-use in which it can exercise statutory powers, for it - as well as the engineer involved - must be satisfied that the existing structure has been properly investigated and realistically assessed, and it would be foolish as well as time-wasting to develop a detailed scheme which is then rejected on submission to the authority because of fundamental disagreements on approach.

The rest of this paper concentrates on specific aspects of the appraisal of ferrous metal structures, namely: identification of the metal, preliminary assessment, testing, and final assessment. The general principles and approach to be applied in any structural appraisal have been described elsewhere (e.g. [1]), and are not discussed further here.

3. IDENTIFICATION OF THE METAL

3.1 Visual Aids to Identification

Distinctive features to aid in the recognition of cast iron members are:

- pitted or 'gritty' surface (from the sand or loam mould)
- thick or coarse cast sections
- 'flowing' sections and profiles (e.g. solid and hollow circular, and X-and H-shaped sections; 'classical' column heads with integral endplates; shaft entasis)
- bottom (tension) flange larger than top flange
- beams of inverted T- or V- section
- bottom flange of beams often curved on plan or elevation
- internal corners rounded (to deal with cooling shrinkage stresses)

Connections between cast iron sections were by simple bearings or by wrought iron threaded rods and nuts fixed through pre-formed holes. Hollow circular columns were often cast in two semi-circular pieces which were then brazed together.

Wrought iron resembles steel in being formed into structural sections by passing billets through rollers. The earliest beams were built up from plate and angles rivetted together. Subsequently rolled beams became available, often being strengthened by rivetted flange plates and web stiffeners. Its tensile superiority over cast iron led to its early use as chains, cables, and links for suspension bridges, and as tie-rods in buildings. The rods were frequently employed compositely with cast iron to form trussed beams and roof trusses.

Wrought iron can be distinguished visually from cast iron by its smoother rolled surface - assuming that not much corrosion has occurred. If more corroded, wrought iron tends to delaminate into thin sheets of nearly pure iron alternatively with slag which can be pulled away from the surface.

It is more difficult to distinguish sound wrought iron from steel as their production and structural forms are so similar. Unless there is conclusive evidence from documents or dating as to which metal is present, it is best to take small samples for identification.

3.2 Dating Evidence

The chronology of iron and steel use in structures is fairly well-defined, although dates vary between one country and another. In the UK, for example, cast iron was used between the 1790s and the early 20th century (columns only after about 1860); wrought iron from 1840 (built-up beams from plates and angles) and 1860 (rolled I-beams), being obsolete by 1914; while steel was introduced structurally in the late 1870s and subsequently was the only ferrous metal used in new construction after 1914.

Thus, if the building can be dated by documentary and/or stylistic evidence, it should be possible to distinguish between wrought iron and steel, except in the 'overlap' period when both were in use. Care in relying on dates is obviously needed when a structure has been altered since construction.

3.3 Sampling for Confirmation

It is necessary to take only a small sample of metal, for chemical and metallurgical identification by a specialist testing house. A 25mm square piece core-drilled from a lightly-stressed location will be adequate for this purpose. In the case of cast iron it is important that identification includes the particular type of cast iron as these have significantly varying properties.

4. PRELIMINARY ASSESSMENT

4.1 Approach

It should be recognised that material specifications, methods of quality control, and regulations covering design and loading, have only recently been developed into the rigorous and numerically-orientated instruments that they are today. It is therefore not appropriate to appraise a 19th century structure of cast or wrought iron by calculations based on a modern steelwork code of practice, even if suitably factored to recognise a different basic stress, not least because the characteristics of these materials as manufactured then are not consistent with those of today's steel.

Nevertheless some simple calculations must be made to establish an idea of member strength and hence the feasibility of re-use. If these are to be relevant, the engineer needs an understanding of material quality and contemporary practice at the time of construction.

4.2 Material Quality

Cast and wrought iron, and early steels, were seldom produced to a nationally defined standard as is steel today. Instead, each ironworks would offer a variety of grades suited more or less to the needs of its market. Extensive testing was carried out on these, and the results were published in commercial literature and textbooks. Quoted strengths were usually at ultimate (breaking) load.

A study of test results for any grade generally reveals considerable variability in strength, which was accommodated by correspondingly large factors of safety (between 3 and 10) for working use.

4.3 Original Design Practice

Before building legislation laid down allowable stresses in structural metals, design was based largely on experience and elementary structural theory. These are frequently to be found in the contemporary textbooks, which in many cases can be regarded as the equivalent of modern codes in recording good practice, as well as providing an invaluable reference source on construction details.

Where building legislation had laid down a design approach and quantified allowable stresses, and was in force at the time of construction, it is reasonable to assume that the structure would have been designed to comply with this, which may be used as a present-day standard for appraisal. (Some building control authorities will indeed require such an approach.) The quoted stresses in these are generally conservative, and may also be used for preliminary assessment of structures pre-dating such legislation.

4.4 Loadings

Nineteenth century textbooks show a wide variation in the allowance made for imposed loads: they were however generally higher than would be considered necessary today.

It is clear, however, that many builders did not adopt such onerous figures for domestic and commercial timber floors (which were sized by experience and/or rule of thumb), and this is probably true also of many building structures with metal beams and columns.

The fact that such structures were clearly always incapable of supporting the over-generous design loads quoted in the textbooks and yet today exhibit no signs of overloading, has led building control authorities to be increasingly reluctant to accept unquestioningly schemes for which current live loading requirements would appear to be less than the original 'assumed' loading. It will therefore usually be necessary to establish member sizes and show by calculation that the existing structure is adequate.

Wind loading on early building structures - rather than bridges - was not often considered.

5. TESTING

5.1 The Need for Testing

Once the preliminary assessment has shown re-use to be feasible, it will generally be necessary to obtain more comprehensive information on the existing structure before making the final, detailed, assessment. In particular, materials testing may be considered.

There is little point in making tests if an initial appraisal has shown that the structure is in an unsound state already, or that it is grossly overstressed in its new use. Conversely, a 'young', well-documented steel structure - and often older structures too - may need little or no testing if they are in sound condition and will be stressed only to modest levels in the future. It is important that the building control authority requirements for testing are identified.

Some authorities are very dubious about the usefulness of testing as an indication of typical strengths in the actual structure: this may be understood by considering that manufacturing quality control in the 19th century was very much cruder than it is today, as was recognised by the generous factors of safety applied. There is thus no guarantee that sampling for testing, or even in situ load testing to failure (e.g. of elements typical of the building but unwanted in the proposed scheme), will give results that can be confidently regarded as 'average', still less as 'lower-bound', for the elements as a whole.

5.2 Criteria for Sampling

It is generally assumed that the strength of a group of similar ferrous metal elements will vary in accordance with a normal distribution: an approximation quite adequate for most circumstances. It is then possible to use statistics to give an estimated strength.

Usually this is a 95% confidence limit based on test results, i.e. a figure below which no more than 5% of the actual strengths should fall. To find this, it is necessary to calculate the mean value and the standard deviation of the test results. The 95% confidence limit will then be a number of standard deviations below the mean, that number being a function of the number of samples taken. Hence, if only two samples have been taken it will be necessary to use a value 6.3 standard deviations below the mean, whereas if six samples are taken this is reduced to 2 standard deviations. For an infinite number of samples, the figure is 1.65, so there is little to be gained by taking more than six samples. Beams and columns may not necessarily be from the same source of supply or even of the same material. This should be established in the initial identification exercise, the number and location of samples being extended as appropriate.

5.3 Choice of Tests

The most useful information can be gained from a standard tensile test, i.e. yield stress, ultimate strength, Young's modulus, and elongation to fracture. This obviously involves destructive laboratory testing of samples cut from the structure. Ideally, samples 200 x 100mm should be cut, which will then be machined to the required shape by the testing laboratory. Samples may be removed using a hacksaw, interlocked drilled holes, or flamecutting (which should only be used with an additional 1-15mm allowance around each cut face to enable removal of the heat-affected zone). In taking the sample a prime requirement must be not to weaken the structure dangerously.

Where it is intended to weld to existing steelwork, a chemical analysis for weldability should be made. This can be done on part of a broken tensile specimen. It is in general not advisable to consider welding existing cast or wrought iron.

5.4 Interpretation

If a sufficient number of test results are obtained, the 95% confidence limit can be calculated as previously described. This should then be divided by a suitable factor of safety. For cast iron a factor of 3 is suggested in view of its brittle nature; similarly, in view of the greater variability of wrought iron, compared with steel, a factor of 3 on the 95% confidence limit of tensile strength seems appropriate.

Recent or better-quality older steel should exhibit a narrower variation in strength: the tests should also confirm whether the steel is of mild or high-tensile quality. The permissible stress adopted for appraisal should, it is suggested, be less than the minimum value of the elastic limit, and be not more than either 0.67 x 95% confidence limit of the yield stress or 0.375 the ultimate strength.

6. FINAL ASSESSMENT

The final assessment of the structure can follow one of two courses.

The first is to appraise the members and their connections using design rules and allowable stresses that were in force at the time of construction. This may be particularly appropriate for earlier structures where the in situ material strengths vary widely, and of course could also be applied in the appraisal of a more modern steel structure. The advantages of such an approach include speed and simplicity of calculation, and the high probability of acceptance by building control authorities, especially when the design rules used were prescribed by them or their predecessors.

The disadvantage of this method is that it may not be possible to justify the adequacy of all parts of the structure using the inevitably simple and conservative assumptions built into such rules. In this case it will be necessary to apply an assessment using theoretical first principles; this will inevitably be more time-consuming, and does not necessarily guarantee success in justifying the structure, but does give much more scope for the engineer to take account of the real conditions in which the particular structure will be serving, and to exercise his judgement in relating these to the analytical model he uses. This approach is particularly useful in assessing the strength of columns with varying degrees of end restraint and imperfections in line and straightness.

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<u>CAST IRON</u> (above) Pitted or gritty' surface texture Thick or coarse sections Internal corners rounded: external corners 'sharp' Tension flange often larger than compression flange Flanges often 'fish-bellied' on plan or elevation



WROUGHT IRON (left)

Smoother surface than cast iron unless corroded, when delamination occurs

Joists rolled in modest sizes only: larger sections built up from joists, plates, and angles rivetted together



STEEL (left)

Visually similar to uncorroded wrought iron but larger sections rolled Maker's name or section reference often stamped on web Standardised section sizes

Characteristics of the various ferrous metals as used in beams.



The ideal a concentric casting.



Not perfectly concentric but structurally acceptable.



Structurally unsound risk of splitting/cracking/ buckling under load.



Two semi-circular pieces joined after casting may split later along the join line at X.

Hollow circular cast iron columns are rarely found to be concentric and are often made up from two halves: problems can ensue.


Typical iron-framed construction: cast iron columns and wrought iron beams. Characteristic features are noted.



Stress/Strain curves for typical cast irons used structurally. Note the non-linearity, and the relative weakness in tension.



The ultimate compressive strength of cast iron columns as predicted by formulae and found by tests in the USA. Note the variability of test results, indicating the need for a generous factor of safety.



Permitted working stresses in compression for cast iron columns as defined for London 1909 (lines A,B &C). Other lines are for comparison of Rankine's formula and contemporary US/German practice.

CONSERVATION PROBLEMS ARISING FROM THE LACK OF STRUCTURAL UNDERSTANDING IN THE 19th CENTURY

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SUMMARY

This contribution concentrates on stability of iron buildings. Stability has not always been as important as it is nowadays. First a short introduction about stability is given. Then three examples are given which are constructed not in accordance with our present structural insights. In one case this did lead to problems and in another structural additions seemed to be wise. The third example had resisted storms for over 100 years without problems. This can put our present views in a different perspective.

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INTRODUCTION

This contribution about structural understanding in the 19th century concentrates on stability of buildings.

Stability is an important field of attention when designing the structure of a building, but it has not always been as important as it is nowadays. In the 19th century stability was fairly neglected which can be concluded from analyses of structures and from literature.

This does not necessarily lead to problems but in some cases it did and then structural additions seem to be wise.

In this contribution follows a short explanation about stability and then three examples are given.

- THE CORN EXCHANGE, Groningen, The Netherlands
- EXHIBITION HALLS, Brussels, Belgium
- THE CENTRAL MARKET HALLS, Paris, France
- THE BALTARD PAVILION, Nogent-sur-Marne, France

STABILITY OF STEEL STRUCTURES

To review structures they usually are described in outline only. Elements as columns and beams are schematized by a line, the axis through the centroid. Connections between the elements and the foundation are approximated by hinged joints, stiff joints and fixed ends¹ (fig. 1).



Fig. 1. Schematization of a structure.

A structure is called stable when it can resist horizontal forces which might cause sliding, overturning and collapse (fig. 2). A force F makes the left structure tip over. It is instable. The right structure can resist the force. It is stable.



Fig. 2. Stability

How stability of steel structures can be realised is shown with a simple rectangular hall as built nowadays (fig. 3).

The structure consists of columns, beams, girders and roof cladding. The connection between column and beam can be approximated as a stiff joint. The lateral stability is assured by a stable frame.



shape

structure of a bay

Fig. 3. Structure of a rectangular hall.

The girders are constructed lighter than the beams. The girder near the facade is not rigidly connected with the column. The forces in fig. 4a will turn over the structure in longitudinal direction. This can be avoided by the intersecting diagonal bars drawn in fig. 4b.

What is the reason that two intersecting diagonal bars are used instead of one?

The force in fig. 5a causes compression (-) in the column and tension (+) in the dipping bar.



Fig. 4. Longitudinal stability.



Fig. 5. Use of intersecting diagonal bars.

The extra compressive stress in the column doesn't cause any problem, the dipping bar can be constructed lightly. The force in fig. 5b causes contrary forces. To avoid buckling in the long rod it has to be constructed relatively heavy. More economical is the construction shown in fig. 5c. The extra compressive stress in the elements will lead to a bit more material; the dipping bar is a tension rod, thus can be slender.

Addition of fig. 5a and fig. 5c gives fig. 5d with two tension rods.

The top of the columns are fixed in fig. 4b. The roof also has to resist longitudinal horizontal forces from the windload on the façade and windfriction on the roof (fig. 4c). The beam, a rolled-steel joist or a lattice girder, can resist a vertical but not a horizontal load. The horizontal load is absorbed in the roof plane by a truss formed by the beam, the girders and the rods (fig. 4d), together forming a huge lattice girder.

When the rods are intersecting diagonals, windpressure and suction can only lead to tension in the rods, like in fig. 5d.

In fig. 4d longitudinal stability is realised by a stability truss. To resist the windforces, stability trusses are constructed in the bays near the lateral facade of the building (fig. 6).

Fig. 6. Stability trusses are usually placed in the last normal bays near the lateral facade. Only the elements in the visible faces are shown.



When lateral stability is not assured by choosing scheme 2a, or when the displacements by wind load in lateral direction are too great, another stability truss in longitudinal direction can be fitted (fig. 7). The tie rods in the trusses also have a function when erecting the structure. Sometimes in 19th century structures, the roofboarding is placed in diagonal direction, instead of tie rods in the roof plane. In this case the roof is rigid in itw own plane.

Fig. 7.

Stability truss in longitudinal direction used when the frame is not stable in lateral direction of when the displacements are too great.

Only the elements in the visible faces are shown.



THE CORN EXCHANGE, GRONINGEN, THE NETHERLANDS, 1865



Fig. 8. The Corn Exchange. The brick building (left) and the hall behind it (right).

The Corn Exchange has a main brick building with two floors (fig. 8 left) and a hall with an iron structure behind this brick building (fig. 8 right and fig. 9).

The lower part of the hall is supported by walls of brickwork and cast-iron columns with nice cast-iron beams between them².

In the upper-level the columns double. The span is 12 m.

The cast-iron columns are slender and provided with cast-iron cantilevers³. Polonceaus trusses⁴ are resting on the cantilevers and support wooden girders with boarding.

Fig. 9. The hall. Masonry walls, cast-iron columns and beams in the lower level; cast-iron columns with cantilevers and Polonceaus trusses in the upper level.



The end of the hall is formed by a hexagon (fig. 10). The half Polonceau trusses are coupled by a ring which is connected by a tension bar to brick $building^5$.



Fig. 10. The end of the hall. The end is formed by a hexagon. The half Polonceau trusses are coupled by a ring which is connected by a tension bar to the brick building. The structure of the upper level of the hall, the columns and the Polonceau truss, cannot resist a lateral load.

The roof is rigid in its own plane by the diagonal boarding (fig. 11). The lateral loads are carried through the roof to the heavy brick building and the hexagonal side.

There the loads can only be absorbed when the six windows are rigid in their own plane and can resist shear forces.

The columns and window frames are constructed lightly so the window-panes must have a function in resisting the lateral forces.

In this case it doesn't causes problems.

Likewise in 19th century glasshouses the window panes sometimes assure the stability 6 .

Longitudinal stability is assured by the brick building in front of the hall.



Fig. 11. Roof plan. Lateral stability. The force is carried through the roofplane to the brick building and the hexagonal end.

EXHIBITION HALLS, BRUSSELS, BELGIUM, 1888



Fig. 12. Final façade of the hall after three bays were torn down in 1909-1910.

Two similar halls were built by Gédéon Bordiau as an extension of the exhibition complex of the Parc du Cinquantenaire (Jubelpark) (1880)⁸ for the international exhibition of 1888 (fig. 12 and 13).

The span of the halls is about 50 m.

One is used now as the aircraft hall for the Army Museum.

The main structure consists of iron lattice arches⁹ and iron lattice girders. The arches assure the lateral stability.

To get stability in longitudinal direction stability trusses are used in several bays of the roof between the arches. In the longitudinal glass façade the stability rods are missing (fig. 14). The glass panes have to absorb the shear force. When the shear force is getting too great some panes will break. When there is a storm the hall has to be closed because of danger of falling glass.

Fig. 13. The main structure consists of iron lattice arches and iron lattice girders.



Fig. 14. Stability trusses in the roof planes. In the glass façade the stability rods are missing. Some glass panes are broken or replaced.



In 1909-1910 three bays of each hall were torn down to get a better perspective view through the new arcade by Charles Girault (1905) and the final façade was made¹⁰.

THE CENTRAL MARKET HALLS, PARIS, FRANCE, 1854-1866 THE BALTARD PAVILION, NOGENT-SUR-MARNE, FRANCE, 1977¹¹

In 1851 the construction started of the new market halls in the centre of Paris. The design was made by Victor Baltard and Félix Callet and mainly consisted of brickwork.

At this time the first iron railway sheds were built and some opposition against the heavy masonry buildings was heard (Napoléon II: "Ce sont des vastes parapluies qu'il me faut"¹², Baron Haussman: "Du fer! Du fer! Rien que du fer"¹³).

In 1853 the construction was stopped and the masonry buildings were demolished. A new design by Baltard and Callet was made based on an iron frame. It consisted of four large pavilions (54 x 54 m) and eight smaller ones (54 x 42 m) separated by 15 m wide covered roads (fig. 15). Under the halls were basements for storage.

The walls of the lower level of a pavilion consisted of a frame of cast-iron columns and arches, with brickwork and glass filling. The upper level was supported by cast-iron columns. The upper façade was an iron frame with a glass filling.

The roof structure was made of iron lattice beams and girders, covered by wooden boarding.

There were no stability trusses in the roofs and façades.



Fig. 15. The halls in a bird's-eye view. Four large pavilions and eight smaller ones separated by covered roads.



Fig. 16. Lateral cross-section through a small pavilion.



Fig. 17. Scheme of the structure of the lower part of a small pavilion. Only the main elements are drawn.

All the beams are rigidly connected to the columns. How is force F1 carried through the structure?

The columns AB and DC are forming a frame with beam BC. As the columns are slender the frame ABCD will not have a great stiffness. Though the wooden boarding is not placed in diagonal direction, the roof plane OSVW will have a certain stiffness. The force F_1 is carried partly through the roof plane to frames similar to ABCD, partly to the frames formed by the columns and beams in planes EFGH and IKLM and also to the lower lateral façades NOPQ and RSTU. The distribution of F_1 over the elements depends on the relative stiffness of these elements.

There were some differences in shape, structural design and ôrnamentation between the large and the small pavilion¹⁴. Fig. 16 shows a lateral cross section through a small pavilion. The 15 m wide roads were covered by lattice arches without horizontal tension rods¹⁵.

What about the stability of the pavilions? In this case we will only look at a small pavilion. How are forces F_1 and F_2 in the middle of the longitudinal façade carried down through the structure? (fig. 16 and 17).

Beam BC is rigidly connected to columns AB and DC. The columns and beams are forming a frame. As the columns are slender the frame will not have a great stiffness.

Though the wooden boarding is not placed in diagonal direction the roof plane OSVW will have a certain stiffness. The force F_1 is carried partly through the roof plane to frames similar to ABCD, partly to the frames formed by the columns and the beams in planes EFGH and IKLM and also to the lower lateral façades NOPQ and RSTU.

The way force F_1 is distributed through the structure depends on the relative stiffness of the construction elements.

A similar discourse can be given about the way force F_2 and longitudinal forces are carried through the structure to the foundation.

The now demolished building complex had resisted storms for over a hundred years and was one of the finest 19th century iron structures.

In 1975 the demolition of the complex started. One of the smaller pavilions, nr. 8, the poultry pavilion, has been taken apart and is rebuilt in 1977 in Nogent-sur-Marne near Paris (fig. 18 and 19) It serves as a multi-purpose hall for all kinds of events, e.g. expositions,



Fig. 18. The Baltard Pavilion in Nogent-sur-Marne. Rebuilding of one of the smaller pavilions.

congresses, dinners, etc.



Fig. 19. The Baltard Pavilion.

The roof boarding was replaced by a metal cladding. At the corners of the lower and upper façades dipping struts are added. Trusses are added in all roof planes.

The roof boarding was replaced by a metal cladding and the way the stability is assured has changed too (fig. 19).

Near the end of all upper and lower façades a diagonal strut was added, which can resist tension and compression. In all roof planes stability trusses were added. Without knowing the backgrounds the heavy dipping façade struts in the lower level seem to be overdone. The metal roof cladding can be constructed in such a way that it can resist shear forces and in that case stability trusses in the roof are not necessary.

CONCLUSIONS

Stability has been a quite neglected field of attention in the 19th century. This can be concluded from the analysis of structures and from the study of literature. Corrugated iron cladding, wooden boarding and glass panes regularly had a

function in assuring the stability of a building.

This did not necessarily lead to problems. In that case it can place our present views in a different perspective.

In some cases structural additions seem to be necessary or wise.



- 2. Circle shaped decorations are often used in the 19th century as well in cast-iron beams and cantilevers as in trusses. They sometimes just have a decorative function, When they have a function in resisting forces, they are often undesirable from a structural point of view.
- 3. A load on the cantilever implies bending of the column (tension and compression). Cast-iron is a material which can resist compression very well, but it hardly can resist tension.

Polonceau truss

The Polonceau truss was invented by Camille Polonceau (1813-1859), a French railway engineer and put into practice for the first time in 1839 in a shed at the Paris-Versailles railway.

It is a common type of truss in the 19th and the beginning of the 20th century.

First article of Polonceau:

4.

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Some historical notes and a structural approach in: NIEUWMEIJER, G.G., De Westergasfabriek te Amsterdam deel II, <u>in</u> Industriële Archeologie, nr. 10, 1984, 4-25.

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- 8. The exhibition complex of 1880 was constructed to celebrate the 50th anniversary of the Belgium independence.
- 9. Lattice arches became popular at the end of the 19th century. Usually the rims are supported perpendicular to their plane to avoid buckling when the rim is under compression. In this case the lower rim is not supported.
- 10. The façade struts are connected to the arch. It would be better to connect them directly with the roof from where the stability truss can carry down the horizontal wind load on the facade.
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Brochures de Pavilion Baltard, Nogent-sur-Marne.

- 12. For me, large light roof structures are a must.
- 13. Iron! Iron! Nothing but iron.
- 14. From a structural point of view the structure of the large pavilions is more questionable than the structure of the small ones.
- 15. The horizontal reaction caused by a vertical load has to be provided by the pavilion. This means an extra horizontal load on it.

THE PADERNO BRIDGE ON THE ADDA: ITALY'S GREATEST EXAMPLE OF 19th CENTURY IRONWORK ARCHITECTURE.

Anna Maria ZORGNO TRISCIUOGLIO*

SUMMARY

The bridge can no longer handle the extra traffic created by the State Railways road-rail link programmes. It will therefore be replaced by a new bridge. Though the new bridge is undeniably essential it also creates the need to affirm the significance of the Paderno bridge and to investigate ways of preserving it. The Paderno bridge is not only a fundamental event in the history of science and construction engineering. It is also the supreme exam ple of the progress achieved by Italy's late 19th century civil engineers and steel industry in the service of the railways.

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INTRODUCTION

Built across the Adda gorge near Paderno in 1887-1889, the bridge is an iron lattice beam arch structure with 150 m span and an overhead road/rail deck. Thanks to its daring concept, elegant proportions, meticulous design and perfect construction it was soon classed among the great bridges of its time like the Mississippi. Douro, Truyère and Schwarzwasser.

Today the bridge can no longer handle the extra traffic created by the State Railways road/rail link programmes and it will be replaced by a new one. Hence the need to underline the significance of the Paderno bridge and to ensure the long-term preservation of a structure that was recognised as an environmental and architectural treasure four years ago.

With this in mind, the Turin Polytechnic study group of which I am a member* first collected a complete dossier on the design and construction of the bridge. We then proceeded to place it in the general context of Italian civil and railway engineering in the late 19th century.

After that we approached the problem of how to preserve the bridge. We were not, at the time, concerned to develop any specific plan for its use or restoration. We were merely conducting an initial general survey into the safety of the structures involved using the appropriate methodologies and instruments, in order to verify the hypothesis of its possible preservation.

THE HISTORICAL BACKGROUND

The steel arch bridge from the early days to the late nineteenth century.

Between the end of the 18th to the second half of the 19th century, many of Europe's greatest engineers, including men like Aubry, Telford, Bruyère, Lamandé and Stephenson, proposed the construction of an iron bridge with a span of over 100 metres. Though technically feasible, the project was never realised for a variety of reasons. In fact the first large span arch bridge was the one built in St. Louis, U.S.A. in 1868-1874 when James Eads put his three great arches, each with a span of over 150 m. across the Mississippi. Over the next twenty years the Europeans again took the lead. In part this reflects the many mountaino us routes and major natural obstacles the railway builders were faced with. It was also the consequence of growing concern (already considerable

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in the 1850s) about the safety of suspension bridges and the weight and cost of beam bridges with a span of over 100 metres. The bridges created in Europe were technically far superior to the St. Louis. For one thing, there was a dramatic development in structure theory under the aegis of Clapeyron, Bresse and Culmann in France and Switzerland during the second half of the century.

It is interesting to note that those works adopted the very criteria used in designing beam railway bridges since the late 1850s. In fact these criteria have been fundamental to large scale bridge building ever since. The use of tubular steel, the lattice type morphology of the beaming structures, the welded plate, section and girder composition, these and the concept of cantilever construction gave birth to the large span bridge.

When it was built, the Paderno bridge had the fifth largest span in the world. It was also the first bridge design based on a rigorous application of the ellipse of elasticity theory (fig. 1).

Italian iron-working and production in the second half of the nineteenth century.

The Paderno bridge is our most concrete proof of the progress made by the Italian iron industry which only began to emerge from long years of foreign dominance in the early 1880s.

When the kingdom of Italy was proclaimed in 1861, Italian iron working was still little more than a cottage industry. We had some, though not much, iron ore but no fossil coal. Furthermore industry was curbed by a restrictive tariff policy imposed first by the individual states, later by the unified kingdom. The first Italian iron works were, in effect, small, primitive workshops producing or refining cast iron. Some indeed were refineries only processing cast iron from abroad, especial ly Britain, as well as the home-produced metal.

It was not until 1870-1880 that major social and economic change began to lay the foundations for substantial progress in the Italian iron industry which benefited from foreign capital, the moderately protectionist tariff policies of 1878 and the creation of an industrialist class committed to the formation of its own collaboration arrangements. Coke also became a more easily obtainable and attractive resource as the development of the railways made for easy, cheap and fast deliveries and steam rapidly replaced hydraulic power.

Furthermore new industries were created out of the development of mechanical engineering processes and the need for new weapons. All these factors combined to stimulate a radical change in the Italian ironworking industry. We see the greatest progress in the production of pig iron since cast iron production was hampered by worked out mines, the lack of fossil coal and foreign competition. This period also saw the start of large scale puddled iron production especially after the introduction of steel rather than iron railway tracks around 1870.



Fig. 1 - The Paderno bridge seen from the valley: a contemporary photograph. The rail tracks used to transport the timber for the service bridge and Moltrasio stone for the abutments are still faintly visible on the partly dried out riverbed.



Fig. 2 - Around the 1870s the Como-Monza-Milan-Treviglio-Bergamo-Lecco area, already outlined by a basic railway network developed in the absence of a unified plan, was covered by a web of additional diagonal and longitudinal branch lines. The widespread introduction of the Siemens furnace also meant that poor quality fuels could be used and the furnaces employed not only for refining cast iron (mostly foreign) but also for re-smelting and forging.

The biggest foundries (Tardy and Benech) were situated in Liguria but others grew up in Lombardy, the Veneto and Tuscany. As well as the primary treatment of iron and steel, the gradual replacement of the old hammer by rolling mills also stimulated secondary processing. The training of managers and workmen showed similar progress. Young Italians out of technical schools began to replace foreigners as factory managers.

The problem of the road/rail bridge over the Adda at Paderno.

Between the unification of Italy in 1861 and the mid-1880s the Italian government was committed to the reorganisation and planned development of the country's railway network as we see from a whole series of proposals for railway organisation, policy statements and administrative measures. These were the years that saw the completion of the comprehensive Lombardy railway network that covered the entire region by the end of the century. It was not until 1875 that the Lombardy-Veneto line was purchased by the Italian government and detached from the rest of the South Austrian railway network.

However as far back as the early thirties the first proposals for the creation of a Lombardy railway network had begun to emerge. The aim then was to supplement the canal network that supplied Lombardy with its major communications system. One such proposal was for a Milan-Como line that would link the Lake Como ferry service to the Alpine passes, especially the Spluga. Another was for a Milan-Venice line that would provide a link with the sea while avoiding state customs barriers. The first railway line to be built in the kingdom of Lombardy and Veneto was the short Milan-Monza line opened on August 18, 1840, the Milan-Como line completed five years later being its natural extension.

In 1857 the Lombardy-Veneto Railway Company opened the Milan-Venice line.

By 1859 many of the frontiers between Italian states had fallen and Lombardy was finally free to develop a railway network. The next few years saw the completion of the Lombard network in line with the region's specific development trends and requirements. Increasingly the railway was required to support the region's industrial growth dating back to the opening of its first cotton and linen mills in 1830-1850. Thus in addition to the lines radiating out from Milan, others stretched down and across the Po Valley. The former linked the plain to the Alpine foothills and mountains where manufacturing industries abounded and stretched as far as the Simplon, St. Gotthard and Bernina passes. The second provided easier access to the Adriatic ports and linked the cities of N.E. and N.W. Italy.

Other diagonal lines were added to the railway web to provide short

cuts between towns already connected by earlier lines. These were vitally important in those parts of Lombardy like the mid and upper Adda valley where both industry and agriculture were in full expansion. The Paderno lock, for example, created to span the rise of some 80 metres at the Adda rapids, could no longer ensure a regular flow of goods from Lecco to Milan. In addition trade between Monza and Bergamo expanded substantially after the Milan-Como-Monza line was opened.

It thus became necessary to fill in the basic framework with a web of longitudinal and diagonal lines forming a system of braces which provided faster communications between the perimeter lines. The Seregno-Usmate-Carnate line extending the Saronno-Seregno and the Usmate-Carnate-Ponte S. Pietro-Bergamo line were longitudinal (fig. 2). The latter was also required to cross the upper Adda. The river at that point was a considerable obstacle since the middle section of the Adda, which feeds and is fed by a lake, runs through a deep gorge and the water level at Paderno is 80 metres below the level of the surrounding land (fig.3).

Structure and size of the Italian metal working industry in the second half of the 19th Century.

When the Italian railways were first developing, the country's engineering industry lagged far behind other countries'. Foreigners supplied Italy with prefabricated steel parts, engineering designs and in many cases the designers and skilled workers engaged in supervising and constructing engineering projects. Not until the decade after unification did Italy begin to supply its own wood, masonry and steel parts and its own work force for building projects.

Even then steel parts were still purchased abroad. Indeed many foreign companies, having won major contracts for steel structure work in Italy, set up temporary workshops on the construction site and dismantled them when the work was completed.

For all these reasons the first Italian companies to produce steel structural parts were only marginally involved in such work. Most of them were foundries or engineering companies working for the railway, shipping or armaments sectors. Their production volumes fluctuated dramatically as crisis followed crisis and such companies changed hands frequently due to lack of capital. The railway companies were therefore forced to go abroad for their rolling stock and the construction materials for major works.

There was no real growth in the structural steel industry until 1870-1880 and even then only in association with other Sectors. However Italian industry did find several worthy representatives at the Exhibitions in Milan (1881 and 1884). Among these we might mention the Impresa Industri ale Italiana di Costruzioni Metalliche, the country's first genuine producer of structural steel, founded in 1870 by Alfredo Cottrau and benefiting from particular political and operating conditions to produce continuous growth.



Fig. 3 - Side view of the Seregno-Ponte S. Pietro railway track across the Adda. The Strade Ferrate Meridionali Works Department modified the route of the Usmate-Paderno line af ter a more detailed examination of the terrain on the left bank. A second design was therefore produced incorporating slight geometrical changes.



Side by side with Cottrau's Impresa Industriale at the Turin Exhibition was the younger Società Nazionale delle Officine di Savigliano. This company was born as a "major repair shop" for the Cuneo railway line and its branches, a rola in which it was supplanted by the Officine di Torino after being taken over by the state in 1861.

This event was followed by a rapid decline in production volumes and a considerable reduction in the workforce employed. It was not until fifteen years later (1878) on the eve of the introduction of new protectionist tariffs that it was decided to revive the company. The old Officine which the Compagnia delle Strade Ferrate dell'Alta Italia had handed over to Savigliano Town Council were transformed into a limited company owned by Ernesto Rolin the former General Manager of a Belgian construction company. The General Manager of the new company was Ottavio Moreno former Head of the traffic and materials service in the Società Italiana delle Ferrovie Meridionali and the designer of several impressive rail shed roofs. By the time of the Turin Exhibition, the company was not only producing rolling stock and steel rail sheds, but had also produced and laid over 2600 t of steel girders for railway bridges and was currently building a further 6000 t as well as having acquired considerable experience in the field of compressed air foundations.

In 1885-86 bridge building was the biggest item in Italian railway work. Bridges were flung over the Adda at Trezzo, over the Tanaro at Asti, over the Po at Casale Monferrato and Casalmaggiore. 1889 saw the completion of the bridge on the Po at Cremona, and the Paderno viaduct on the Adda. By that time the Savigliano was already well on the way to becoming the biggest bridge building company in Italy and one of the biggest in Europe.

The Savigliano Project.

When the Higher Council for Public Works put out a tender for a bridge across the Adda near Paderno, the Società Nazionale delle Officine di Savigliano was one of four bodies to present projects, the others being the State Office itself, the Strade Ferrate Meridionali and another Italian company. The Savigliano project was for an iron viaduct consisting of a large 150 m span arch with a rise of 87.5 m on rock abutments, topped by a road/rail deck 266 m wide supported by nine piers 33.25m apart (fig. 4).

Four of the piers are supported by the iron arch, two are on the abutments and the remaining three are mounted on iron piles reting on masonry plinth. The lattice beam deck is dual purpose. The railway line is lodged inside the beam with the road 6.30 m higher running above it (fig. 5).

The deck has two horizontal bracing systems one below the roadway trussing, the other underneath the railway line. The iron bridge is made of two arches, the axis of each being a parabola placed at an angle to the horizontal and both having a span of 150 m and a rise of 37.5m.



Fig. 4 - Projection and elevation view of the bridge. The continuous deck is divided into eight bays and hinged to the arch between bays 4 and 5; all the other bearings on the piers and abutments are sliding roller type.



Fig. 6 - View of the bridge from the left bank: from a contemporary photograph. As a result, the width of the arch increases from 5 metres at the key to 16,346 m at the springer. Each arch varies in height from 4 m at the key to 8 m at the springer line and is supported by a variable section upright and diagonal struts (fig. 6). The two lattice arch walls are linked by lattice trusses reinforced by two continuous bracing systems, one at each side. The arches rest on masonry plinths surmounted by cast iron wedge-regulated bearings. Each pile consists of two raked trellis frame struts linked together by a system of horizontal beams and St. Andrew's crosses. A service walkway 1 m wide runs along the axis of the bridge.

Having studied the four designs presented, the Higher Public Works Council opted for the Savigliano project which offered the necessary stability at the lowest cost and the shortest construction time.

The General Managers of Strade Ferrate and Savigliano signed the contract on January 22 1887 on the understanding that the bridge would be completed 18 month from that date.

The designer.

Jules Röthlisberger (1851-1911) was studying under Culmann at the Zurich Polytechnic in the years when the first editions of Die Graphische Statik, Parts I and II were spreading their revolutionary message on the basic principles of static concepts in Germany, France and Italy. After graduating in 1872, Röthlisberger joined Ott & Co. in Berne as a structural steel designer. Here he was able to learn from the widely experienced Moritz Probst and the German engineer Paul Simmons. Röthlisberger and Probst designed the ReufsBruche in 1877 and the Javroz bridge in 1878-80. Röthlisberger then worked with Simons on the Schwarzwasser bridge project (1881-82). All of these were major achievements of late 19th century bridge building. The three men worked together on the Kirchenfeld bridge on the Aar at Berne (1881-83).

Ott & Co. closed down almost simultaneously with the completion of the Kirchenfeld bridge, so Röthlisberger and Simons set up their own studio first in Berne, later in Milan. The two designers were extremely successful as is shown by their winning the international tender put out by the Rumanian Ministry of Public Works in 1882 for two bridges, one over the Danube, one over the Borcea. The Röthlisberger-Simmons design for the Danube was a beam arch bridge with the arch half above half below the beam in three spans of 206.7 m each and incastré springers.

Röthlisberger and Simons split up almost immediately after winning the Rumanian tender. Simons settled in Berne, while Röthlisberger accepted the invitation to join the Società Nazionale delle Officine di Savigliano, where he soon (1884) became Head of the Technical Division, a post he feld for 25 years. It was thanks to Röthlisberger that the Savigliano company dominated Italian bridge building during this period. The bridges on the Po at Casalmaggiore, Cremona and Piacenza, the Trezzo and Paderno bridges on the Adda are just a few of the most important iron bridges



Fig. 5 - Detail of deck and arch junction.

built by the Savigliano company to Röthlisberger's executive drawings. Nor is that all.

In 1885-1900 Röthlisberger designed bridges were built by Savigliano in Switzerland, Greece and Rumania. His expertise in the field of metal structure stability was also widely recognised, as when he was asked to investigate the Mönchenstein disaster (1892).

Structural calculations.

The springer arch system was widely adopted in Switzerland from the earliest years of Swiss structural iron and steel production (cf. The Olten railway bridge over the Aar 1854-1856 and several Ott & Co. bridges in Berne). This preference reflects the Swiss bridge builders' emphasis on stiffness, shown in their frequent use of the continuous beam and welded joints in trellis beams and their employment of extra-stiff bracing. The influence of Culmann was significant in this respect, since not only at the Zurich Polytechnic, but in his private practice he emphasised his preference for hyperstatic designs as providing the greatest possible stability.

Furthermore, especially when it was necessary to cross deep ravines so that a single span bridge was the only possibility, the most suitable assembly technique was to use temporary falsework rather than cantilevering The Swiss of course were highly skilled in this technique thanks to centuries' experience in the building of wooden bridges. Another standard feature of Ott & Co. projects was the use of arches encastered into the springers, a deck-type roadway, and the characteristic spatial geometry created by the dense bracing system linking twin, rated parabolic arches.

Very probably the Paderno was one of the first large arch bridges designed and constructed according to the ellipse of elasticity theory. It is certainly the only one for which the designers published the entire calculation process.

As early as 1885 Röthlisberger and Simons had published the calculation methods used in designing the Cernavoda bridge on the Danube in 'The Engineer', having been invited to do so by Robert Hudson Graham who was concerned at the ignorance of Culmann's treatise on elastic arches displayed by most British engineers. The 1885 article already demonstrated what Röthlisberger was to call the 'practical analytical method' when he published a series of memoirs in 'Ingegneria Civile e Le Arti Industriali' (1886), a method that is also presented in the Savigliano monograph of 1890. The practical analytical method is in fact the eclectic blend of drawing and analysis most authoritatively exploited by W. Ritter.

Culmann has been the first, in the last part on 'Die Graphische Statik' to recognise the fact that the interrelation of forces and movements at the end of a beam contained all the parameters required for the definition of the ellipse of elasticity. However, it was Culmann's pupil at the Zurich Polytechnic, Wilhelm Ritter (1847-1906) who clearly established the basic principles of graphic statics and in particular the ellipse of elasticity theory, transforming these theories into practical ways of analysing structures. Ritter's work was a great help to the engineers of Culmann's time who had been as disconcerted by the range and depth of the master's work as they were impressed by his ease of expression, clarity of concept and stunningly elegant graphic methods.

In the Appendix to Volume III of his work, Ritter recapitulates the basic elements of the ellipse theory as outlined by Culmann, presenting in clear and meticulous detail the various steps in the calculation procedures emerging from the theory. Here we see that Ritter was the first to understand the importance of using both drawing and analysis to solve construction problems. He was also the first to realise that one could be used to verify the other, exploiting the particular advantages of each system. This eclectic approach quickly won widespread acceptance from the mid-Eighties on. On the one hand it helped to reconcile the differences between the passionate supporters of pure analysis and the equally fervent apostles of pure graphics. On the other, it enabled many designers to acquire a solid professional stock of alternative struct<u>u</u> ral calculation methods they could use to engender a certain flexibility in the design process.

Röthlisberger 'practical analytical' method for calculating the resistance of metal arches as described in the 'Calculation Report' attached to the Paderno bridge project clearly belongs to the eclectic school. Note however that Ritter saw analysis as merely one way of verifying results obtained graphically and did not insist that it always be used in applying the theory. Röthlisberger, on the other hand, viewed the analysis itself as the application of the theory, using graphics merely to summarise and represent the analytical results (figg. 7-8).

In historical terms Röthlisberger solution to the problem of the interaction of arch and beam is particularly interesting. In the early stages he envisaged the deck as an elastic structure superimposed on an infinitely rigid arch, and evaluated the reactions developed by the rigid piers and expressed by the trusses. Later he applied such reactions to the arch, postulating an elastic arch and an infinitely yielding deck. Having calculated the movements at the contact points between deck and piers which result from the deformation of the arch, he repeats the calculation for the deck which is now considered as a continuous beam on yielding piers. The first stage of Röthlisberger's work ends with this statement of a step by step procedure. What the procedure indicates is that Röthlisberger saw the Paderno bridge not as a beam resting on an arch but as a combined system, a single structure involved as such in a single static experience.

Like the eclectic school, in other words, Röthlisberger's work belongs to a particular period of transition in structural mechanics, bridging the gap between the analytical mechanics of the Enlightenment and the early 19th century and the analysis of form that dates from



Fig. 7 - Measuring stresses in the arch lattice trussing rods. Distribution of total stresses in the arch beams and plate distributions.



Fig. 8 - Stress distributions in the arch beams under different loads.

the late 19th century and continues into the present day. Röthlisberger and the Eclectics offered their contemporaries practical tools for use in design engineering, providing a 'designer's manual' that was clearly and comprehensively expressed, the procedures and methods descibed in detail, supported by examples and instructions for their use.

The construction stages.

The construction of the Paderno bridge was fast, efficient and extremely well organised.

Work on the Service bridge began in May 1887, based on Röthlisberger's own executive drawings. At the same time another work party was busy excavating the foundations for the abutments of the arch.

The building of the abutment walls began in September 1887 and ended in May of the following year. In the meantime, Savigliano had nogotiated a contract with a German company for supplies of cast iron parts for the arch springers and had started production of the arch parts. These in fact were manufactured with such care and precision that no adjustments were required when they were put together. The big service bridge resting on seven arches with a clear 46.75 m span between the centre piers was finisced in May 1888.

The timber used in its construction was cut and shaped in timber yards on the banks of the Adda near Bergamo and then transported to the site for assembly. A temporary wooden deck laid between the road and rail levels and equipped with an auxiliary railway line was put up for the purpose. The arch was assembled by means of two frame cranes symmetrically positioned in relation to the bridge axis and fitted with lateral straddles designed to cover the work at its widest point. In this way assembly could take place simultaneously from both abutments, finally meeting at the keystone (fig. 9).

The time between the signing of the contract and the completion of the bridge was 26 months. Indeed only 22 months elapsed between start and finish of the actual construction work, including 50 days in the winter when work had to be suspended.

Over 140 executive drawings were made of the steel structure and masonry parts and the service bridge. Our own documentation contains a hundred or more. The care taken in illustrating every detail bears witness to the professional skill and graphic ability, not to mention the unusually high degree of conceptual clarity inherited by the Savigliano company from its traditional involvement in railway engineering.

This graphic expertise certainly made a significant contribution to the company's success in an era when projects were laid out by hand using hammers, chisels and set-squares and precision depended on the availability of detailed drawings complete with accurate measurements. Certainly this was essential if assembly was to proceed at speed with no pauses for the construction of made-to-measure pieces.

There is no doubt that a complex structure like the Paderno bridge


Fig. 9 - The completed service bridge (contemporary photograph).



Fig. 10 - View of the fracture in tensile strength test pieces and two notched bar test pieces (magnification X1. 5). The two notched bars were cut transversally with the notch parallel and perpendicular to the plate sides. could not have been finished in so short a time without such drawings.

The material.

Towards the end of the 19th century, when the mild steel produced in Bessemer convertors or Siemens furnaces was becoming as commonly used as wrought iron, the Governments and engineers of various countries became increasingly concerned about the standards and precautions required in the construction and maintenance of iron and steel structures.

Between 1887 and 1893, the old inadequate regulations in force in the different European countries were replaced by a comprehensive new code in line with the heavier rail traffic, improved iron and steel production techniques and advances in construction science characteristic of the era. The new codes were introduced almost simultaneously in Austria, Hungary, Germany, Switzerland, France, Russia, Britain and the U.S.A. Italy followed suit a little later.

A large number of experiments into the mechanical properties of materials and other experiments on completed projects lay behind the introduction of the new regulations, as the results received widespread publicity at International Congresses in Philadelphia (1876), Hamburg (1878), Brussels (1885), Milan (1887), Paris (1889), St. Petersburg (1891), London (1895) and again Paris (1900).

In Italy, the first official statement on the quality and resistance standards to be met in the ferrous metals used on bridge decks was the Ministry of Works 'General tender Conditions for State railway constructions' published in 1887. In the same year the General Railway Inspectorate published its 'Special tender conditions for the metal decks used in auxiliary railway constructions'. This document gives details of stress tests, construction standards, and the tests to be conducted on finished structures as well as specifying design and general materials quality standards. These standards became law in 1888.

In January 1887, Savigliano accepted the conditions proposed by the contractor, Strade Ferrate Meridionali. On the subject of materials quality the contract specified that "all ferrous metals are to be perfectly laminated, mild, not fragile, malleable hot or cold" with a texture that is "fibrous, fine, grained, homogeneous, cohesive and bright" and finally that the metals should have a strain resistance and Young's modulus elasticity limit above 35 and 15 Kg/mm2 respectively and a tension of no less than 8%".

The company's calculations showed the following maximum tensions in the iron framework parts: arch ribbing 5.7 Kg/mm2; lattice bars 5 Kg/mm2; braces only 4.2 Kg/mm2. These figures lie within the standards imposed by the 1888 Code. The resistance tests specified in the Code and carried out by the company also gave satisfactory results. Of the 57 samples only 17 revealed a strain resistance of less than the required 35 Kg/mm2, three were not cold malleable and four were seriously defective.

In view of these results and on the basis of current standards,

it seems reasonable to assume that the material used on the Paderno bridge was the type known as wrought or weld iron.

Measurements and structural tests.

The first load tests were conducted on the finished viaduct in 1889 (preliminary test) and repeated in 1892 (final test). By contemporary standards the testing was extremely meticulous. Whereas testing was usually limited to measuring the deflection of the main beams, the Società delle Meridionali contract signed by Savigliano insisted that not only should all flexible parts be subjected to deflection tests but also that permanent deformations, the lateral oscillations caused by fast rail traffic (the permitted maximum being 2/10.000 of the distance between the beams) and the effective stress of the parts subjected to most strain. The preliminary test carried out in May 1889 imposed loads of 3.9 t/m over the entire length of the roadway and 5.1 t/m on the rail deck. The deflections in the roadway structures measured by hydraulic test pieces fitted with graduated tubes and the deformations of the arch measured by 'slide sighting stakes' agreed with the theoretical results in both static and dynamic tests. The tests were repeated in 1892 when the introduction of new government standards for railway structures and operations (a new type of locomotive was introduced on the line in 1891) made it obligatory to compare the first and second set of results in order to 'provide reliable information on the stability of the viaduct'. The test conditions were rather different the second time since the service bridge had been dismantled, the road traffic could not be halted. and the new type of locomotive was used for load testing. The results however were as satisfactory as before.

Maintenance operations.

Since 1894 the maintenance of the bridge has been the joint responsibility of the Provincial authorities and the State Railways.

Some of the deck ribbing suffered bomb damage in 1944-45 but the great iron arch was essentially unharmed.

The Army of Occupation carried out temporary repairs and in 1953 the bridge was properly repaired, when diagonals and a section of upper beam in the badly damaged 3rd and 4th bays were replaced. Parts of the framework (beams, cross members and girders) were also repaired and strengthened, the road deck frame was rebuilt as were the Zorès plates in three sections of Bay 3. The temporary emergency welding was also reinforced by rivets.

In 1956 the viaduct was completely repainted.

It was in the Fifties that the State Railways imposed a 15 Km speed limit on the rail deck in view of the much heavier loads the bridge was required to carry.

At the same time, the Provincial authorities imposed an 8 kph speed limit and alternating one way traffic on the road deck while maintaining the 3.9 t/m weight limit and the 100 m spacing of vehicles on the bridge. Finally in 1972 simultaneous rail and road traffic was avoided by the installation of traffic lights to halt road traffic when trains were crossing the bridge. When advanced corrosion was also found in the Zorès plates on the form this was dismantled and replaced by an orthotropic floor of 15 mm thick steel plates, longitudinally braced.

Currently the weight and speed limits on the railway deck are 16t and 10 kph respectively.

STRUCTURAL INVESTIGATIONS

Material analysis and mechanical tests.

Since it is presently impossible to test material from the bridge under investigation, in order to identify, or at least get a general picture of bridge mechanical and metallurgical properties it was first of all necessary to seek information and data obtained from tests already carried out on any bridges and construction materials of the same era that could reliably be compared with Paderno bridge.

The information collected confirms a fundamental material property - material structure is, overall, non-homogeneous and anisotropic, contains a large number of non-metallic inclusions and is systematically stratified, the strata lying parallel to the lamination plane and extending in the direction of lamination.

Baumann prints, carried out on a sample section of a contemporary bridge and on Paderno Bridge material in 1972, show sulphur segregations arranged in extended veins parallel to the stratification plane and denser towards the sample core. The break has a woody, sometimes book-like, appearance with pronunced alignment of non-metallic inclusions.

Chemical analysis reveals a very low percentage of carbon, confirming the ferrous nature of the structure, and an extremely high phosphorous content (almost ten times the minimum permitted by current regulations covering present-day steels).

The full range of documentation relating to metallographic investigations and chemical analyses fully confirm the fact that the material used in the Paderno bridge is "wrought iron" as classified by the Philadelphia International Commission of 1876. This was obtained by agglomerating and laminating pasty masses formed from scrap blooms (bloom iron) or decarbonated molten cast iron in air furnaces (puddled wrought iron).

The results of tensile tests carried out on 57 bridge material samples at the time of its construction show that the iron displays reasonably fair yield and failure stress values.

Stretch values are, on the whole, lower than those specified for present-day steels and its poor ductility was confirmed time and time again.

When the results of the tests carried out at the time of bridge construction are compared with those carried out today in as much as they are comparable after nearly a hundred years using different test procedures, it may be concluded that Paderno bridge materials today essentially conserve their original mechanical properties both in terms of strength and ultimate elongation (fig. 10).

The results of Mesnager resilience tests carried out on Paderno bridge material in 1972 were compared with the results of recent tests carried out on material from bridges of the same era. The most important finding was the lack of toughness displayed by the Paderno bridge material. This was to be expected on the basis of the stratified iron structure and the high phosphorous content shown by the chemical analysis (fig.11).

Structure safety in relation to material properties.

Available documentation reveals that Paderno bridge material mechanical, metallurgical and chemical properties fall short of present day steel requirements on the whole. The non-homogeneous structure, stratification, high phosphorous content, pronunced orthotropy, especially as regards ultimate elongation and resilience, and extremely low resilience values all add up to give a negative impression of bridge material.

Since the bridge is, however, a riveted structure it is not subject to the heat induced changes and self-stresses due to shrinkage that plague welded structures. For this reason riveted construction material need not be nearly so tough as the material used in a corresponding welded structure, disregarding the effects of initial or subsequent defects. Finally, a riveted structure is not subject to the discontinuity of shape notch effects often found in welded structures.

All those conditions are met by the Paderno bridge and we are convinced that the lack of material toughness shown by tests carried out to this date is neither a cause for concern nor particularly significant in determining bridge safety under the present conditions of use.

State of conservation of the structure.

At thirty years since its last painting, as far as we can see the bridge's state of decay is dependent on original design defects and situations arising from badly performed maintenance operations. The bridge's state is also characteristic of iron structures and similar problems have been encountered during maintenance or restoration work carried out on other nineteenth century structures.

Within the first category we can count the excessive slenderness of some trusses, especially within the arc braces and the tendency of deck tubular section supports to buckle. Other problem areas are the backwaters and refuse collection points, particularly in arch braces between banks and springers.

Within the second category we must count the failure to replace the protection and curtaining of structural metal and plates along the present compound trussing joints, originating from the leakage of water onto interstitial joint surfaces, in turn aided by the fact that rivet spacing is' relatively greater than plate thickness (fig. 12). Another



Fig. 11 - View of the fracture in the nine notched-bar test pieces (magnification X2) from the material used on a contemporary bridge (on the Lambro).

Fig. 12 - Curtaining of a plate and an an gle bar in the T sec tion of a deck diago nal.



problem coming into the second category is the inefficiency of road deck expansion joints which are all inefficient at present.

Geometrical conception and new structural calculation.

An examination of the drawings permitted us to satisfactorily reconstruct the process underlying bridge geometry at the time when it was built and in addition to establish the geometry of the new spatial model in line with the designer's original ideas.

This examination particularly highlighted the exceedingly simple geometry of the bridge: the four basic parabolas characterising the arch delimit a rigid, solidly anchored pyramidal section structure able to efficiently counter side-acting forces: these may be simply reproduced on a drawing sheet without the need to construct a three-dimensional model.

New bridge calculation was based on the construction of a spatial model of the structure able to take account of existing restrictions and spatial configuration in representing bridge behaviour. This model permits us to allow for "secondary stresses" at the nodes, a far from irrelevant factor due to the high rigidity of the trusses but which was overlooked during the original bridge calculation. The adopted layout, incorporating the whole bridge in a single model as it does, also allows us to thoroughly evaluate arch-deck interactions. The model consists of two parabolic curves both inclined by the same amount with respect to the longitudinal plane of symmetry. All arch trusses are included as on the actual bridge. These are transversally connected by actual braces. Only simplification was adopted: the double St. Andrew's cross braces lying towards the springers are reduced to a single cross. The underlying riveted plate, box section pile mounted section is ribbed and therefore much less likely to buckle than adjacent sections. This section has been represented as a spatial framework with trusses a thousand times more rigid than adjacent trusses (fig. 13).

Bearing in mind the unexceptional torsional rigidity of the deck, a result of the absence of efficient section diaphragms, the actual tubular lattice has become two flat, parallel beams consisting of four quoins for each 33.25 m bay. The two beams are connected transversally through a set of dummy braces (fig. 14).

In the encastered node spatial framework represented by the model, nodes at points where the deck rests on the piles are represented as carriages permitting longitudinal displacement and rotation about the axis of constraint.

The arch pile node at the straight deck centre line is, however, an exception as it consists of a single cylindrical joint and is considered to be a fixed support.

The structural analysis was carried out in a flexible field using an automatic calculation code based in the finite element method. In this way both static and dynamic problems could be resolved (Hercules



Fig. 13 - Plotted projection of the structural calculation model.



Fig. 14 - Model of a deck half-bay.

Code).

After checking model geometrical accuracy against the drawing and static correspondence by comparing calculated distorsion with induced test distorsions, we went on to calculate the general stress coefficients affecting all trusses and all node displacements. In this way we designed the best possible tool for the evaluation of induced structural effects under any load conditions whatever the conditions of use of the bridge.

Because of the bridge's lattice structure the effect of standard stress was always found to be by far the most important factor in all the tests carried out. For this reason, in the tests carried out, all stress influence lines were loaded to the same extent, i.e. corresponding to the maximum standard stress value.

Forces acting on the bridge structure and their different combinations were determined with reference to the technical standards covering road bridges and the associated instructions since the State Railways plans seem to indicate that the bridge will be mainly used for road traffic in the future.

Load conditions represented by bridge weight and permanent loads are, surprisingly, little affected by the yielding nature of the supports. In addition, in spite of the relatively short lattice beams, these reactions closely resemble those of slender beams subjected to constant inertia.

The new results essentially bear out the validity of calculations performed at the time of construction. Load conditions determined by heat variations, by moving loads and dynamic increase, longitudinal braking actions and wind effects were also considered.

The set of load conditions examined constitutes a basis for any safety check that may be carried out today, in a flexible field, on bridge structure. The only item of information missing for this check is the maximum stress that may be borne by the material under present conditions: a single value that could be broken down according to the different members in relation to their state of decay and planned restoration work.

Assuming, therefore, that we know the maximum material stress. The K parameter was used to define maximum operational overload for the bridge. The admissible stress method was applied to the following three load combinations:

 $\begin{aligned} G_1 &= g_1 + g_2 + \varepsilon_3 + q_3 \\ G_2 &= g_1 + g_2 + \varepsilon_3 + q_1 + q_2 + 0.6q_5 \\ G_3 &= g_1 + g_2 + \varepsilon_3 + q_1 + q_2 + q_3 + 0.5q_5 \end{aligned}$

When the proceeding load combination equations were applied to determine maximum stresses in truss outer sections, three diagrams, G_1 , G_2 and G_3 were constructed for each truss. These represent changes in truss maximum stress i.e. the test stress, as a function of multiplier



Fig. 15 - Diagrams of the arch structure in use, showing the major trusses involved.

coefficient K (fig. 15).

Whereas arch beams are most shielded from the effects of moving loads, arch wall trusses are hardly affected by permanent loads and the relative effect of moving loads on these trusses is much more pronoun ced.

The line set extended to all structural trusses is the best tool for assessing structural safety under any condition of bridge use or restoration. This set represents an accurate bridge utilisation diagram.

Conclusions.

In concluding this section on bridge safety, within the context of the investigation carried out, we would like to consider some alternatives for bridge reuse arising from the results obtained.

The archwas originally designed to take an effective deck overload of 9 t/m comprising 5.1 t/m on the railway and 3.9 t/m on the roadway: admissible material stress was assumed to be 600 Kg/cm2. This amounted to mean stress exerted on truss sections since bending stresses were systematically disregarded. If these stresses had been considered, although this was not technically possible at the time, admissible reference stresses would have had to be increased to maintain the same proportions. That is, on the basis of the ratio we found between maximum stress and mean stress (generally between 1.10 and 1.35) an admissible stress of some 800 Kg/cm2 would have had to be assumed.

Today, when the structural calculation was repeated with an extremely diversified spatial model, different load combinations were applied, bending stresses were considered, permanent loads were increased and wind action more than doubled, we found that for the same effective overload value of 9 t/m, maximum stress does not exceed 1200 Kg/cm2. This is true only for the first wall trusses attached to the springers. For all the beams and the other trusses, the stress falls below the stated figure of 800 Kg/cm2. This conclusion indicates that there is not much sense in limiting bridge use, until its demolition, to loads under 5 t/m for the safety of the arch and hence preventing its use as a road. Even required absolute admissible stress values (i.e. 700Kg/cm2 for an overload of 5 t/m) is not a cause for concern. Indeed, since the bridge is riveted, yield stress is always the determining factor: a yield stress of below 2200 Kg/cm2 has never been recorded either for Paderno bridge material or for materials used in any other contemporary bridge we considered.

There seems to be no risk involved today in allowing such material a reduced admissible stress value of 700 Kg/cm2, 1400 Kg/cm2 in the new bridge. The lower figure takes account of the degree of corrosion. With restoration and the strengthening of some trusses, it should not be difficult to increase admissible stress to 800 Kg/cm2, corresponding to an effective overload of over 10 t/m, more than twice the maximum required of the road bridge today. It has been suggested that this great bridge should be demolished or used only by pedestrians or bicycles once it has been abandoned by the railways as it will be once present state railways programmes are implemented. The bridge has doubtless suffered from the prolonged lack of maintenance but its 2400 tonnes of iron structure still ensure wide safety margins for road bridge operations. If it is suitably restored, these safety margins may easily be maintained far into the future.

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REGISTER OF THE DOCUMENT FILE EXISTING IN THE ARCHIVES OF THE SOPRINTENDENZA AI BENI AMBIENTALI ED ARCHITETTONICI OF FLORENCE AND PISTOIA CONCERNING THE PAVILION OF "LA MERIDIANA"

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May 23, 1874

This is the first relative document regarding the construction of the "Coperta in cristalli con armatura di ferro all'ingresso del quartiere di S.M. alla Meridiana dalla parte del Giardino di Boboli".

In this the architect, Ernesto Piazza presents for the approval of the Administration of the Royal House the proposed budget for the execution of the work based on the design approved by His Majesty. The architect writes about other designs that he is doing on a major scale, in order to proceed with the ordering of materials, for the execution, under the approval of the budget valued at L. 15,000,000. Making evident the urgency to terminate the work for the re-entry of the Royal Family at the end of the summer hunting season, he assures that he has sent ". . . pratiche officiose presso il rappresentante della Casa Mathieu di Lione, ma avuto riguardo alla mancanza di lavoro nelle officine del Paese, oserebbe proporre di essere facoltizzato a trattare con alcuni artisti e fonditori di qui, coi quali si procederebbe alla stipulazione di relativi regolari contratti, qualora si potesse ottenere uguale lavoro a pari spesa".

May 29, 1874

The Minister of the House of H.M. responds to the preceding with lament as to the rather elevated price of L. 166.00 to the sq.m., in comparison to the 90.00 lire to the sq.m. cost for the construction of "due eleganti tettoie in ferro e cristalli, state eseguite in questi ultimi anni a questa Residenza, e collocate una alla palazzina in capo alla Lunga Manica e l'altra nel cortile principale della Reggia all'ingresso del quartiere di S.M.". The Minister advises the architect that in case elevated costs cannot be contained by ordering materials from local factories, he should ask for "offerte dalle Case Guppy e Finet-Charles di Napoli, che eseguirono le cennate tettoie a questa Residenza". Also taking note that "... nel presente bilancio manchino affatto alla categoria delle straordinarie, i fondi necessari per la tettoia in parola". From this the advice is to save as much as possible.

May 31, 1874

The response to the letter of 5.29.74 from the Minister of the House of His Majesty, on the part of the architect, E. Piazza. The architect, irritated with the restrictions placed on his previsions of the budget, explains that due to the urgency of the matter he had not been able to compile a more precise calculation. But beforehand, he had, however, specified that having had the approval of the budget, valued in lire at 15,000,000, he would have been able in consequence to obtain in every possible manner some sensible savings during construction on the pre-arranged price. Further explaining that, putting himself in contact with the Mathieu House of Lyons, he would have then been able to confront the prices of this, as well as those of the Offices of Florence, and therefore have decided to whom he should commission the works of fusion and realization. Making clear also that, given the total dimensions of the structure for the cover of the staircase, the space preceding and the lateral parts of the stairs, specific materials would have served among which would be "eleganti colonnine in ferro ed analoga armatura . . . per cui avrebbe calcolato nel costo anche tutta l'armatura per sostenere la medesima".

June 12, 1874

The architect Piazza gives notice with a letter of having studied the development of the project and being able therefore to proceed to compile the relative estimate with all the possible details.

Having decided the precise dimensions and having defined the design, he addressed himself to the House of Finet-Charles of Naples, as advised by the Minister, but no response was given even though the urgency of the case was presented and even though 15 days had passed. He advised, however, the Administration that, because of limited time, and seeing the procrastination on the part of the House of Guppy in giving a definite response to the present requests, if it would be opportune to give to him the possibility, after having the approval on the part of the same Minister of the R. House, to accept the offer for the House of Florence, in case the House of Guppy should once again delay the contract. Together with this letter is a detailed calculation in which the total amount is equal to L. 15,200,000, calculated with all the possible attention (various items are not reported as the calculation for them is not included).

June 15, 1874

On this date the response from the Impresa Industriale Italiana di costruzioni metalliche of Naples was received.

The manager of the company regrets that he is unable to accept the offer due to the limited time at his disposal. He indicates, however, the company De Lamoche di Capodimonte as being able to accept and execute with care the project.

June 20, 1874

Architect Piazza regrets the negative answer that he received from the House of Finet-Charles of Naples, for the delay in receiving news from the Guppy Company, and also for the missing permission from the Supreme Ministry regarding his previous request for contacting local companies and to proceed as soon as possible to initiate the work.

June 20, 1874

With a letter from Rome, the Minister J. D'Aria announced having approved with decree 2809 the inscription of the Category 26a, article 2, the amount of L. 15,000,000 in favor of the passive budget of the complete act.

June 25, 1874

In this letter it is to be remembered that the project was for the construction of the covering in crystal and the iron encasement at the entrance of the quarter of S. Maestà alla Meridiana, presented to His Majesty for approval on May 22, 1874.

Specifying the functions of shelter from rain, for carriages and passengers in waiting, ". . . onde fosse semplificato l'accesso alla palazzina tramite la scalinata già esistente . . .", there follows the first technical report on the work, divided into "Preliminare" and "Stima".

Preliminare

1[°] intento = coprire la scala.

- 2⁰ intento = lasciare libere le luci del doppio ordine di finestre, poste fra le colonne ioniche di finestre, poste fra le colonne ioniche in pietra.
- 3° intento = Il sostegno sarà di colonnette ed architravi di ferro ad ali traforate pure in ferro, al fine di renderle solide guanto occorre e nel tempo stesso leggera all'occhio ed elegante.
- 4⁰ intento = Previsione di un'altra copertura, di fronte alla scala per la sosta delle vetture. Questa seconda con misure previste di m 6,80 di fronte e m 4,00 di fianco, questo per avere, di fianco, uno spazio libero di almeno m 3,40 per il comodo passaggio delle vetture.
- 5⁰ intento = Le caratteristiche costruttive sono le medesime delle precedenti, e tutt'e due saranno unite a formare un solo corpo.

Stima

Questa è riferita chiaramente al progetto allegato, realizzato dall'arch. Ernesto Piazza.

The cost includes the realization of "Armatura composta di 2 pilastri quadri sui piedistalli della scala, due colonnette nel mezzo dei laterali, spalle ed alettine traforate con archetti alla parte superiore, ed architravature. Più due colonne più grosse agli angoli esterni della seconda coperta per le carrozze, architravature relative, ecc.".

At an estimated weight of 4500.00 kg., with the work of the assistant worker of mechanic operations, the painting, etc. a calculated cost of L. 90.00 per kilogram brings the total to L. 4050.00. The covering of iron and crystal of the stairway including the labor, "montature, decorazione d'ornato, canali, verniciatura e montatura da parte del meccanico e del vetraio ...", for a total of 44.64 sq.m. were estimated at L. 100.00 each sq.m. for a total of L. 8649.00. The lateral coverings also in iron and crystal for 9.20 sq.m. (at the first space) and 4.30 sq.m. (at the second space) and two lateral gutters of 9.50 sq.m. for a total 23 sq.m. were estimated at L. 80.00 each sq.m. for a total of L. 1840.00.

The total amount predicted for the realization of the covering in crystal with iron encasement of the entrance of the guarter of H.M. alla Meridiana was for L. 14,539.00.

Under the title "Avvertenze", before the signature of the architect E. Piazza we can read what follows: "... si cercheranno tutti i mezzi onde ottenere quei risparmi che saranno possibili, e come al solito si procederebbe alla stipulazione di contratti parziali quando non si potesse ottenere di farne uno complessivo con qualche fabbrica di vaglia".

"Capitolato per la costruzione della coperta in cristalli e arm. in ferro all'ingresso del quartiere di S.M. alla Meridiana a forma del progetto perizia n. 27 in data 12 giugno 1874 approvato dal Ministero della Real Casa con decreto del 20 giugno stesso n. 2809."

Article 1 of the specification says, ". . . progetto di massima che viene rappresentato nel bozzetto unito al calcolo ..., . . . che deve servire sia per la formazione che per le dimensioni nell'effettuazione del progetto stesso".

Article 2 discusses the possible contract to arrange for the realization of the single parts after single study of the design.

Article 3 proposes the hope for a deadline to the work at the end of the month of August. But considering the short period of time at their disposal, they give the possibility of terminating by that time only the operation of the iron encasement (making it possible to use the stairway), postponing for one month the completion of the work, unless another postponement were to take place due to the presence of the Royal Family.

Article 4 foresees a fine for the contractor of 100 lire each day added to the agreed day of completion. Also in the case of unfinished work he (the contractor) should be in charge of dismounting and returning the work to its original state, assuming responsibility for all expenses of labor and material.

Article 7 explains the terms of payment from the Royal House which will be in three distinct terms. The first on the delivery of the iron material, the second at the beginning of the month of September (at the completion of the iron encasement and placement of the crystal), the third at the completion of the entire project.

June 30, 1874

To the honorable direction of the Ufficio Tecnico della Reggia di Firenze dated the 30th of June, the answer from the Opificio di Costruzioni in iron full and hollow of Natale Gozzini (who was contacted in the beginning by Architect Piazza, but we have not found the letter). Natale Gozzini accepted the execution on the terms of the time established, of the construction of the roof in iron and crystal, also accepting the established penalty of the contract at the price of L. 15,000.00, including two coats of paint in oil and minium. Thus he proposes a package ". . . aumentando di L. 3.000.00 cioè al prezzo di L. 18.000.00 si subordinerebbe a tutte le modificazioni anche di abbellimento cui cotesta Onorevole Direzione stimasse introdurre in corso di costruzione intendendo il sottoscritto eseguire un lavoro tutto di ferro battuto, escludendo la ghisa all'infuori delle parti decorative e di qualche eleganza rispondente al cospicuo luogo cui è destinata . . .".

July 1, 1874

The letter of architect E. Piazza to the Administration of the Royal House of Florence notes a decision from the architect himself in favor of the company of Pistoia, in spite of the offer of Gozzini and of the explanations regarding the tardiness of the response on the part of the House of Guppy of Naples, the House of Finet-Charles, the House De Lamoche, and Gozzini contacted by him. Thus he suggests the construction company Fonderia in ghisa Lorenzetti Roberto, having already reached an agreement concerning the work. Following this Piazza writes: ". . . Questa mattina sulla faccia del luogo, ove stassi innalzando il modello dello scheletro della Coperta di cui trattasi, assieme al sullodato Sig. Lorenzetti, venuto qui appositamente si sono combinate le parti principali, ed in ufficio sui Disegni le parti in dettaglio, e s'è concluso il compromesso che pure qui si unisce in originale . . ., onde essere più certi della sollecitudine si è fatto unire al surripetuto Sig. Lorenzetti, il M^O Magnano Sig. Luigi Fazzi ben cognito . . .".

He afterwards discusses the needed materials to be bought and he concludes saying: "Ormai non rimane altro partito che quello preso, e con ciò si può ritenere che per la fine di agosto la Coperta troverassi compiuta nel senso di cui all'art. 3⁰ del Capitolato."

July 1, 1874

In the Lorenzetti contract all works and costs are mentioned, as follows:

"The undersigned promises the execution of the eight columns in cast iron with the ornamentation according to the planned design, and including one coat of minium put at the cost of L. 85.00 a quintal, so that the columns like the frieze composed of two edges of pliable rims and the band in wrought iron together with an iron girder placed above ornamented with cornices; and for the lantern in pliable iron, as well as the vertical parts with their own skeleton in flat iron, thus forming a play of square designs to be determined, not exceeding the holding boards of the lantern itself; everything put in order, and as said above with one coat of minium, will come to a sum of L. 180.00 a quintal."

July 2, 1874

Architect Piazza affirms that the Master Blacksmith, Luigi Fazzi, has already initiated the work regarding the construction of the iron and crystal covering at the entrance of the Quarter of H.M.alla Meridiana.

July 7, 1874

On this date the architect Piazza makes a request to the management of the work department of the Italian Railway company of Northern Italy in Florence: ". . . le seguenti longarine di ferro malleabile, che non si possono avere che dalla Strada ferrata:

N. 5 lunghe m 6,27 alte e grosse in proporzione

N. 2 lunghe m 4,23 ma alte e grosse come le precedenti

N. 2 lunghe m 4,37 alte e grosse come le precedenti."

July 18, 1874

Emission of the first payment in favor of Lorenzetti Roberto for the work already completed up to this date for a total amount of L. 4,500.00 (2,000.00 up to the first of July and L. 2500 for the remaining period).

Included is the report of the work completed composed of the finished founding of four columns and preparation of the material needed for the structure of the pavilion.

July 21, 1874

The architect sent a letter to the Royal House communicating to them that in order to continue the work for which he was commissioned at the Marquise, he had to empty several rooms and restore part of the rooms such as painting, and tapestry in paper (wall-paper) of the dressing room. He also had to provide for bringing gas into the said room on the request of the Countess.

The architect points out the need of reinforcing the old wooden beams located in the bedchamber of the Countess, with iron girders in the form of a double T. He ensures the proceeding of the work affirming that there remains only the reinforcement of the beams and the attachment of the electrical bells.

At this point he presents the calculated expense for the work completed, due to the fact that the above work was not included in the previous budget for the covering. The total amount is L. 1,950.00.

July 23, 1874

The chief division engineer of the railroad of Northern Italy sends to the Administrator of the Royal House a letter (we think, due to protests regarding the material furnished on request) in which he explains that due to administrative reasons payment for the materials should be made. Also informing them to advise this office in Via Nazionale, 4 the amount of the 9 runners for a total of L. 376.86. Regarding the price of 220 lire per ton, you should notice that they are not unserviceable runners, but they are in mediocre condition, this being the reason for the application of the above price which is the same price from our warehouse.

July 31, 1874

In the letter of the architect to the Administration it was pointed out that as the foundry-man had finished his fusion work, an amount of L. 1,500.00 should be given to him deductable from the total amount of his payment.

July 31, 1874

On the same date, Architect Piazza made a request for a payment in favor of the blacksmith, Mr. Fazzi, for the work completed for the amount of L. 2,000.00.

August 10, 1874

Reporting on the work in progress, architect Piazza tells the Administration that he proceeds to ". . . riordinamento del lastrico corrispondente al piano sotto il coperto per le carrozze ed ai laterali della scalinata". In order to do it he had to remove that and work completely with the addition of a third new pavement.

In this special case he thought it was best to provide the carriage house with gas illumination. Excusing himself for not making this known before, due mainly to the short time at his disposal, he gave the notice on this date, thus applying for approval for the extra expenses already consumed for L. 2,300.00.

August 17, 1874

Third payment in favor of Roberto Lorenzetti for L. 1,500.00. The architect justifies this, announcing that in addition to the completion of the fusion work, installation of the entire structure is also at an end.

August 19, 1874 - Rome

The approval arrived from the Minister of the Royal House for the necessary work of the pavement and the fixtures for the illumination, but not the approval for the payment of the amount of L. 2,300.00 as it was not provided for in the Cat. 26, hoping that that amount could be deducted from the savings predicted from the initial budget totaling L. 15,000.00.

August 20, 1874

Payment invoice of L. 1,000.00 to the blacksmith Luigi Fazzi.

August 21, 1874

Architect Piazza strongly responds to communications received from Rome, with the knowledge of the report sent by himself, and he continues his insistence on the request for the amount of L. 2,300.00, saying that in no way can this sum be considered a part of the stipulated total, due to the fact that this work was not included in the initial presentation of the budget, or conception of the project.

September 2, 1874 (Rome)

The approval for the budget of L. 2,300.00 arrived on this date, in which the Minister says thanks to the "schiarimenti forniti con la pregiata nota . . . del 22 agosto".

October 31, 1874

In this letter the architect compiled the work completed in order to justify the expenses explaining that ". . . Oltre ciò devesi osservare che mentre nel preventivo si era calcolata la superficie da coprirsi a vetri a soli mq 109,49, in atto pratico si dovette aumentare fino a mq 126,82 non già alterando la pianta, ma aumentando la chiusura nelle parti verticali, e ciò anche ottenere che l'acqua di Stravento non avesse qualche volta a rendere inutile la spesa. Per le accennate ragioni la detta spesa che era stata approvata in L. 15.000.00, come ben si rileva dall'allegato inserto A1 è ascesa alla somma di L. 19,538.78."

"Anche la spesa per la rinnovazione del lastrico e del riordinamento della illuminazione che era stata approvata in L. 2.300.00 si è portata alla somma di L. 2.953.00."

He also specified that, the work for the covering being finished, he will retain indispensable ". . . rendere armonioso tutto il piazzale di detto quartiere della Meridiana e si dovettero quindi eseguire le pulizie, i tinteggiamenti, le verniciature sia alla facciata sia ai muri laterali e di prospetto, non che all'imposte, ai fanali, candelabri come pure la pulizia alle statue, . . . si ha l'altra spesa di L. 453.20".

He concludes by establishing the fact that his total rises to L. 22,944.98 with an addition on the previous budget of L. 5,644.98. For this he requests both approval and payment for the amount.

November 9, 1874 (Rome)

The Minister approves with decree number 4903 the payment of L. 5,644.98 under Category 26, article 2 of the passive budget of the year 1874.

THE PAVILION OF THE PALAZZINA "LA MERIDIANA" IN BOBOLI GARDENS, FLORENCE

GENNARO TAMPONE *

SUMMARY

The original survey carried out on the building allowed a deep analysis of the architectural features, the structural conception, the decay -both corrosion and stability diseases- of this iron double-body canopy, erected in 1874. Archive investigations prove that substantial differences exist between the original Ernesto PIAZZA's project and the work actually built.

Principles for consolidation and conservation are given, followed by practical proposals.

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Fig. 1,2. The pavilion in 1978.

The double penthouse situated on the south facade of the "Palazzina della Meridiana" in the Boboli gardens, (Florence) was designed and constructed in the summer of 1874, exactly a hundred years ago. The official reason for it to be built was that of allowing the King and Queen to enter and leave their carriage under cover, but a second reason was surely that of enlivening the severe appearance of the eccessively long and plain facade with the furnishing that could be provided by an articulate, deep, transparent canopy. This was thus designed as a furnishing, entailing the use of materials in the style and following the construction methods prevalent in Europe of those days, especially France.However, it was original both in design and in execution, wherein the refusal to imitate the classical styles that characterise, on the other hand, many contemporaneous foreign structures, is evident.

The project was undertaken by Ernesto Piazza, Chief Architect and Technical Inspector of the Royal Palaces and Villas, on whose life and work very little information exists (Cresti -Zangheri,1978), (Bencivenni, 1981), (Chiostri, 1972).

A draft of the project was approved by the King on the 22nd of May (1). The work was carried out in the summer and was already complete early in August.

Two versions exist of this penthouse: the project pertaining to the Architect and the plan drawn up by Roberto Lorenzetti, who in Pistoia owned a foundry for decorative iron work.

The project is to be found in a well-known but unpublished design which is clearly a succesive elaboration of the plan approved by the King, as it bears the date of the 4th June 1874. (2).

Lorenzetti also drew up a design, referred to in the file of the correspondence as an alternative meant to achieve rapidity and economy; this has not been found, probably because it was used in the workshop.

Comparison of the two different versions, that is, the design and the actual construction, yelds very interesting results and the not insignificant differences which occur, lead to aconsideration of how, during the actual construction, due to time or money factors, the work can in many cases undergo so many important changes to justify the questioning of the paternity of the architect and the verification that the work carried out is according to the project ideas. It must be stated however that Piazza did accept (3) the altered design and tested its viability by erecting together with Lorenzetti, on the 1st. of July, a



Fig. 3. The other entrance to the Palazzina on the right side.

wooden model of the canopy frame (4) and also procured the services of the blacksmith Luigi Fazzi for its execution.

THE PROJECT

The design and even its title make it clear that to the architect the most important part was the canopy covering the stairs, that is the part attached to the already existing facade.

Here he had to solve the difficult problem of the coupling without substantial figurative alterations which would have upset the equilibrium of the whole facade; there was also the problem of sufficiently characterize the new addition so that it would not appear false.

Piazza searched for a global solution to these problems and found it by designing two transparent pavilions, thus choosing a light and not encumbersome metal structure and a transparent glass cover.

By dividing the work into two parts, he tried to achieve a gradual transition from the stonework to the glass and iron structure.

He designed the two sections such that they would have an independent form but above all separate though connected structures. He conceived the one above the staircase as a development of the existing construction and this he achieved by means of two ingenious expedients. The first one consists of a stone pilaster (5) placed upon the "pedestal G" on which are based on opposite faces, two metal half-columns: this is an architectural prolepsis that recalls and unites the stonework lying behind.

The second is a "serliana" (one on each side) which is made of metal and matches the design of the semi-circular window within the staircase walls and which is placed on the same vertical axis.

The "serliana" is also there to give character to the construction defining the axis parallel to the facade which follows a direction tangential to the line of approach of vehiches and pedestrians.

In turn, the stone pilaster also serves to move towards the facade the half-column pertaining to the "serliana" in order to allow the correct positioning of the latter on the vertical axis of the window beneath and to achieve the correct insertion of the score of the intercolumnation in the proportion of 1; 1,5; 1.

The two pavilions, as has been stated, consist of independent structures connected by the stone pilaster. The problem which arises due to the split level is brilliantly resolved by unifying the height of the columns and continuing the two lower columns with a formally independent base; besides, the position of the beams of the lower structure is at the same level as the lintel of the upper one. The beams



Fig. 4. Piazza's "Progetto per la costruzione di una tettoia a coperta della scala all'ingresso del Quartiere di S.M. il Re all Meridiana dalla parte del Giardino di Boboli, con aggiunta di altra tettoia per coprire le vetture reali" (dated 4th June 1874).



Fig. 5. Piazza's "Progetto per la costruzione di una tettoia a coperta della scala all'ingresso del Quartiere di S.M. il Re all Meridiana dalla parte del Giardino di Boboli, con aggiunta di altra tettoia per coprire le vetture reali" (dated 4th June 1874).






Fig. 7,8. Cover of the courtyard of the Villa La Petraia.

of the latter, are however raised higher and are situated above the curve.

The structure was constructed by making use of metal columns and beams in the form of St.Andrews crosses. The roof is made of transparent glass panes that descend in the form of a curtain even though they are folded vertically on the sides and together with the hangings situated on the front resemble a baldachin and thus stress the furnishing aspect of the structure. The two front columns are spirally shaped.

The design contains some slight incongruencies which might perhaps be interpreted as the results of indecision and of the study of variants. The column on the facade designed in the section is seen (more correctly) as a half-column on the plan.There is no correspondence between front and plan as regards the lateral coves of the cover of the lower pavilion.

The unobtrusiveness of Piazza's project and his consideration of the already existing structures attain great significance when seen in the light of another two of his works.

One of these is the cover containing a skylight of the inner porch of the villa "La Petraia" at Sesto Fiorentino (Chiostri, 1972) built to protect Volterrano's mural paintings, wherein the subject was faced and resolved with sapid technicality used to distinguish the articulation of the members of the metallic structure. The horizontal beams are resolved, even here, with trusses in the form of St.Andrews crosses; with which the Architect obviously was familiar.

Besides its technical aspects, this structure is noteworthy for the attempt made to fit in with the building so as not to overwhelm it by means of the glass and metal covering. Its lightness is thus attained by the refusal to allow a concentration and tangle of elements whilst allotting each component an independent space.

The other work consists of the restoration of Buontalenti's grotto in the Boboli gardens, where he also operated with great concern.

THE FINISHED WORK

Lorenzetti's realisation of the work contains sizable differences with respect to the project.

The stone pilaster with the half-columns is missing and in its place is to be found a column which forms part of the structure of the two pavilions. The "serliana" is also missing. The half-column on the facade was not included in the final work and the columns on the stairs





Fig. 12. Side elevation.











Fig. 15. Cross section.



latig Gueraieri

Fig. 16. The columns on the walls.







Fig. 18. Details of the connections with the façade.





Fig. 21. Collarino, decoration and capital of the column on the wall.

Fig. 22. Decorative section.



become three a side. The lowest columns differ in proportion from the other six and their bases are not longer on the same horizontal plane. The horizontal beams are on different levels. The lowest part is covered by means of a canopy instead of a double sloping roof. The decorations are totally different, especially the hangings which are substituted by false beams "a gioco di quadretti" which resemble beams of the "Vierendel" type, and by a long sheet decorated with flowers and leaves in relief.

The apparent homogeneity of the materials of the canopy is contradicted by the presence of different materials: malleable iron used for the beams and the iron girders, the plates, etc., cast-iron for the columns, plate utilised in the ornamental bands, glass in the cover and the sides, wood for some mouldings in the upper parts of the pilaster-columns.

The supply of these materials gives rise to interesting considerations. In order to build the beams, double-headed rails were used which formed the load-beams structure: these were supplied by the "Società delle Ferrovie dell' Italia Centrale", and on arrival these were in fact found to be used! These were rails of the Stephenson type, which after the upper part has worn away, can theoretically be turned round to be once again placed in a socket: however, lateral deformation and wearing away of the material do not allow a good fit to be made with the socket, and they were thus soon replaced by more reasonable sections.

It is interesting to see from the accounting file of the work that there was a contentious with the supply company which demanded payment (6) as the material delivered was said to be "used but mediocre", i.e. still capable of being used.

The columns were designed by Roberto Lorenzetti and built in his foundry. The design is original, well-studied, different from the elements that the Architect had foreseen.

Lorenzetti's designs are different from those being currently produced, bearing floral motives obviously of asiatic, or more specifically indian origin, pertaining to the 18th century concepts which derives primarily from Vitruvius and which sees the tree as an archetype column on a vertical support, in general whith the conseguent progressive tapering, wherein even the ribs and the flutes are classical in origin; the upper collarino is, on the other hand, more generic, bearing plant motives, and the lower parts of the longer columns are more "functional" and geometrically rigid. However, the severity of the capitals is to be greatly admired, as here the plant decorations are not made up of repetitions of the classical forms, but are developed autonomously and coherently in polygonal shapes, in harmony with the geometry of the shaft; this gives rise to the motive of the pulvini, which in turn are polygonal and inserted so as to separate the wings of the false beams and to place on different levels the two parts of the structure.

The motives used are those currently produced for lamps and candelabres, but here the shaft is not interrupted by means of a collarino which is generally situated above the floral decorations, and is thus an original development.

An interesting analogy is to be found in the columns of the Wolkonsky Villa in Rome, which was designed by Gaetano Koch. The floral motives used by Lorenzetti are in this case rounded acanthus leaves (of roman origin) arranged in double rows at the base, spiny acanthus (greek origin) on the capital, also in double rows, and "palmette" on the collarino beneath the capital.

The shaft is corinthian with linear tapering and the ribs are cut at the edges.

The leaves of the capital are reset on the shaft: some are in fact also missing.

COMPARISONS

Lorenzetti's alterations and manifest changes which occurred after completion of the work are deleterious to the clear conception of the project and introduce a number of complications.

The elimination of the "Serliana" destroys the planimetric design based on a double axis.

The consequences resulting from the elimination of the stone pilaster are more serious, as here the connection with the masonry of the staircase and the facade is lost and, which is worse, it is no longer possible to distinguish the structures of the two pavilions. Besides, it was no longer possible to space the columns evenly on the stairs, and therefore their position, which is dictated by the vertical axis of the semi-circular window and the presence of the pedestal, results as being casual; this is also due to the fact that the two semi-columns situated one at each end of the upper pavilion are also missing.

The various elements and glass planes thus result as merely resting on the structural framework, with no connection in between.

The structures are interconnected haphazard, overlapping in such a way as to create, fatally, an increase in the degree of "hiperstaticity" and therefore a greater vulnerability of the structure due to its complexity. The architectural configuration is also compromised in the same way and to the same degree. It is not known why the foremost columns differ in height, but maybe intended to create a prospective levelling of the lane which runs lower.

The glass panes to be found today are not transparent and thus even here they radically change the concept of the project. The panes alternate in size and this underlines the aim to attract attention to them, as the bands "a gioco di quadretti", situated on the perimeter, repeat.

The sense of display of the work is lost, even though the structure can still qualify as a furnishing, with however an autonomous existence. The idea of a curtain is replaced by a sizeable cover; the transparency is changed to a milky diafanousness recalling the wings of a butterfly.

The structural deteriorations to be described in the following paragraphs, as far as the structural connections are concerned, curiously show that Piazza was in fact right, as the two semi-columns upon the pilaster in correspondence with the pedestal, once replaced, are spontaneously produced.

THE DEGRADATION PRESENT

The canopy is deteriorated in various ways, especially regards structural degradation.

The metal is also deteriorated, partly due to the structural degradation, and partly, at least as far as the columns are concerned, due to imperfections in the casting.

The most evident and characteristic structural deterioration concerns the two pedestal columns, and here vertical cracks passing through and extending to almost the whole height of the shaft can be seen. At the top are also present transverse cracks, also passing through and large laceration with subsequent loss of large areas in the lower part of the left column.

The tubular geometry of the columns, their restraint which can reasonably be supposed as vertical pins, and the configuration of the cracks, led the search into the cause of the damage to the sinking of the base of the two columns; in fact, these are placed directly on the ground as opposed to the others which are placed on the lateral walls of the staircase.

An expeditious survey confirmed this supposition, and it was thus followed by accurate determinations of the levels, the perpendicularity and its alterations, documenting the soil settlement both geometrically



Fig. 23. External side of the column on the right pedestal. Note the vertical crack and the two horizontal branches, the first being situated on the little cantilever meant to support the beam.



Fig. 24. Degradation of the internal side of the same column. The cracks are passing through the shaft.







Fig. 26. The left column is affected in the same way, but here an ample loss of material has occurred.



Fig. 27. Many pieces of the frames and a few glass panes are missing, giving way to further decay of the remaining parts.



Fig. 28. Defects of casting, repaired with stucco, at the base of the column shown in Fig. 26. and dimensionally.

All the forms of degradation present have thus been interpreted as caused by a translational, prevalently vertical, absolute settlement.

It is to be supposed that the columns placed upon the staircase walls did not sink, and this is confirmed by the forms of degradation which were studied by means of optical instruments of a topographical nature; determinations were however only partial and thus imperfect due to the presence of a scaffolding which, though it allowed the taking of direct measurements, hindered the visibility of the structure as a whole.

The upper part of the capitals of the columns on the pedestal of the two walls were utilised as reference level. It was noticed that the left column, which rests on the ground, had sunk about 22,5 cm with respect to the one situated on the pedestal, and 27 cm with respect to the lateral one.

This results in unevenness in the upper parts of the lateral walls, and more importantly to a rotation of the lateral beams of the pavilion.

Given the nature of the connection of the lateral beams (bands, rail and frames) with the column on the pedestal, the height of the beams, sizeable with respect to the diameter of the columns, the constraint can be hypothetically assumed to be perfectly fixed. The rotation of the beams becomes a bending for the columns, which is greater in the left hand one, and of the beams themselves.

The degradation thus seen in the columns and the beams are congruent with the internal stresses which derive from the assumed external stresses.

Due to the bending of the columns, these are tended in the part which faces the palace and in these we thus see transverse cracks.

The tubular section of the columns and the presumed attachment with vertical pies of their base, explains the vertical craks according to the interpretation indicated in the diagram of the figure.

The most evident signs are to be found in the lower section of the columns. The one on the left, which is more affected due to a greater rotation, has lost quite a lot of material, and this exposes the internal structure of the column.

Careful observations led to the realisation that the casting is very spongy in those areas, that the thickness, on average about 2 cm, is very variable, attaining a value of 5.5 cm in the widest, lower part, that parts of the material are sometimes missing, and that the surface cavities were, during construction, filled with gypsum and then painted over.

The state of disorder of the work and the consequent action of the rain water resulted in an advanced degree of oxidation and widespread stains in the coping of the walls, which are also typically weathered (the Pietraforte, due to the action of water , forms superficial crusts 3-4 mm thick).

The lower parts of the beams undergo compression which, given the composite nature of the section and its height, which is significant when compared to its transverse dimensions, produce twists. In this frame should be interpreted the disconnections of the inferior plate.

Many elements in the frames of the band "a quadretti" are partially loosened or lost. Some acanthus leaves on the capitals are also missing. Many parts of the sheet shuting are deformed, loose or missing.

The small wooden mouldings are unconnected.

The paint is greatly damaged, especially on those parts facing West which are almost totally exposed and corroded. Most of the glass panes are broken or missing.

THE PROJECT OF RESTORATION

The main task of the intervention should be stability.

This is to be achieved removing the causes of instability, that is to say the soil settlement. The following operations have to be planned.

First of all the internal tensions in the whole structure, caused by the settlement, have to be released. Foundations of the columns together with the lower layers of soil have to be inspected and naked, after a proper propping. Underpinning with usual due care, i.e. partial digging and ready filling, aims to provide a larger base in order to reduce the stress on the soil and at the same time to settle down a base for further phases. New foundations, according to a necessity of general structural linkage and to the rules regarding seismic areas recently extended to the territory around Florence, should be connected between themselves and with the staircase; steel reinforced concrete, being able to counteract tensile stresses, is to be preferred.

The second step is to raise the bases of the columns by means of jacks. Probably it will be impossible to recover all the entity of the sinking, because of the permanent deformations which surely occurred in the whole structure, especially in the connections; from another principle, recovering of the original geometric configuration is not the main task. Completion is made with filling of empty spaces between old and new foundations.

When the values of the internal stresses have been lowered all the connections have to be inspected in order to check the bolts and the degree of corrosion of every part. It seems less important, in this kind of architectural work, the conservation of the bond because the connections are of a geometric nature. A few substitutions and integrations of parts have thus to be foreseen.

This operation is also necessary for the frames and for the mouldings, whilst broken or missing crystal panes have to be replaced. New iron materials can have special surface treatments and bear impression of the date.

Once the causes of the static deseases have been removed, the repair of the columns can be simply faced by means of welding of the cracks; where the faces of the crack are to close, little holes can be made to receive weld material. The real composition of cast iron must be found out in order to use proper electrodes which will ensure weldability.

The missing parts of the left column, for many reasons such as protection of the edges and of the inside, improvement of the strenght, recovering of the symmetry of the round section, have to be replaced. A suggestion can be the use of plexiglas instead of new cast iron, in order to show the internal sections. A possible alternative is the insertion of a part of thin pipe of steel, shaped like the perimeter of the void and sized with the same internal diameter of the column.

For the corrosion of the metal, particularly for the rust, should be used rust converters. Final protection is to be achieved with paints.

* * *

The dimensional survey of the work has been guided by the author in the seminar "Aspetti Tecnologici e Costruttivi della Architettura Moderna" for the Course of "Storia dell'Architettura" held by Professor Gian Franco BORSI in the Faculty of Architecture, University of Florence (1983-1984).

The measurements have been taken by the students: Stefano Baldisserri, Michele Berti, Roberto Bettini, Rita Cantagallo, Catia Guerrieri, Nora Lombardini, Daria Michelini, Ferdinando Poggi, Magda Spagnoli. Roberto Bettini and Ferdinando Poggi carried out the topographical survey.

Catia Guerrieri developed the measurements and elaborated the drawings under the guidance of the author for the mentioned Course and for the Course of "Restauro dei Monumenti" held by Professor Giuseppe CRUCIANI FABOZZI in the same Faculty. Partial drawings had been made by the other students mentioned.

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- (1) Letter of the Architect Piazza dated 25th July 1974 (Ernesto Piazza, 1826-1882, was Chief Architect and Inspector of the Royal Palaces and Villas. He was member of the Collegio degli Architetti ed Ingegneri di Firenze).
 This document like all the others here cited, and the original Piazza's project are in the accounting file of the work, in the Library of the Soprintendenza, classified as: 1874, n.2, p.3, ins.7 (for further references see Bencivenni, 1981).
- (2) Letter of the Architect Piazza to the Amministrazione della Real Casa di Firenze, dated 12th June 1974.
- (3) Letter of the Architect Piazza to the Amministrazione della Real Casa di Firenze, dated 1st July.
- (4) Ibidem.
- (5) In the Piazza's project the parts which are made of masonry are indicated by section lining with raking lines, the parts in metal by section lining with vertical lines.
- (6) Letter of the Ingegnere Capo Divisione delle Ferrovie dell'Alta Italia, Florence, dated 23rd July, addressed to the Amministrazione della Real Casa.

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Fig. 29. Iron coat-of-arms of the Savoia Family on the front of the two pedestals.

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IRON BRIDGES IN THE LOWER SILESIA REGION

Jerzy ROZPĘDOWSKI

SUMMARY

The paper deals with the beginnings of constructing iron cast bridges in the Lower Silesia region starting from the end of the 18th century up to the 1930s. First, iron cast bridges designed by English constructors Wilkinson and Baildon are discussed. Other bridges designed by local engineers are also included. These are girder, arch and suspension bridges.

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1. Medal designed by F. Endler depicting the bridge in Zazany.



2. Eazany, bridge from 1794-1796, before dismantling.

The industrial revolution that had started in England, long before other countries joined in, accounts for the leading position England held in the process of technical and economic changes. English industry and technology aroused much interest in economically underdeveloped countries which, in many ways, tried to learn the ins and outs of these rapid industrial and technological developments. One way to accomplish this⁽¹⁾, and perhaps the most preferable, was through studies carried out at the source - in England - or by importing English-made machines and other technical products. At the end of the 18th century two technicians, namely William Wilkinson⁽²⁾ (an Englishman) and John Baildon (a Scot) contributed much to the development of metallurgy in the Silesia region, then a part of Prussia. John Baildon, who over the period of 1793 to 1848 was working in the Silesia region and in the countries then belonging to the Czech Kingdom, had for all his life been dealing with constructing steel mills, smelting furnaces, steel mill machinery and rolling mills⁽³⁾. One of the steel mills in Katowice, designed and constructed by John Baildon and still in operation today, has been named after him to honour his memory.

In Małapanew steel mill in Ozimek⁽⁴⁾, William Wilkinson started his attempts at lead and iron smelting, using coke in old charcoal-fired furnaces. Even earlier from 1781 to 1785, in France, he built the first coke oven for ironmaking on the Continent. At the suggestion of Wilhelm von Reden, then manager of metallurgical industry in the Silesia region, John Baildon came to work in Silesia in 1793. From 1794 to 1796 he built in Gliwice the first modern steel mill in Silesia and Prussia. Later, in co-operation with Bogatsh and Wedding he constructed a big coke oven for ironmaking. Parts for the oven were imported from Carron Ironworks, Scotland. According to the design the 40.3 m³ oven was equipped with cylindrical hydraulic-driven blower and in autumn 1796, the first twentyfour-hours heat of 2.5 t was tapped⁽⁵⁾.

The technological barrier that hampered large portions of melt to be obtained was finally overcome thus enabling the production of bigger metal elements which, following the example of England, were used in the construction of bridges. Besides, the introduction of cylindrical blowers and replacing loam moulds with sand moulds considerably improved the technological process.

The first iron bridge in the Silesia region (often cited in literature as the first on the Continent(6)) was cast in 1793 at Małapanew steel mill, probably on the design of John Baildon⁽⁷⁾. The idea was put forward by Earl Burghaus who Was well acquainted with the latest contemporary bridge constructions in England and America. Burghaus made an endowment of the bridge in his own estate, Łazany, on the Strzegomka River on the road from Strzegom to Wrocław. The elements of the bridge were transported to Łazany in December 1794 and assembled by J. Baildon during 10 weeks of 1796⁽⁸⁾. To commemorate the occasion, bronze and silver medals designed by F. Endler were issued⁽⁹⁾ (Fig. 1).



3. Gliwice, elements of the bridge from 1820.

The arch bridge in Łazany, disassembled before the war, was 2.81 m high and 6.25 m wide and had a span of 12.5 m. The arches (ribs) were joined in a key block. This singlespan bridge consisted of five ribs spaced every 1.56 m each of which had three arches. The space between the upper arch and the bridge deck was fitted with a row of openwork rings proportionally diminishing in size towards the centre of the bridge. The remaining lower arches were additionally braced with rigid, chain-like cast rods (Fig. 2). The bridge was mounted in specially constructed cast-iron bearings sunk into stone abutments. The bridge deck was slightly raised in the centre and rimmed with sidewalks protected with metal railings(10). The construction of the bridge, which imitates that of the Severn Bridge in the way the arches are joined, is a logical structure where the group of arches of different radius splits aside after passing the key thus yielding a favourable pattern of moments. This constructional solution takes after T. Pain rather than after the cut with the deck arches in the Severn Bridge.

A small bridge in Hronce (Czechoslovakia), similar in construction to that in Łazany, had three cast-iron arches joined in a key block to make one whole(11). The Małapanew steel mill after having mastered the technology of bridge structural elements, cast in 1798 the elements for a bridge in Berlin which carried over the Kupfergraben, in 1801 it produced a bridge for Potsdam, in 1803 for one of Charlottenburg's parks and in 1804 for Paretz(12).

Already in 1800, a newly-built steel mill in Gliwice launched the production of bridges. Its first product, a small 6.61 m span, 6.94 m wide arch bridge, was designed to span the Gliwice Canal. It consisted of eight ribs with a line of rings diminishing in size between its floor and the lower arch. In 1936 the bridge was disassembled.

Similar in form was a bridge designed in 1804 by J.G. Gaertner from Wrocław but never built. The elements of the bridge were supposed to be cast in the Gliwice steel mill and then to be assembled and thrown across the Kłodnicki Canal(13). In 1819 this steel mill contracted a bridge designed by Schinkel for one of Berlin's castles and many other structures for sale. In 1820 the mill cast a model of an arch bridge to advertise the then new construction. Parts of this model have been preserved to modern times and are on display at the premises of the mill⁽¹⁴⁾ (Fig. 3).

A little earlier, in 1815, Schinkel designed for Wrocław a cast iron bridge to be engineered by Eng. Moritz from Małapanew. The Schinkel bridge was to span the city moat before the Oławska Gate. On both ends the bridge was terminated with tripartite gates with four openwork pylons topped with ornate elements. The arches of the gates consisting of Neo-Gothic arcades made the pylons one coherent whole (Fig. 4). The arch of the bridge, a sort of deviation BRUCKEN- UND WEGEBAL BRESLAU



97. Gegenentwurf Schinkels für das Ohlauer Tor in Breslau

BRÜCKEN- UND WEGEBAU

4. Wroclaw, K.F. Schinkel's project for the bridge gate, 1815.



5. Wroclaw, bridge designed in 1815 by K.F. Schinkel.



6. Wroclaw, bridge design from 1822.



 WrocXaw, illustration (dated 1823) of a bridge built in 1822.



 Malapanew, 1827 bridge, general view and projection. Drawing done in 1980 at the Institute of History of Architecture, Art and Technology, Wroclaw Technical University in 1980.



 Malapanew, view of the bridge. Photo: A. Broniewska, 1974. from the logical design of the whole construction, was a series of vertical Neo-Gothic arcades, diminishing in size as they approached the centre of the arched profile (Fig. 5). This bridge, though the top achievement of the time, belongs to the classic tradition of design. The design has never been carried out, only drawings have been preserved⁽¹⁵⁾.

The next bridge to be constructed in the Silesia region. in 1822, was the arch bridge cast at the Gliwice steel mill best known as the Royal Bridge spanning the city moat in Wrocław in front of the Mikołajska Gate. The 15.08 m span, 13.62 m wide and 2.51 m high bridge consisted of 11 ribs joined in a key block (Fig. 6). The bridge, joined stiff in the key and the bearings, was an over-rigid system. The openwork lower arch, in the form of arch blocks in its central parts, met with the bridge deck. Between the bridge deck line and the lower arch, stiffening rings were fitted. The bridge deck ascended towards the centre, sidewalks were covered with cast iron plates and secured with metal On both sides lamps were placed (Fig. 7). The railings. only decorations of the supporting structure were, apart from the stiffening rings, acanthus leaves at the key block and at the root of the ribs. The bridge had survived until 1866 when it was disassembled as part of a town-planning program concerning that part of the city(17).

Apart from arch bridges, there is also information on constructing girder bridges. Unfortunately, due to lack of illustrations and written sources, we are not able to analyse their forms. Most probably they took after wooden constructions with thin-walled cast iron structural elements. One of these, 12.5 m long and 4.8 m wide, is known to be thrown across a canal in Małapanew in 1833. It was supported in the middle(18).

The oldest metal bridge still in use in Silesia is the suspension bridge in Ozimek near the Małapanew steel mill. It was built in 1827 and spanned the Mała Panew River on the road from Ozimek to Opole. Its chain construction follows the example of the then-known structures like bridges in Nürnberg or Strassnitz in Moravia dating back to 1824(19). Despite its small dimensions, this bridge, thanks to its elegant proportions of openwork gates, provides an interesting example of bridge architecture reflecting an ascetic attitude of its designers who tried to find suitable forms fitting new materials.

The bridge was designed by "Werkmeister" Schotelius from Małapanew. The pylon-to-pylon span of the bridge is 31.5 m, railing-to-railing and chain-to-chain width is 5.66 m, and the height from suspension level to the pylons' intrados is 5.90 m (Figs. 8 and 9). The wooden construction of the bridge deck, later replaced with steel I-bar girders was suspended from chains by means of suspension members (Ø 35 mm). The chains consisted of two pairs of strings (Ø 45 mm each) placed on two levels (Fig. 10). The suspension members were mounted in the strings' joints by



10. Malapanew, chain joints. Photo: A. Broniewska, 1974.



11. Malapanew, isometric drawing of the suspension joint. Drawing by E. Sledziński, 1968.



 Mažapanew, suspension member joints. Photo: A. Broniewska, 1974.

 Malapanew, suspension members of the bridge. Photo: A. Broniewska.





14. Malapanew, suspension chain bearing, drawing done in 1981, courtesy of the Institute of History of Architecture, Art, and Technology, Wroclaw Technical University.
means of special straps (Figs. 11 and 12). They were spaced alternately on both chains; thus the upper chain was loaded with 10 suspension members while the lower one with only 9. This solution greatly simplified the already complicated suspension joints. The chains rest on arch-like bearings (Fig. 14) and then, at the distance of 20.30 m from the axes of the gates, are anchored in underground foundation chambers.

The pylons are of latticed cast iron plates decorated with simple tracery. The inside walls of the gate are in true topped with openwork tympanums of arched intrados. The date of cast, 1827, and the inscription MALAPANE are placed on oval shields placed on tympanums⁽²⁰⁾. The iron, cast in Silesia, was widely recognized abroad. The suspension bridge across the Vistula River in Warszawa was to be built from iron imported from Silesia⁽²¹⁾. This bridge was designed in 1820 by Eng. L. Metzl. In its construction it departed from the bridges built until then in America and England. A similar construction can be found only in an illustration presenting the Navier's suspension bridges (cf. the Invalids Bridge in Paris built in $1826^{(22)}$).

The five-span Warsaw bridge was designed to be 2340 feet long. One chain of the bridge that had been experimentally tested in the scale of 1:1 withstood a four times greater load than expected. The wooden base of the deck covered with metal plates was not suspended from the chain; instead, it rested with vertical girders on the supporting strings.

The bridge with a straight-line deck did not have pylons since the descending chains, fixed in piers, formed the, so to speak, inverted 22-foot-high arches determined by the chain curves.

This constructional solution, while requiring more wood to be used, made the whole structure more rigid and of better performance than that observed for the bridges suspended from the top. This construction was analysed in detail by A. Stern and J.K. Skrodzki and their opinion was in favour of this solution; however, under the pretence that this was a many-span structure, the solution was turned down despite numerous examples of many-span bridges on the Thames, Seine and Neva rivers. Of interest here is a very detailed code of practice and technical specifications including, among others, information concerning the method of pier foundation, chain fixing, deck construction, analysis of water levels, temperature, strength and expansion of the steel used.

In concluding this brief review on the pioneering constructions of cast iron bridges in the Silesia region, attention should be focused on at least several significant problems :



- A. in Zazany B. unrealized design by K.F. Schinkel C. in WrocZaw D. in Gliwice.

- 1. The bridges discussed above despite their rather small dimensions present the synthesis of a certain mathematical, statical and technological knowledge. Built rather as experiments they served their function well for a long time. Compared with the then-prevailing trends in world bridge technique, the state of engineering exemplified by the aforementioned structures should be a credit to the technicians then working in the Silesia region.
- 2. Judging by the forms of the bridges, certain formal attempts to arrive at a sort of compromise between two apparently conflicting tendencies can be noticed (Fig. 15). The first of these, economy-oriented. advocates the introduction of new materials (metal) thus placing itself in clear conflict with a more classical approach. The other one, by defending against the interference from new trends very often adapts new materials in a traditional way of which the classical all-metal portico cap of Langhans Exchange (1824) or the multicolumn cast iron portico of Raczyński Library in Poznań (1829) are meaningful examples. The pressure for using new materials was met half-way by allowing the barbarization of forms in other styles, e.g. Moresque or Neo-Gothic. C.F. Schinkel, an outstanding 19th century architect, makes attempts at using new material just in Gothic forms (cf. the aforementioned design of the bridge at Oławska Gate in Wrocław). His work, however, although elegant and formally perfect, is already outdated. It is the bridge in Lazany with its triumphal gates which in a more convincing way relates us to the future of architecture.
- 3. While reviewing the history of bridge structures in Silesia, one cannot fail to notice the obvious relationships with industry. It is beyond any possibility of argument that without progress in the steel mill industry no technical improvements could be achieved. Here, the role of England in transplanting new technologies on the Continent comes out plain and clear. This short history of only two steel mills in Silesia, i.e. in Ozimek and Gliwice presents us with a very interesting picture telling us the story of the industrial development in the region. Nowadays, the two mills render possibilities for technicians not only from Poland but also from Belgium, Denmark or Sweden to study improvements or new technologies currently being introduced.

In conclusion, I would like to extend my special thanks to Mr. H. Quentin from Liverpool for his precious bibliographic comments on the life and works of W. Wilkinson and J. Baildon.

- 1. E.g. Wilhelm von Reden, held responsible for the development of metallurgy in Silesia, studied in England in 1776; also, under the auspices of the Prussian Government, F.A. Eversman in 1784 was sent to England for 18 months to study the latest technologies there. W.O. Henderson, Britain and Industrial Europe 1750-1870, Leicester University Press 1965, p.152. Milan Myŝka, John Baildon - Hutnik Szkocki a poczatki rewolucji przemysłowej na Sląsku i w krajach czeskich, Sobótka No.3, pp.331-349.
- 2. William Wilkinson, born ? and died in 1808, very often mistaken for his brother John Wilkinson, built in France in 1781-1785 a big furnace for ore smelting using coke. Invited by the Mining Office to Prussia. In 1789 he stays in Copenhagen. In the same year moves to Silesia and carries out the smelting of lead ore using coke. In Ozimek, at Małapanew steel mill he makes attempts at smelting iron ore using coke. Later, with Reden, he leaves for England.
- 3. John Baildon, born on December 11, 1772 in Carron, Scotland and died on August 7, 1846 in Gliwice, Silesia. His father, William, was the head of Carron Ironworks in Sterlingshire near Edinburgh, where he learned about the practice and technology of iron making and machine Comes to Silesia in 1793 and in 1794-1796 construction. builds in Gliwice a steel mill together with a furnace equipped with a cylindrical hydraulic-driven blower. In 1802 he designs and builds furnaces in the Royal Steel Mill, in Silesia, Frydland and in Czeladno (Czechoslovakia) and in 1805 in Bytków. In 1811 builds a furnace in Stodoły, Silesia. In 1823, J. Baildon builds "Baildon" steel mill supplemented with puddling furnace rolling mill in Dab near Katowice, Silesia. and Beginning in 1846 he launches a series of new furnaces and plate mills from wrought iron. Designs and constructs machines, cylindrical water or steam driven blowers. In 1802, in Gliwice steel mill he installs a machine for drilling cylinders and then builds a steam engine for Berlin. In 1814 he builds the Boulton-Watt type steam engine to drive a fuller in Frontiskovo, Moravia. In 1796 he assembles in Łazany, Silesia, a cast iron bridge manufactured at Małapanew steel mill in 1794. In 1804 his younger brother, William Baildon, a technician co-working with John, comes to Silesia. Myŝka, op. cit., pp.331-349. J. Piernikarczyk, Historia górnictwa i hutnictwa na Górnym Sląsku. Vol.2, Katowice 1936. Z. Kwaśny, Hutnictwo żelaza na Górym Sląsku w pierwszej

połowie XIX w., Wrocław 1968.

G. Reitböck, John Baildon und die Baildon-Hütte in Oberschlesien, Die Bergstadt, R.9 1920.

- The Małapanew steel mill in Ozimek was the first state 4. owned plant in the Upper Silesia region (1753). Beginning the production took place in 1754. Two big charcoal furnaces were installed. At the end of the 18th century its annual output was 13000 cwt of pig iron. O.S. Popiołek, Huta Małapanew 1755-1955, Ozimek 1955.
- Głąb Jan Wojciech, Zeszyty Gliwickie No.6, Gliwice 1968, 5. p.51.
- A little earlier, two decorative bridges were built : one 6. in Carskie Sioło near Petersburg (1782-1786) and the other in the Worlitz park near Dresden (1791). Helmut Stelzer, The Role of Iron in the Historical Architecture on the Basis of Examples from the GDR, in Eisen Architektur, Bad-Ems 1978, p.310.
- The authorship of J. Baildon (1793) needs to be verified. 7. It is known that J. Baildon came from England to Wrocław on July 1, 1793. In autumn that year he visited the Tarnowskie Mountains and Buchwald. In March 1794 he was in Małapanew steel mill and other mills. The bridge was cast in December 1794 and J. Baildon assembled it in 1796. Provinzialsblättern 1796, V.24, pp.368-377 : Sammlung
- 8. nützlicher Aufsätze und Nachrichten, die Baukunst betreffend. Für angehende Baumeister und Freunde der Architektur, V.I 1797, Berlin, pp.166-167. Waldemar Herrmann, Die Alte Schlesischen Brücken, Wrocław 1942, pp.121-122 (Dissertation - typewritten copy).
- Herrmann, <u>op. cit.</u>, p.122.
 The bridge weighed 900 cwt and was tested in 1928 by Wrocław Technical University proving to withstand 6 t of slowly travelling weight. The fragments of the bridge after its disassembling were transported to one of the Wrocław parks. Unfortunately they were not found when the war was over. Herrmann, op. cit., p.122.
- ll. Pavel Adamuv, Pamiatki lejarskiej techniki z latiny na Slovensku, in Vlastivedny Casopis R.32, No.4, 1983. Bratislava, p.151.
- 12. Herrmann, op. cit., p.121.
- 13. Ibidem p.122.
- 14. Katalog Zabytków sztuki w Polsce, Powiat Gliwicki Vol. VI photo 5, p.24.
- 15. G. Grundmann, Karl Friedrich Schinkel, Lebenswerk, Berlin 1941, pp.152-154.
- 16. Königsbrücke put to service on October 18, 1822, destroyed in 1866. According to the preserved design its dimensions were : 48' span, 43'3" wide, two sidewalks 8'8" each, 26' bridge deck, 4'4" distance between the arches, 2½" arch thickness and 3 to 1½" rings thickness. The name of Thiel is written on the back of the plan but it is not sure whether he was the designer, though as a building inspector he could make the plans. It is possible that the bridge was designed by J.F. Knorr who at that time directed the works on the promenade to

replace former fortifications that remained after the Napoleonic war. The bridge was put into service on the 10th anniversary of the victory over Napoleon, That the archival plan may exist was suggested to me by Cz. Zając. Schlesischen Provinzialblättern 1822, T.76, p.350. Privilegierte Schlesische Zeitung, No.123 (October 19, 1822),pp.390-395. J. Kościuk, Most Królewski na pl.l Maja in Wroclaw,1981

(type-written copy).

- 17. In 1981, during earth works, the remains of the bridge abutments were found. The reconstruction of the bridge was done by J. Kościuk.
- 18. Herrmann, op. cit., p.129.
- 19. E. Werner, Die ersten Ketten- und Drahtseilbrücken, in Technikgeschichte in Einzeldarstellungen, Verein Deutscher Ingenieure 1973, No.28, p.55.
- 20. Herrmann, <u>op. cit.</u>, pp.128-129.
 E. Sledziński, <u>Most na Małej Panwi</u>, Gliwice 1968 (inventory together with the history and description the bridge, type-written copy), Archiwum Woj. Kons. of Zabytków, Opole No.1106. Grundmann, op. cit., p.152. Werner, op. cit., pp.25-27.
- 21. Report on the experiment with an iron chain ..., in Roczniki Towarzystwa Królewskiego Warszawskiego Przyjaciół Nauk, T. XIV, Warszawa 1821, p.230 nn.
- 22. In 1823 Navier submits his report on bridges. One of the figures presented in this report is a picture of a single span bridge with chains lowered below the deck line.

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- 8. Rozpędowski J., Różycka E., Jelenia Góra, Wrocław 1975.

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