MICHEL TOURNAY

INTERNAL RESISTANCE TO CORROSION IN STEEL HOLLOW SECTIONS

CSFTA

Notice 1059

CIDECT

Rapport final
10 B 78/3

MICHEL TOURNAY

INTERNAL RESISTANCE TO CORROSION IN STEEL HOLLOW SECTIONS

CSFTA
Notice 1O59

CIDECT
Final Report 10B-78/3

The following is a full English translation of the original work, published in French under the title:

LA RESISTANCE A LA CORROSION DE
L' INTERIEUR DES PROFILS CREUX EN ACIER

An introductory summary has been added by the Corus Tubes, Corby, U.K. in 2002

SUMMARY

RESISTANCE TO INTERNAL CORROSION IN STEEL HOLLOW SECTIONS

This report covers detailed investigations into internal corrosion in steel structural hollow sections which have seen service in widely differing geographical and environmenta1 locations.

The samples investigated were removed from the following structures.

America	Pittsburg	Trolley bus poles. Urban atmosphere. 40-50 Years service.
	Dayton, Ohio.	Lighting columns. Urban atmosphere. 59 years service.
Britain	Nore Forts	Tubular gangway. Marine atmosphere. 10 years service.
	S.S. Aquitania	Lifeboat davits. Marine atmosphere. 37 years service.
	Chelsea F.C.	Floodlighting tower. Urban atmosphere. 21 years service.
Germany	Wiesental	Transmission towers. Rural atmosphere. 18 years service.
	Hiltrup	Roof trusses. Highly corrosive atmosphere over pickling bath. 10 years service. (Dismantled due to heavy external corrosion).
Japan		Lighting columns. Urban atmosphere. 5-11 years service. (Investigation into location of drain holes at base of columns).
Italy		Lattice braced tower cranes. Urban atmosphere. 10-20 years service. Tubular steel framed buildings. Industrial atmosphere. 25-30 years service.
France	Valenciennes	Outside loading gantry. Industrial atmosphere. 14 years service.
		Sulphate store. Highly corrosive next to pickling plant. 10 years service. (Roof bracings and stair handrails)
		Stores building. Industrial atmosphere. 15 years service.
		Factory building. Industrial atmosphere. 16 years service.

These investigations all show that steel hollow sections which have been sealed by welding or have their ends flattened do not corrode internally. The majority of such samples investigated still had the original mill scale adhering to their inner surfaces where it remained unimpaired, revealing only slight internal corrosion. Sections which have been sealed at one end only show internal corrosion adjacent

to the open end but elsewhere are not seriously impaired.
The report also deals with hot dip galvanising of structural hollow sections, including drilling, draining and venting. It touches briefly upon the subject of 'breathing', and the advisability of providing "pressure balancing" holes to obviate ingress of water during inhalation due to temperature changes.
It also refers briefly to concrete filling and moisture venting.

The following companies and organisations referred to in this booklet are now part of the organizations shown:

British Steel Tubes Division and Stewarts & Lloyds are now part of Corus Tubes, Corby, UK

GIE-Cometube and Cometube are now part of Arcelor Tubes, Aubervilliers, France

Mannesmannrohren-Werke are now part of V & M Tubes, Dusseldorf, Germany

---

ACKNOWLEDGEMENTS

The author wishes to thank all the organisations which took part in this research work. In particular, he would like to extend his appreciation to the members of the Technical Commission of CIDECT as well as to the experts on corrosion not belonging to CIDECT, who have made it possible to gather the data on which this work is based.

TABLE OF CONTENTS.

1. FOREWARD.

It is perhaps strange that so much energy and not inconsiderable sums of money have been devoted to an investigation to prove that in the case of hollow sections sealed at both ends internal corrosion does not exist.

It should be obvious!

If the research over the years has been haphazard it is simply because no international organisation has taken the initiative to coordinate and analise the available information. It is to fill this gap that CIDECT some years ago asked GIE Cometube to collate the existing information and from it form an authorative understanding of the conclusions to be drawn from existing structures.

This investigation into the simple protection of the interior of hollow sections was carried out by Cometube, who are indebted to the following for financial assistance.

The Federation of Steel Tube Makers (CSFTA).

The International Committee for the Development and Study of Tubular Construction (CIDECT).

This investigation has made possible the reports of the National Test Laboratory (LNE) in Paris.

The purpose of this paper is to present the information which is available world-wide, together with that which has been gained from more recent investigations in France.

2. BACKGROUND.

2.1. Theoretical

Corrosion can only take place if certain elements are present; iron, oxygen and water, in the form of moisture in the air. If a section is hermetically sealed the moisture in the entrapped air will allow only a limited amount of corrosion to take place. As the oxygen is used up oxidation will cease, since the entrapped air cannot be replenished.

2.2. Practical.

On the basis of this theory it seems obvious that the protection of hollow sections is simply a question of air tightness. Thus the general outlines of the investigation are clearly defined; the inspection of structures which have been standing for many years must prove that the normal methods of fabrication are sufficient to prevent internal corrosion.

3. SURVEY OF EXISTING LITERATURE.

It is impossible to list here, even briefly, all the publications which have been issued on this subject and which may have come to our notice. We shall therefore limit ourselves to mentioning some particularly interesting accounts which are based either on very detailed theoretical investigations or refer to significant experiments.

3.1. **Article by G. B. Godfrey from "The Civil Engineer" Journal of May1961** [1].

This article describes the investigation carried out at that time (1961) and mentions particular cases where observations could be made on existing structures, more often than not as a result of fortuitous accidents, such as that which occurred to the footbridge at Le Nore.
Further details on this particular structure is given in the chapter dealing with British experiencies.

3.2 Report by Omer W. Blodgett in the Lincoln Electric Co. Journal of August 1967 [2]

This report investigates the problems presented by the welding of hollow sections used in structures and in particular the protection given to the interior of sections when closed by welding.

On the basis of his own observations and on foreign experience, he reaches the conclusions which we reproduce in full below.

1) Sealed hollow sections require no internal protective coating and may be regarded as essentially immune from corrosive attack.

2) Condensation in a sealed section is impossible, and when found upon inspection is evidence of an opening having developed -possibly a small opening that is drawing surface water in through capilliary action.

3) Adding a "pressure equilibrium hole" at any point in a hollow structure where water cannot enter by gravity will prevent aspiration in an imperfectly sealed system. (If the engineer has qualms about condensation, he might as well put the hole at a low point where it would serve for drainage also - merely to satisfy his peace of mind.')

4) An "open" system should generally be kept as tight as feasible with rubber gaskets used at manholes and such closures positioned so as to avoid water accumulation and the possibility of its entrance by capillarity action or aspiration. A strategically placed pressure equilibrium hole might be advisable. Such Systems should be protected with an interior coating.

5) A ventilated hollow structure should be internally protected and have adequate ventilation holes at each end and in the sides.

6) Bolt and rivet holes should be avoided where-ever possible; they create conditions conducive to water entrance by capillarity action.

In general, good design and good practice should eliminate concern about corrosion in hollow steel sections. The overwhelming mass of evidence, scientific analysis, and European experience suggest that it is - as the Englishman said - more of a "bogey" than a serious engineering problem.

3.3. **Bulletin of the American Iron and Steel Institute, February 1970** [3]

This important study carried out by a working group originating from American Steel Production and Construction Industry is based upon extensive evidence in North America and Europe.

A substantial part of the report is devoted to the theoretical investigation of corrosion. The authors discuss the equations relating to the electro-chemical reaction of oxidation. In addition they give mathematical expressions which make it possible to calculate the thickness loss of metal on the assumption that there is a possibility of partial renewal of the internal air.

We reproduce below, in full, the summary given in that bulletin:

"An investigation carried out on electricity poles, water tank supports, orthotropic decks of bridges, tubular footbridges for marine applications, davits and welded steel columns indicates that, contrary to some opinion, the internal surface of closed steel components do not corrode under atmospheric conditions, even if they are not completely sealed. Only slight corrosion occurs since the quantities of oxygen and water contained in the imprisoned air within the component are limited, and the condensation which is necessary for corrosion to occur is very rare. Calculations based on the oxidation reaction, taking into account the surface area, the enclosed volume of air, the relative humidity and the air changes, indicate that the loss of steel thickness due to such corrosion is negligible

Therefore, the use of closed steel sections in bridges and buildings can be considered now that we know there is no fear of loss of strength due to internal oxidation. This principle applies to all closed steel sections, regardless of size, from relatively small tubular structures to large size box sections. The fact that the internal surfaces of closed steel sections do not require painting to prevent corrosion means a substantial reduction in maintenance costs and the elimination of manholes with removable covers, which have been common practice until now. Schwendenan estimates a saving in maintenance costs amounting to as much as 45% in the case of closed box sections for bridges if the painting of the internal surfaces is considered unnecessary."

4 INVESTIGATIONS CARRIED OUT THROUGHOUT THE WORLD

4.1 **American experience**

The observations given hereunder are extracts from the major publication quoted in section 3.3 [3].

4.1.1 Trolley Bus Poles in Pittsburg

Thanks to the cooperation of Mr. C. E. Schauck of the Allegheny County Port Authority, Pennsylvania, it was possible to obtain some samples from poles used to support trolley bus cables in the Pittsburg area. These poles which have been in service for 40/50 years are stepped poles fabricated from three telescoping sizes of tube, the sizes of which are given below. All the sections had the same nominal thickness of 12.7mm.

lower section: hollow section 219mm dia. height 5.80m.
middle section: hollow section 193.7mm dia. height 2.20m.
upper section: hollow section 168.3mm dia. height 2.20m.

In order to establish the loss of steel due to corrosion, the thickness of the wall of the 219mm sections was measured with an audio-gauge, an ultrasonic measuring apparatus using flat crystals. Unfortunately, for the measuring of the wall thickness of the 193.7 mm hollow sections, and the 168.3mm sections, the audio-gauge could not be used owing to the sharper radius of curvature.

Although the upper ends of the columns had been left open to the weather, it was noticable that the corrosion in the 219mm dia. tubes ,which were half a century old, was negligible, as indicated in the following table:

Sample No.	Nominal thickness		Measured thickness		Difference with regard to nominal thickness
	ins	mm	ins	mm	
1	0.500	12.7	0.493	12.32	-1.4%
2	0.500	12.7	0.474	11.8	-5.2%
3	0.500	12.7	0.526	13.2	+ 5.2%
4	0.500	12.7	0.498	12.48	- 0.4%
5	0.500	12.7	0.520	13.0	+ 0.4%
6	0.500	12.7	0.492	12..3	- 1.6%

The origina1 specification allowed for a tolerance of ±12.5% with regard to the nominal thickness. The chemical composition of the 219mm diameter hollow section, taken at random, was 0.8% carbon, 0.58% manganese, 0.10% phosphorous and 0.005% copper. The small copper content did not increase the steel's resistance to corrosion.

The comparative atmospheric corrosion rates for an open hearth steel of similar chemical composition and of a copper open hearth steel have been determined by the A-5 Committee of the ASTM. The Committee found that in Pittsburgh the average number of years required to perforate 22 gauge corrugated iron sheets, with 0.02% copper content, was 1.3 years, whereas that for a 0.21% copper content was 4.8 years. The sample trolley bus pole should probably have had an atmospheric corrosion resistance amounting to ¼ to ⅓ of that of a copper steel and yet the inside surfaces of the post were practically intact after half a century of service. It can therefore reasonably be concluded that the inside surface of tubes placed vertically and not closed shows virtually no corrosion in the atmosphere.
At least 22,000 poles of this type were installed in Pittsburgh. After 40 to 50 years of service, with their upper ends open, some 18,000 are still in use and functioning in good condition. The other posts have been dismantled following the replacement of the majority of the trolley buses by ordinary buses.

4.1.2 Lighting Columns in Dayton, Ohio

Mr. I. G. Holmer, Director of the Department for Municipal Affairs of the Dayton Power and Light Company, Dayton, Ohio, has supplied a sample of lighting column which had been installed in 1905 and removed in 1964. The upper part of the column was curved through 80^{o}. No internal protection had been provided.

The sample had been cut just above the ground level. The chemical composition of the material was as follows: 0.04% carbon, 0.38% manganese, 0.002% phosphorous and less than 0.0005% copper. The section had been cut longitudinally. The internal surface was examined and found to have retained the original mill scale. There was no pitting of the steel which would indicate atmospheric corrosion. The external surface of the column had been repainted periodically. With regard to the internal surface, this had remained intact after 59 years of service. None of the columns in this series, installed at the same time, had been damaged by corrosion.

4.2 **British Experience**

4.2.1.Catwalk at the Nore forts - Thames Estuary.

The following is an extract from a report drafted in 1953 by the Stewarts and Lloyds Research Department, today the British Steel Corporation - Tubes Division [4].

The information given here has intentionally been limited to those paragraphs covering only the subject with which we are concerned, the resistance of hollow sections to internal corrosion.
In 1943 Tubewrights supplied catwalks connecting the forts erected offshore on the Nore. These were fabricated from both seamless and welded CHS in diameters ranging from 33.7.mm to 168.3.mm. At the time of erection, these sections were covered with a first coat of "Drynamels" anti-rust paint. Obviously all the ends of the hollow sections were sealed so that their interiors were not exposed to the marine atmosphere and, naturally, no internal corrosion took place.

Ten years later, the steamship "Baalbek" collided with one of these catwalks in foggy weather. The ship suffered substantial damage and the catwalk was completely destroyed, as can be seen from the photographs. It must however be observed that, in spite of the extent of the damage, there were comparatively few broken hollow sections; the whole structure was deformed in a ductile manner. Subsequent inspection showed that, even where the hollow sections were broken, the rupture was not of a brittle nature.(Figs. 1-6).

Given the doubt often expressed as to the ability of Bessemer steel to stand up to impact and substantial deformation, it was thought useful to collect a few of these damaged hollow sections for a more detailed examination. Many users of tubular structures had expressed some concern as to the possibility of internal corrosion taking place in spite of having ascertained that the sections were properly sealed.

It is difficult to imagine more corrosive conditions than those endured by these catwalks, exposed as they were to moisture, a marine atmosphere, variations in temperature etc. Consequently, this accident presented a unique opportunity to examine the inside of the tubes.

Naturally, only a small part of the catwalk was removed for this examination, the samples being cut out of the main members. These samples suffered further considerable damage while lying on a scrap heap and during transport. The photographs accompanying the report show the state of the components. It must be pointed out that a detailed inspection of the inside of the tubes failed to reveal any deterioration which is not shown on the photographs.

Figure 1: Joint unit with parts of the chords showing severe deformation and rupture at the point of impact.

Figure 2: Detail of the rupture at the point of impact showing the ductile fracture.

Figure 3: Various parts of the twisted and damaged side chords.

Figure 4: Detail of the upper chord from Fig. 3

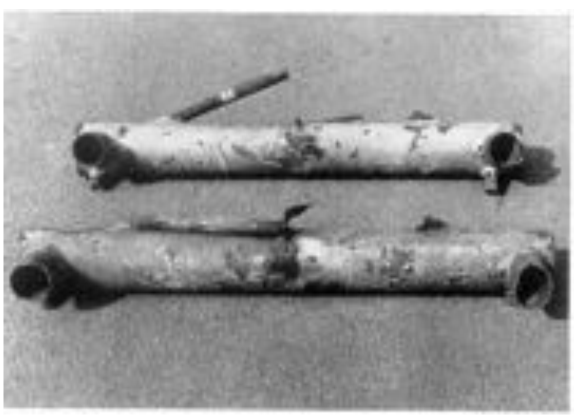

Figure 5: Compressed members with ends still sealed, the ductile bending of the lattice members should be noted.

Figure 6: Web member at the bottom of Fig. 5 indicating that the weld has not parted in spite of the large bending force.

1 - State of the external surface

It was rather difficult to check the state of the external surface owing to the extent of damage which had been done to the coat of paint during the accident and, even more, during subsequent handling. However, most of the external surface seemed to have remained in a good condition, and at the spots where the coating had been damaged on the surface, the primary coat had kept its original qualities.

One major case of external corrosion was however observed. This can be seen on the photos, Figs. 7 and 8, where a hole has developed in one of the lattice members. It appears that another component of the framework or even possibly a rope had been in contact with this member causing abrasion which assisted the penetration of moisture, thus intensifying the corrosion. A proper inspection would have made it possible to detect damage of this type.

No variance of corrosion rate between weld and parent metal due to electrolytic action was observed either at the welds or elsewhere. Indeed, providing that the paint coat was properly maintained, this tubular structure could have lasted indefinitely.

2 –State of the internal surface

At the time of the cutting out of the samples and before their arrival at Corby, a large number of hollow sections, previously sealed, had been opened at the ends. The number of components still sealed was nevertheless sufficient to allow for inspection. When these were opened, it was found that the internal surfaces still bore the original mill scale, identical to that which is found when leaving the mill.

The photos showing the internal and external surfaces of these hollow sections illustrate these points quite clearly (Figs. 9 to 12)

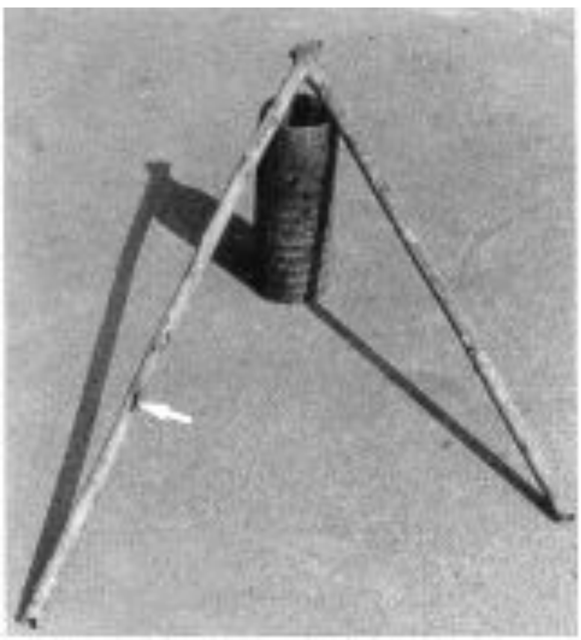

Figure 7: Perforated member, probably the result of rubbing against another part during its working life.

Figure 8: Detail of the corroded openings of the members in fig. 7.

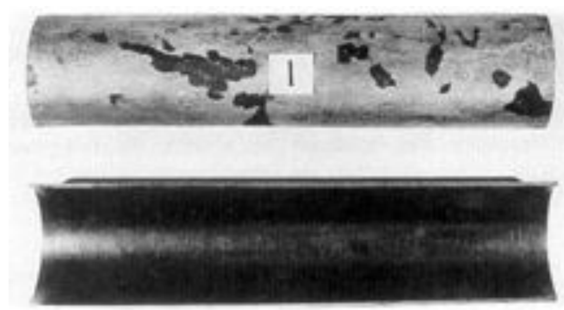

Figure 9: Hollow sections 114.3.mm dia. internal surface: perfectly preserved. External surface paint chipped during handling.

Figure 10: The same part. The traces of pre-welding heating can still be seen intact after 10 years.

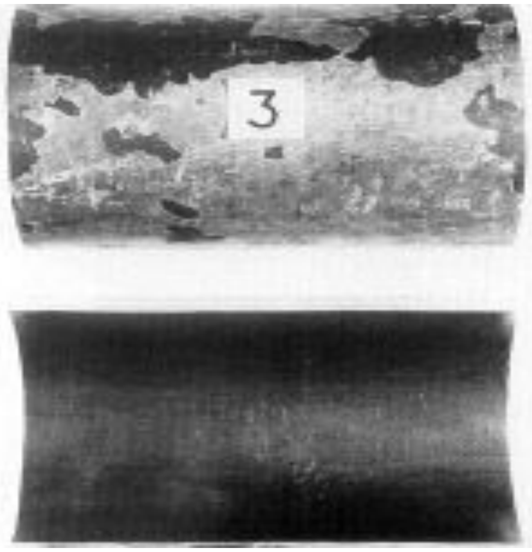

Figure 11: Hollow section 168.3.mm dia internal and external faces

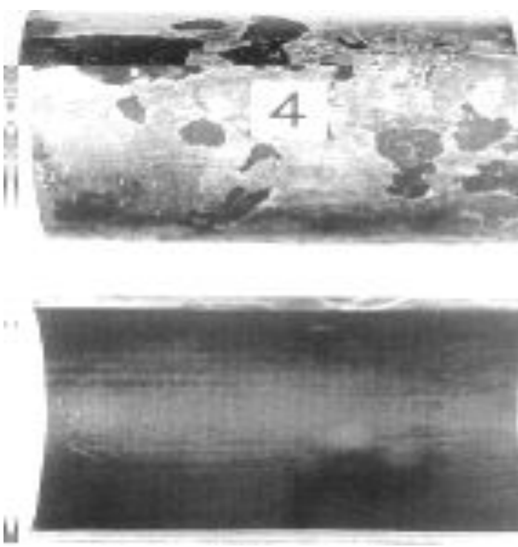

Figure 12: Same component as Fig. 11, the bright appearance of the internal surface should be noted. Some of the origina1 mill-scale adheres to the wall.

Figure 13: Complete S. S. Aquitania davit as delivered for inspection

It is interesting to note, on Figure 10, the indication of the area heated during the welding operation, visible on the internal wall. Nevertheless no deterioration occurred in this region.

4.2.2 Davits from S. S. Aquitania

This is an excerpt from a report of the 6th May 1960 produced by the Corby Works of the Tubes Division of the British Steel Corporation [5].

Two davits, supplied initially by Stewarts & Lloyds, for the liner 'Aquitania" were kindly given to the Research Centre at Corby so that they could be examined in the course of an investigation into the internal corrosion of hollow sections. The davits were installed in "Aquitania" at the time when she was built in 1913 to 1914. The ship was scrapped in 1950. Two davits were than dismantled and used for various demonstrations at Stewarts & Lloyds over several years, until they were finally scrapped at the "Globe Tube Works" in Wednesbury, England.

These davits were then about 37 years old and had been exposed to a marine atmosphere for the greater part of their lives. As can' be seen in the photo (Fig. 13) each davit is made of tube approximately 406 mm diameter and 52 mm thickness, cylindrical at the centre and conical at each end, where the diameter is reduced to about 170 mm. Both ends are sealed by welding, one with a steel ball to carry the lifeboat and the other by means of a circular plug in mild steel. The total length was about 9 meters. One of these davits was cut with the flame cutter so that the interior could be examined.

Figure 14 shows a sample of the cylindrical part, figure 15 a sample of the upper conical part and figure 16 a sample of the lower sealed part.

Unfortunately, bearing in mind the size and the weight of the various components, all the cuts had to be made with a torch and very often the resulting flashes soiled the internal faces that were to be inspected. This is why the photos seem to indicate a somewhat rough surface, whereas in fact there was no internal corrosion whatsoever in the davits inspected. The true appearance of the internal surface is better shown at the centre of the section in Figure 14.

It can be stated in conclusion that, as one would expect no internal corrosion occurred in these davits in spite of their 40 years' service at sea.

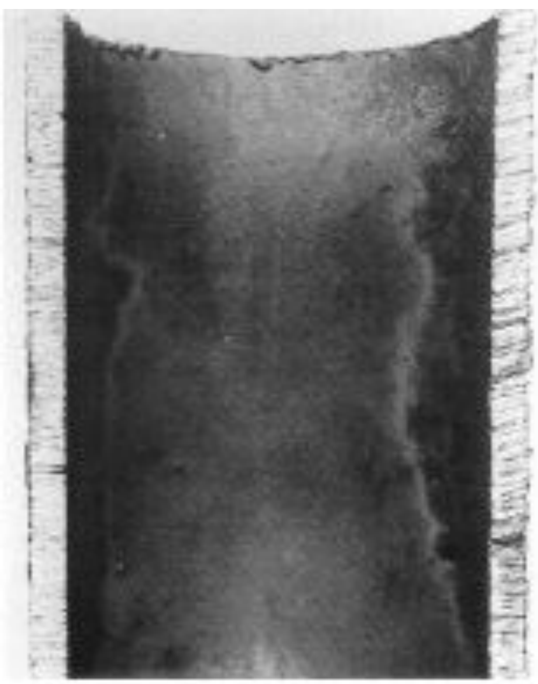

Figure 14: Internal surface of the central section of the davit

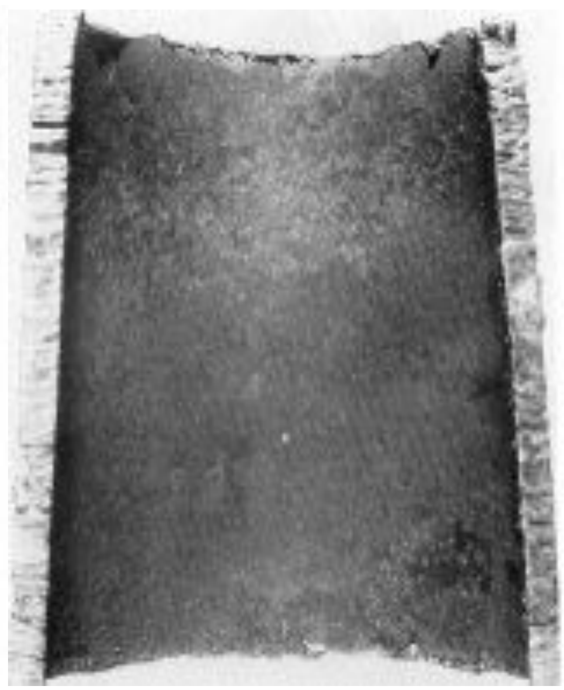

Figure 15: Upper part of the davit post cut open. (note the white spaces and the small spots due to oxyacetylene cutting)

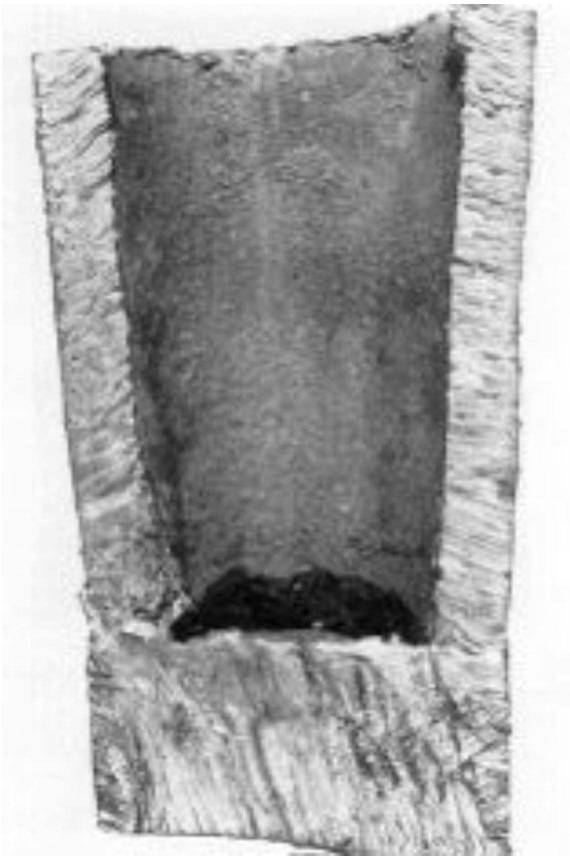

Figure 16: Lower part of the davit post as cut open.
(The white spots are again due to oxyacetylene cutting)

4.2.3 Floodlighting towers at the Chelsea Football Club.

Extract from the journal "Tubular Structures Exposed" of 1977[6]

The Chelsea football Club acquired an international reputation in the mid-sixties when its young team, managed by Tommy Docherty, gained fame both in the European field as well as in the national one. This action on the football field was matched by an impressive record with regard to the improvement of the stadium, and the new stand at Stamford Bridge was among the very first to be built according to the Wheatley proposals for crowd safety. The erection of the new grandstand meant that two of the "Tubewrights" tubular steel floodlighting towers installed in 1954 would be hidden.

In 1975, Tower Structures Marketing informed Dick Williams of the Market Development (SHS) Department that these towers were going to be demolished and steps were quickly taken to obtain sections from the towers in order to examine them. The sections were stored temporarily in the London warehouse of the Tubes Division in Pudding Mill Lane) and were sent by the first available lorry to the Research Centre at Corby for examination.

A case Study on the question of Internal Corrosion in sealed Hollow Sections by Charles Dawson, Tubes Division, British Steel Corporation.

The samples cut from the two Chelsea towers came from the CHS legs, 159.7 mm dia. by 6.3 mm or 4.5 mm thick, and 114.3.mm dia. x 6.3 mm thick. These were closed at the ends by solid flanges which were then bolted together.

The flanges had a diameter of 504.8 mm x 16 mm thick with four BSW bolts 28.6 mm x 80 mm long at a pitch circle diameter of 209.5 mm. The external protection of these components consisted of a zinc coating applied after fabrication, in accordance with British Standard 729.

These towers had, naturally enough, been painted in the Chelsea colour, blue. The upper part of the structure and the portal bases had been fabricated from hollow sections and galvanised plates. The weld seams had subsequently been shot blasted and zinc sprayed. The joints were then covered with a coat of zinc rich paint and the whole unit was finished with an application of aluminised paint.

Examination of the samples collected.

Sample no. 1: 159.7 mm dia. was slit longitudinally in order to reveal the internal face (Figure 17). Very slight signs of internal corrosion were observed, other than surface discolouration, due to the oxygen and the humidity in the imprisoned air. Much of the original mill scale was also visible. The slight rusting which was found at the centre of the sample was recent, having appeared after the tube had been cut open for examination.

Sample no. 2: Also l59.7 mm dia. included an intermediate flange assembly (Figure 18). The conditions of the internal face of the flange, which had been enclosed and hermetically sealed by being welded to the CHS, was still relatively bright, the original marking-off lines being clearly visible. The intermediate flange assembly was dismantled in order to examine the contact faces of the flanges (Figure 19)

Figure 17: Circular hollow section 139.7 mm showing one of the half cylinders cut longitudinally. The slight amount of rust in the middle the tube is recent and has appeared since the tube was cut for inspection.

Figure 18: Circular hollow section l39.7 dia. welded to a solid flange showing clean conditions of the internal of faces. The original marking off lines on the flange are still perfectly visible.

On the outside of the flanges a certain amount of corrosion was discovered, but this was, in fact limited to the area which was outside the pitch circle diameter of the bolts and was obviously due to the progressive ingress of rainwater between the flanges over many years of service (Figure 19).

The amount of corrosion that was discovered was not considered sufficient to adversely affect the strength of the joint. The penetration of water in this manner is a problem normal to all structures which use bolted joints exposed to the weather. The effect can, however, be reduced, if particularly critical, by using jointing material that will seal the connection or by applying mastic between the flanges.

Other samples were also examined and these again showed the excellent condition of the interior of the circular hollow sections and the internal faces of the flanges, demonstrating an almost total absence of corrosion.

The fact that these sealed hollow sections show such a high resistance to internal corrosion is not surprising to engineers familiar with this type of construction. Indeed, it is because this is so well established that the clause referring to this problem in BS 449 allows structural members in hollow sections, which are hermetically sealed at the ends, to be thinner than corresponding members in conventional open sections.

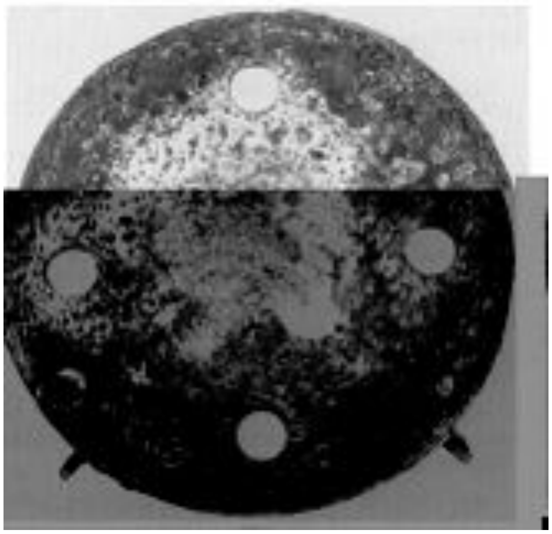

Figure 19: Contact faces of the solid flange after dismantling.

Figure 20: High voltage transmission tower. External view of the cut out joint sample.

4.3. **German Experience**

4.3.1 Verification of the internal condition of tubular members in transmission tower. Report of the Mannesmann Research Institute in Huckingen. December 1974 [7]

Summary: The internal surfaces of four hollow sections originating from a joint in a high voltage transmission tower do not show any corrosion defect after 18 years of service. When the hollow sections are hermetically sealed, their use as a structural element does not present any problems with regard to internal corrosion.

Background: In 1956 the Rath Works of Mannesmannrohren-Werke delivered guyed towers for a 220/380 kw power line from Wiesental (Laufenburg-Kembs) to Badenwerk AG, Karlsruhe. After some 18 years tower No. 13 at Stackingen was withdrawn from service, presumably following some alterations. This made it possible to cut out some samples and to assess the state of the internal surfaces.

Result of the examination: Figure 20 shows the part of the pylon which was supplied by Mannesmannrohren-Werke. This sample had been cut out of a joint situated some 12 m above the ground.

At this joint four tubular bracing members were connected to one of the concrete filled chords. These members were made of seamless hollow sections, hermetically sealed, in steel corresponding to the old grade Marwe 134 a (which now corresponds to steel St.55 of standard DIN 1629). The hollow sections were cut at about 40 cm from the junction with the chord.

Figure 21: View of the internal faces of the brace component No. 1.

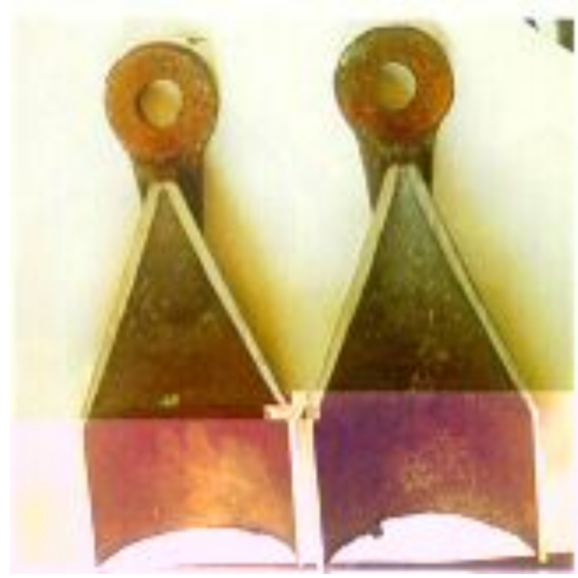

Figure 22: View of the internal faces of the brace component no. 2.

Figure 23: View of the internal faces of the brace component no. 3.

Figure 24: View of the internal faces of the brace component no. 4.

In order to be able to examine the internal surfaces, the four bracing members were detached from the chords and cut longitudinally in half (Figures 21 to 24).

The internal surfaces were perfectly smooth and did not present any sign of corrosion attack. This complete lack of internal corrosion was confirmed by the presence of the mill scale going back to the original rolling of the section, as well as the good preservation of the 'blue' colour due to the heating caused by the welding of the fixing lugs. These observations apply to both the upper and lower ends of the diagonal bracing members.

Conclusions: The observations carried out showed that there is no fear of internal corrosion where hollow sections have been sealed by welding and that they can be used as constructional elements in structures intended for long-term service.

4.3.2 Trusses in hollow sections above pickling baths. Report of the Hoesch Company (1974). Extract from the report by Dr. H. Kotter. [8]

In 1953 a new building was erected for the installation of a pickling plant for precision tubes at the Hoesch Tube Works in Hiltrup in Westphalia.

Symmetrical double slope trusses were made in hollow sections. The framework consisted of a lattice system without any gussets, with sealing welds throughout. A crane rail was suspended from the lower chord. The framework was initially covered with a coat of anti-rust primer.

The pickling plant comprised the following open baths:

1.- Pickling bath with 25% sulphuric acid (H_2SO_4) – temperature 75 ^{0}C.

2.- Hot and cold water washing baths.

3.- Phosphate solution (H_3PO_4) baths at a temperature of 65^0 to 70^0 C with added oxidisers (nitrite and nitrate solutions)

4.- Lubrication baths at a temperature above 90^{0}C.

The fact that the pickling baths were open caused an almost permanent high level of humidity with the formation of vapour. The ventilation openings provided along the roof ridge did not reduce this to any extent. In particular the sulphuric acid carried by water droplets was causing very serious damage to the steelwork. A second coat of paint had to be applied after a short time, the rust having been previously cleaned off by hand. Three years later, a re-paint was necessary, but this time after sanding and the application of an anti-rust primer

In spite of these three painting operations, the corrosion on the external surfaces was so extensive by 1962, i.e. less than 10 years after the erection of the building, that the first deformation became evident and it was found necessary to dismantle the roof structure.

After being dismantled, the trusses were cut up with a flame-cutter into sections of relatively short length and scrapped. It was thus possible to examine the internal surface of the members through the cut ends. (see fig. 25).

Although external corrosion had caused some holes through the wall thickness at certain localised points, no internal corrosion whatsoever was observed. The original mill scale was still clinging partially to the internal surface.

It was thus possible to verify that, under particularly severe conditions of use no internal corrosion takes place in hollow sections providing the sections have been sealed properly. This confirms the previous investigations of Seils and Kranitzky [17] on this subject.

Figure 25: Truss component located over a pickling bath. The external surface shows an advanced state of corrosion, due to the ambient atmosphere, whereas the inside is well preserved, the traces of damage are entirely due to the oxyacetylene cutting operation.

Moreover, this experience demonstrates that, even when the weld seams are not perfectly sealed or small holes have been made in the section, no internal corrosion follows. The most that can be found is a slight trace of superficial rust in the immediate neighbourhood of the holes or the welds which are not airtight. In conclusion, it is therefore possible to confirm that which has already been demonstrated in previous investigations, namely that in the case of welded structures in hollow sections there is no fear of internal corrosion.

4.4 **Japanese Experience**

<u>Enquiry concerning urban lighting columns. Report by the Sumitomo Metal Co. - February 1977 [9]</u>

Structure: This document refers to the investigation carried out on the internal corrosion of lighting columns for public thoroughfares with a high level of traffic (Figure 26).

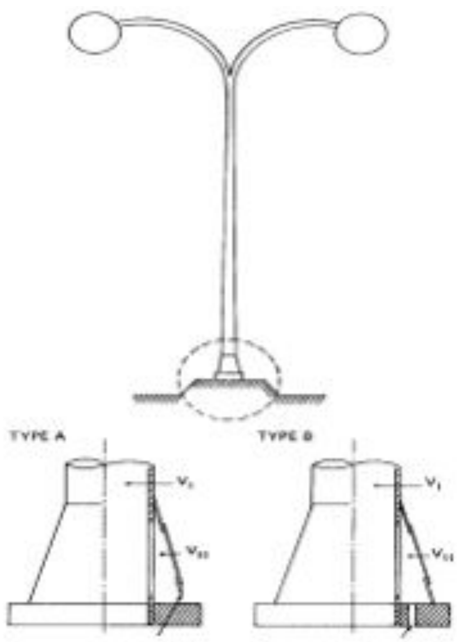

Figure 26 - Urban lamp-post: water drainage hole 10 mm radius for both types
Type A: side hole Type B: base hole

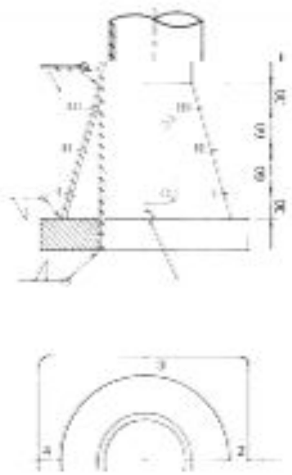

Figure 27 - Column Base

Table 1: Amount of interior corrosion (t mm)

N°(a)	POINTS DE MESURE (b)															Moyenne	Type (c)	Zone (d)	Années (e)
	I					II					III								
	1	2	3	4	Moy.	1	2	3	4	Moy.	1	2	3	4	Moy.				
1	.8	.4	1.0	.2	.6	.5	.0	.2	.1	.2	.2	.0	.0	.0	.1	.3	A	X	6
2	1.8	1.8	.6	.1	1.1	1.1	1.0	.6	.2	.7	.0	.0	.3	.0	.1	.6	A	X	6
3	.5	.0	.7	.5	.4	.0	.1	.7	.7	.4	.0	.0	.3	.2	.1	.3	A	X	6
4	.4	.9	1.3	.6	.8	.6	.1	.7	.9	.6	.0	.0	.3	.8	.3	.6	A	X	6
5	1.2	.7	.7	.6	.8	1.0	1.2	1.0	.4	.9	.1	.0	.2	.2	.1	.6	A	X	6
6	.8	.4	.1	.9	.6	1.9	.1	.2	1.7	1.0	.4	.1	.0	.4	.2	.6	A	X	6
7	1.7	.5	.7	1.0	1.0	.4	.6	.5	.0	.4	.3	.0	.1	.0	.1	.5	A	X	6
8	1.3	.6	.8	.7	.9	.8	.1	.1	.6	.4	.0	.2	.2	.0	.1	.5	A	X	6
9	.7	.9	1.0	1.1	.9	1.0	.7	.8	.6	.8	.6	.2	.3	.2	.3	.7	A	X	6
10	*	.8	.7	.3	(1.3)	.8	.5	1.7	.9	1.0	.7	1.1	.6	.6	.8	(1.0)	A	Y	10
11	*	*	*	*	(3.2)	1.5	.7	.7	1.3	1.1	1.1	1.5	.7	.5	1.0	(1.3)	A	Y	10
12	*	*	*	*	(3.2)	*	*	*	*	(3.2)	.5	.9	1.4	1.6	1.1	(2.5)	A	Y	10
13	.1	.0	.0	.0	.0	.1	.0	.1	.1	.1	.1	.1	.1	.1	.1	.1	A	Y	7
14	1.7	.7	.7	1.3	1.1	.2	1.0	.7	.2	.5	.0	.0	.6	.4	.3	.6	A	Y	7
15	2.0	.0	.7	.3	.8	.1	.1	.4	.1	.2	.1	.0	.1	.0	.1	.3	A	X	5
16	1.1	.0	.6	.1	.5	.1	.0	.1	.1	.1	.1	.0	.1	.0	.1	.2	A	X	5
17	1.7	.1	.1	.0	.5	.0	.4	.1	.0	.1	.1	.2	.1	.1	.1	.2	B	Z	11
18	.2	.1	.1	.2	.2	.0	.0	.2	.1	.1	.0	.1	.2	.1	.1	.1	B	Z	11
19	.0	.0	.0	.0	.0	.1	.1	.1	.0	.1	.1	.1	.1	.0	.1	.1	B	X	11
20	.2	.0	.1	.0	.1	.1	.1	.1	.1	.1	.1	.1	.2	.0	.1	.1	B	X	11
21	.1	.0	.1	.2	.1	.0	.0	.0	.0	.0	.2	.1	.0	.0	.1	.1	B	X	10
22	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	B	Y	7
23	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	B	Y	7

Notes:

(a)	No. 1-2	lighting posts reference number
(b)	I, II, II and 1, 2, 3, 4	measuring point locations, see fig. 27
(c)	Types A and B	location of water drainage hole, see figs. 26 and 27
(d)	Zone of location	X – industrial, Y – commercial, Z – residential
(e)	Annees	years in service

* thickness less than 1 mm, no measurement possible

calculated internal corrosion thickness, t = original thickness (3.2 mm) – remaining thickness

Measurements carried out: The internal corrosion was measured by means of an ultrasonic thickness tester. The measuring points (I, II and III) are shown on Figure 27. There was no internal paint.

Amount of internal corrosion.: The measurements of internal corrosion for those columns examined are given in Table 1.

Result: The relation between t (thickness reduction due to internal corrosion and T (years elapsed since installation) are shown on Figure 28 for two types of water drainage holes.

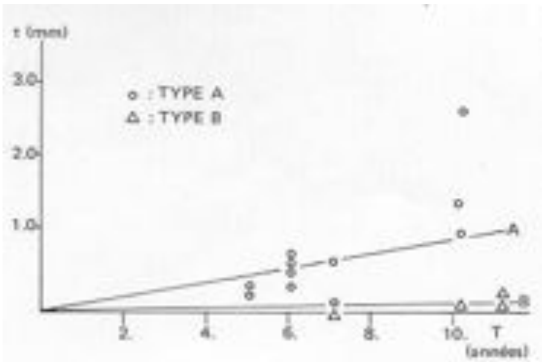

Figure 28: -t/T ratio in relation to the type of drainage hole (years)

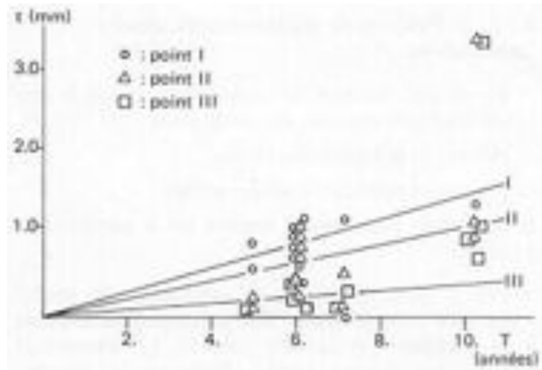

Figure 29: Type A column. t/T ratio in relation to the measuring points(years)

Conclusion: The following results have been obtained at the end of our investigation.

1) The location of the drainage hole is one of the most important factors affecting internal corrosion. Type A posts with a drainage hole on their tapering sides do rust severely, whereas type B posts with a drainage hole on the base plate do not rust.

2) Corrosion is particularly severe at the point where the edge plate is welded to the base plate.

3) There is little relation between corrosion and the nature of the posts' environment.

4.5 **Italian Experience**

Extracts from the report of the 3 March 1977 – ref. SCN/339 by the FIT Ferrotubi Co. of Milan.[10]

4.5.1 Cranes

We have had the opportunity over some thirty years of activity as constructors, particularly when dealing with lattices of tower cranes for building sites, to observe that if the weld had been carried out according to established practice and if consequently, the hollow section was airtight, the interior of that section showed no sign of corrosion even after 10 or 20 years of service. The amount of iron oxide present was not greater than that present at the time of welding or that which had formed as a result of the oxygen remaining inside the hollow section.

4.5.2 Industrial buildings

Some buildings with a tubular framework, belonging to our Company, which were erected 25 or 30 years ago, are due for dismantling. These will enable us to carry out a detailed investigation on this subject, but we have already cut out some samples from a tubular lattice component and we are sending these to CIDECT.

The 3 samples taken from an industrial building had been cut longitudinally and examined (see figure 30). There is no trace of internal corrosion in spite of the age of the structures (more than 10 years) and the conditions of exposure (industrial atmosphere).

Figure 30 - Internal and external appearance of three samples
cut from the tubular framework of an industrial building.

4.5.3 Telecommunication masts - Lighting towers

In the case of structures which are continuously exposed to the weather, e.g. telecommunication towers, posts or towers for public lighting, the protection usually adopted is hot dip galvanising. Both external and internal surfaces of the hollow sections are then protected. The techniques particular to this treatment and specific procedures mentioned in (i) allow for the prevention of any subsequent ingress of water and for the provision of drainage to eliminate the danger of ice formation within the structure.

(i) *The Italian author refers here to the provision of holes to facilitate immersion during galvanising and also the provision of 'pressure balancing' holes.*

5 INVESTIGATIONS CARRIED OUT RECENTLY IN FRANCE

5.1 **The investigation carried out at Valenciennes in March 1974**:

This factory situated in the industrial region of the North of France was chosen on account of the numerous possibilities it offered for cutting samples.

Indeed, the high number of hollow section structures more than 10 years old made it possible to find, in the same location, the range of samples which was sought, e.g. members which were hermetically sealed at both ends, members which were partly sealed and members flattened at the ends.

5.1.1 Obtaining the samples: This work commenced on the 28th March 1974 in the presence of Maitre Bettignies who was Legal Officer at Valenciennes. It was Mr. Veaux, Head of the Material and Structure Dept., who represented the National Test Laboratories (LNE). Mr. Tournay, responsible for the Research Dept. at Cometube, was observing the operation for the Chambre Syndicale des Fabricants de Tubes d'Acier (CSFTA).

All the structural components were listed and photographed on the spot by the LNE representatives. They were then sent for examination to the LNE Laboratory, 1 rue Gaston Boissier, in Paris. With the exception of the gantry leg, which was sent as it was to the LNE, all the members were cut out on site.

5.1.2 Description of the structural components which were taken as samples: The choice of members depended essentially on the methods used for joining, which we wanted to test. The final decision regarding the sampling was obviously influenced by the need not to disturb the construction work which was in progress.

Figure 31: Valenciennes Works -General view of the loading portal before dismantling.

Figure 32 - Cutting out of a sample

The actual units chosen were therefore as follows: 1) external loading gantry, 2) sulphate shed 3) storage shed - eastern extension and 4) factory shed - wind girder.

1) External loading gantry: This gantry (see Fig. 31) had been used for mechanical handling and for loading the structural components fabricated in an adjacent workshop. It had been erected in 1962, and had not been used since 1970, so it was due for dismantling. This is the reason why the highest number of members cut out came from this structure. The working and maintenance conditions for this gantry were those which are commonly encountered in metal workshops of the Valenciennes region, i.e. an industrial atmosphere and severe climatic conditions, being exposed to the weather.

It comprised 2 leg structures 10 m high, and triangular in section, and a horizontal girder of 20 m span. The lower chord, in one section, served as a crane rail.

Samples were cut out from the horizontal girder after it had been dismantled (see Fig. 32). Among these members 1 had 2 fixing holes for electric insulators which had been removed four years previously. The two holes, about 8 mm in diameter and some 50 mm apart, had never been plugged.