

One of the gantry legs (see Fig. 33) was of particular interest for the following reasons:

- a) it included a service platform which was badly corroded externally
- b) the access ladder to this platform made it possible to cut out a large number of samples,
- c) one of the three uprights of the leg had suffered an accident several years previously and had remained open over a height of about 1 m.

For these three main reasons it was thought beneficial to send the complete leg unit to the LNE for a detailed investigation.

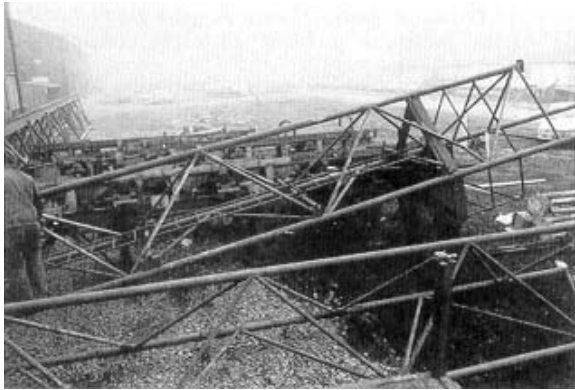


Figure 33: One of the gantry legs comprising the ladder and access platform which was sent as a complete unit to the LNE.

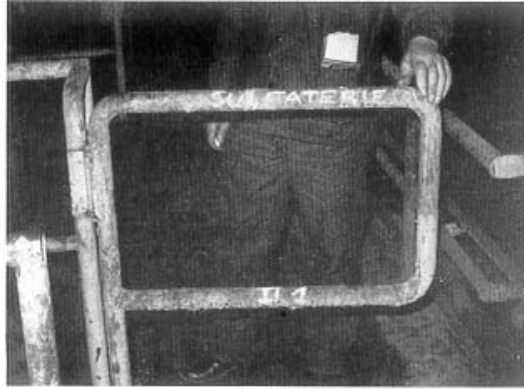


Figure 34: A sample of the railing which had been removed from the sulphate works. Particularly badly corroded externally.

2) Sulphate shed: This relatively small building had been housing the sulphuric acid baths since 1964. It was next to a pickling plant and the whole of the steel framework was situated in a particularly hostile atmosphere owing to the sulphuric acid emanating from the pickling bath operations.

Two samples were taken:

- a) the bracing members of the roof structure. These were hollow sections of 34 mm external diameter flattened at both ends and in the centre for bolting purposes
- b) the lower rail of the bannister which had been sealed at both ends by welding and whose external appearance showed an advanced stage of corrosion (see Fig. 34)

3) Storage shed - eastern extension: We were dealing here with a building of 20 m span, the upper part of which (trusses and purlins) was a tubular structure. Built in 1961, this building served as a fabrication workshop until 1970. Since that date it has been used as a storage shed. The following samples were selected:

- a) From the roof, a lattice purlin comprising an upper chord in hollow sections 45 mm square and a lattice in CHS of a smaller diameter
- b) From a stabilising portal frame (see Fig. 35), two units of bolted lattices, which had been dismantled. These had been joined at their flattened ends.

4) Factory shed - gable type wind girder: This building, constructed in 1958, had components which had been exposed to the industrial atmosphere since that date. One sample only was taken, namely a wind girder support (see Fig. 36). This strut was bolted at the top through a welded plate and at the bottom simply by flattening.



Figure 35: Dismantling of two bracing members with flattened ends.

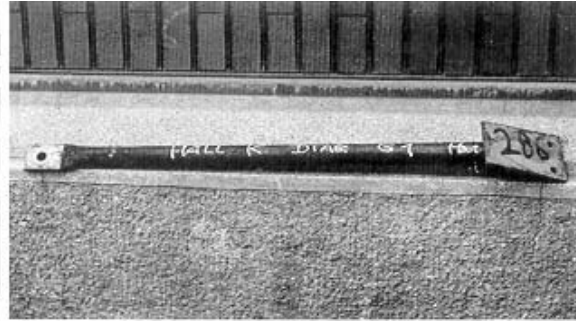


Figure 36: Diagonal member flattened at one end and welded to a plate at the other.

5.1.3 Observations made about the samples: All the observations we were able to make on site, when the samples were being cut, were complemented by careful examination in the LNE laboratory in Paris. 48 of the 100 samples taken were examined.

These 48 samples were made up as follows:

37 members, sealed at the ends, showed an internal surface which had remained intact.

4 members, originally open at the ends, were corroded inside.

7 members, which had either been badly sealed or had suffered damage, had also undergone a change

All these observations are recorded in the very full report of the LNE, which includes, apart from the typescript, photos of the cutting out of the samples, as well as colour photos depicting the comparative state of the internal and external faces of each sample.

This report, Number 403.136, can be consulted either at Cometube or the Chambre Syndicale des Fabricants de Tubes d'Acier [11].

1) External gantry crane: Without going into a detailed description of each member, descriptions being given in the laboratory report, it is however interesting to underline particular points which have arisen during the course of this investigation.

a) Horizontal girder: 5 diagonal members were taken as samples. All of them were sealed by welding and their internal condition was perfect. Member A31, however, deserves to be dealt with at greater length (see Fig. 37). This member featured 2 holes, for attaching insulators, which had remained open for several years. Corrosion was discovered in the immediate vicinity of the 2 holes, but the corrosion was strictly limited to that area. The internal face of the rest of the member was intact.

b) Leg structure B: This leg structure produced 77 samples, 36 of which were examined. Two details should be commented upon. First of all, this triangular leg structure included three members in circular hollow sections having a diameter of 90 mm. Only one of these three chords exhibited a longitudinal opening over a height of about 1m. The other two chords had remained in perfect condition.

The comparison between these is very easy to make: the open chord was very corroded inside; the

LNE detected a substantial quantity of rust at the bottom of this member and the two undamaged chords retained their original mill scale over a very large area.

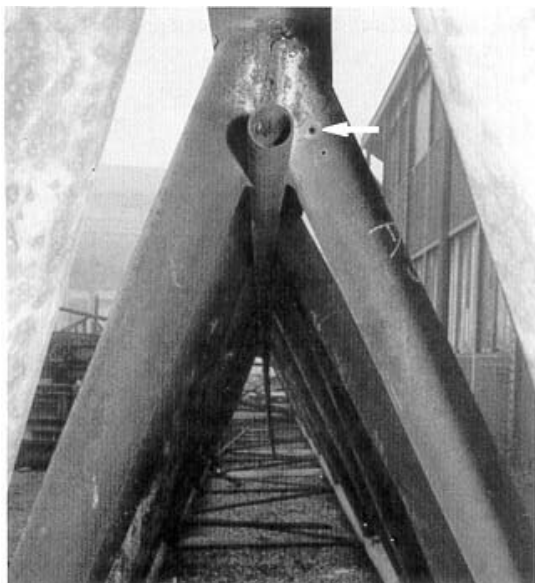


Figure 37: Lower part of the A3 diagonal member showing the two attachment holes (note that the triangular girder is resting upside down)



Figure 38: Platform with RHS stiffening. Only the longitudinal members with sealed ends have kept a corrosion-free internal surface.

The ladder of the leg structure was also of great interest; all the rungs in circular hollow sections were welded at both ends and their original internal condition had been preserved. On the other hand, the two uprights of square hollow sections, which had not been sealed at the ends, were in an advanced state of corrosion, both inside and outside.

It is useful to recall that the ladder and the platform were of a temporary nature and had been out of use for more than 4 years; consequently, they had not been painted since being given the original coat of anti-rust paint.

The access platform to the hoist consisted of a chequer plate stiffened by longitudinal and transverse members in RHS (see Fig. 38).

The cross members were open at both ends and their internal faces were in an advanced stage of corrosion. The longitudinal members which were welded at right angles to the transverse ones, and were thus sealed at both ends, had internal faces which remained in an absolutely perfect state. On the whole of this leg structure, 25 of the 36 members, which were examined, were in a perfect condition internally. Of the 11 members which had suffered corrosion, 4 were open at both ends and 7 had deteriorated either at the beginning or during their working life.

2) The sulphate works building: Only a few samples were taken, but all were significant. Indeed, in spite of the particularly corrosive atmosphere (sulphuric acid vapour), the bracing members with flattened ends had been well-preserved internally. A few of the ends had suffered slightly.

The railing sample from the vicinity of an acid bath showed an external surface which was excessively corroded. On the other hand, this member, sealed by welding at both ends, had kept its original internal condition with remains of the mill-scale. The contrast between the two faces of this sample was particularly significant; the sealed interior is protected whatever the external atmosphere.



Figure 39: End of a lattice purlin with a bolt hole through the chord.

3) Storage hall - eastern extension: The lattice purlin included an upper chord member in square RHS sealed at both ends, but drilled through for bolting. The bolt had blocked the hole, apart from clearance, and it is interesting to note that some of the original mill-scale fell from the hole when the bolt was removed. (See Fig 39)

The adjoining diagonal members had flattened ends. These showed slight traces of internal corrosion in the areas where the flattening operation had detached the original mill-scale.

4) Factory hall - wind girder: Here again only the flattened end showed traces of superficial rust due to the flattening operation. Everywhere else the original mill-scale was still to be found in spite of 16 years in an industrial atmosphere.

5.1.4 Conclusions to be drawn from the observations: Our findings are confirmed by the LNE report:

- all the members with sealed ends showed an intact internal surface,
- in the cases we have examined, where the members were flattened at the ends, the sealing was sufficiently well done to prevent internal corrosion, when openings were present, either due to the original design or as a result of an accident, internal corrosion has been noted within the hollow section.

These observations do, of course, fall in line with what we thought at the start, closing the ends of a steel hollow section will ensure that no internal corrosion will take place.

We must, however, comment on this enquiry carried out at Valenciennes. It is noticeable that the proportion of severely corroded members appearing in this report is fairly high. This is explained by the fact that, in agreement with the LNE representatives, we deliberately looked for structures which were located in particularly unfavourable situations.

The choice of a portal frame which had been out of service and submitted to weather conditions without maintenance for many years, as well as that of components situated in the corrosive atmosphere of a sulphate works, was dictated by the scientific guidelines agreed for this investigation.

5.2. Investigations carried out in Dunkirk in July 1975 [12]: In the case of the earlier sampling carried out at Valenciennes, the hollow sections observed were limited to a diameter of 90 mm, and located in an industrial atmosphere. It remained therefore to complete the investigation by taking samples from components of larger sizes (up to 500 mm diameter) situated by the sea. It was to meet these two requirements that the Vallourec Tubeworks in Dunkirk were chosen for the continuation of the enquiry.

This new phase was financed by the Chambre Syndicale des Fabricants de Tubes d'Acier (CSFTA) and the Comité International pour le Développement et l'Étude de la Construction Tubulaire

(CIDECT). The sampling and inspection work was followed by Cometube and was carried out by the Laboratoire National d'Essais. The conclusions of these investigations are recorded in the official report of the LNE, No. 507.055 [12].

The full text is reproduced below including the tables of samples and the black and white photos depicted in it. Some of the colour photographs of samples taken in the laboratory have been omitted from this report.

The report itself can be consulted at any of the organisations which participated in the research:

Chambre Syndicale des Fabricants de Tubes d'Acier, 57, Avenue George V, 75008 Paris

G.I.E. Cometube, 102, Rue des Poissonniers, 75018 Paris.

CIDECT, Technical Secretariat, 12 Addiscombe Road, Croydon, CR9 3JH (England)

THE NATIONAL TEST LABORATORIES, PARIS - TEST REPORT No. 507-055/DMS/3/302

5.2.1 Objective

The Laboratoire National d'Essais was to examine the state of the internal surfaces of hollow sections used as steel frame components in sizes greater than 90 mm in diameter. This dimension was the upper limit of the first phase of the enquiry relating to the internal corrosion of hollow sections (see report no. 403.136 dated 22 October 1974), in which hollow sections with open and closed ends are compared.

5.2.2 Sampling cutting conditions

Cometube sent to the Laboratoire National d'Essais samples cut on the 9 July 1975 from old tubular structures at the Vallourec Works, Dunkirk. The sampling was carried out in the presence of the client, an engineer from the Laboratory, Maître Prevot, the Legal Officer of Dunkirk and a representative of the Vallourec Works at Dunkirk.

All the hollow sections were listed and photographed on site by the Laboratoire National d'Essais (Figures 40 to 52). Flamecutters were used to cut out the samples on site. In the Laboratory, the hollow sections were slit longitudinally by sawing in the plane of the axis, avoiding the line of the seam weld.

Type of samples: Table 2 lists the samples that were cut out. For each of them the following is shown:

- its date of erection and the type of environment
- its size, function and type of assembly
- an identification number given by the Laboratoire National d'Essais, following the sampling programme.

Observation methods used: The hollow sections were examined following the methods established for the previous enquiry, the main comparison being between the appearance of the internal surface of the hollow section in relation to that of the external surface.

5.2.3 Result of visual examination of the samples

Column of Hall III: The hollow section marked "Column D-18-I" was cut from the horizontal bracing of a crane rail stanchion in No. 2. tube mill after more than twelve years in an industrial atmosphere. This stanchion numbered "D-18 row B" is shown on Figures 40 to 41. Figure 42 shows the same stanchion after 800 mm had been cut out from the bracing. The sample is shown in Figure 43. It is a seamless circular hollow section about 168 mm external diameter, sealed at both ends where it is welded to the

Table 2: List and details of samples

| General information | | | | Properties of the member | | | | | | | | |
|---------------------------|--|----------------|---|--------------------------|---------------|-----------------------|--------------------|----------|--------------------------|----------------------|------------------------|--------------------|
| Location of samples | Type of structure | Date installed | Working environment | Prog. Ref. | Figure number | Usage | Circular or square | Size mm | Member detail | Production location | Position | Protective coating |
| Hall III Row B D-18 | Column supporting building | 1962 | Inside tube production hall | 1 | 40 to 43 | Brace | Circ. | 168 | Welded sealed tube | Seamless, Aulnoye | Horizontal | Green paint |
| Hall V | Lifting beam | 1965 | Stored inside for 5 years | 2 | 44 to 46 | Lifting beam | Circ. | 500 | Ends welded to end plate | Welded, Dunkirk | Horizontal | Not painted |
| External | Wind girder from Halls I, II or III from 1 st phase | 1961/2 | Dismantled and stored outside for 5 years in industrial atmosphere near sea | 3 | 47 and 48 | Chord | Circ. | 168 | Welded sealed tube | Seamless, Aulnoye | Horizontal | Green paint |
| | | | | | | Brace | Circ. | 76 | Braces welded to chord | Welded, Valenciennes | Horizontal for 5 years | Green paint |
| | | | | | | Brace | Circ. | 70 | | | | |
| External | Access catwalk between Halls I & II row B | 1961/2 | | 4 | 49 and 50 | Top rail Bot. rail | Circ. Circ. | 70 26 | Open at ends | Seamless, Aulnoye | Horizontal | Anti-rust paint |
| | | | | | | Brace Brace | Square Square | 50 50 | Sealed, welded to rails | Seamless, Aulnoye | Inclined brace | Green paint |
| External | Single tube, half portal in Hall I | 1962 | Dismantled and stored outside for 3 years in industrial atmosphere near sea | 5 | 51 and 52 | Half portal | Circ. | 460 | Ends welded to end plate | Welded, Dunkirk | Horizontal | Yellow paint |

vertical chords, also of circular sections, taken from stanchion D-18. The external surface, painted green over an anti-rust primer of a red colour, is in good condition.

The internal surface is covered, as is normal, with a thin film of rust which does not affect the integrity of the structure of which the member is a part (Fig .59)

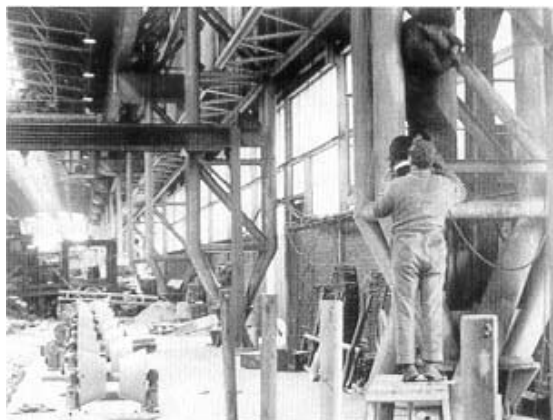


Figure 40: Hall III, Row B. Column D-18 and general view of hall.

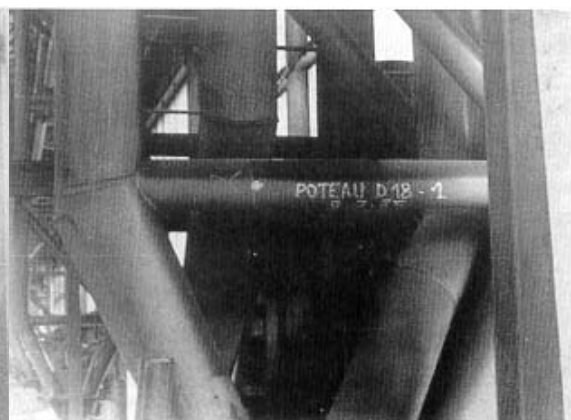


Figure 41: Distance piece 1 in column D-18

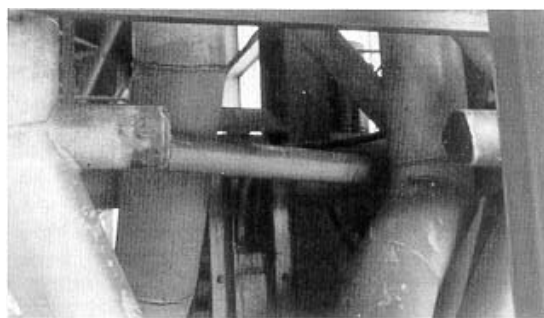


Figure 42: Column D-18 after part of the distance piece has been removed.



Figure 43: Sample cut from distance piece 1.

Lifting beam of Hall V: Lifting beam 2, which went into service some 10 years ago, has been stored in No. 5 tube fabrication shop for five years, (Fig. 44)

It consists mainly of a circular hollow section welded longitudinally, external diameter about 500 mm by some 6 m long, in a horizontal position with sealing plates at both ends. A sample was cut from one end, approximately 200 mm long (Figs. 45 and 46). The unpainted external surface is uniformly pitted by corrosion. The internal surface, which as is normal, is covered with a superficial film of rust and looks satisfactory (Fig. 60): the marking off lines are still visible on the end plate which still retains the original mill-scale in certain areas (1).

Wind girder 3: This was erected some thirteen years ago in the tube mill, was removed from its initial position five years ago, and has since been stored outside in the open air (Fig. 47) in an atmosphere both industrial and maritime (about 1 km from the North Sea). This girder consists of two tubular chords connected by diagonal bracings in hollow sections. The sample delivered to the Laboratory (Fig. 48) is a 600 mm length cut from the end of one of the chords.

This chord consists of a seamless CHS with an external diameter of 168 mm, positioned horizontally and sealed at both ends by end plates. The sample includes a node point where two diagonal bracings meet the chord. These are continuously welded tubes, measuring about 76 mm and 70 mm in diameter, and have also lain horizontal for at least five years. The latter were sealed at their ends by the chord member to which they were welded.



Figure 44: Hall no. 5, lifting beam 2
- General view.



Figure 45: Lifting beam 2 – cutting out of sample

The external surface of the whole structure has been covered with green paint applied over an undercoat of red coloured anti-rust paint, which has flaked, apparently allowing some corrosion to take place.

The internal surface of the chord is covered, as is normal, by a uniform superficial film of rust, which cannot affect the integrity of the structure. The internal surface of both diagonal members remained in a satisfactory condition (original mill-scale and superficial rust) (1).

Gangway No. 4: This was installed thirteen years ago on line B between halls I and II and ran inside these halls. It was dismantled five years ago and has since been stored outside the building (Fig. 49) in an industrial atmosphere and close to the sea.

The sample delivered to the laboratory (Fig. 50) was about 850 mm long, cut from one end of one of the two gangway guardrails. It consisted of a longitudinal rail and secondary rail connected by two diagonal members in hollow section. The rail and secondary rail consisted of two seamless circular hollow sections of 70 mm and 76 mm approximate external diameter respectively, horizontal and open at the ends. The sample includes the node point of the two seamless 50 mm RHS diagonal members, which were sealed at their ends by being welded to the external face either of the rail or of another hollow section; one is laid in a vertical position and its external wall is welded to the external wall of the secondary rail, the other is in a sloping position.

The external face of the two circular hollow sections is covered by an anti-rust paint of a red colour, which has suffered considerably. This surface has been pitted by corrosion. The internal walls of these hollow sections, which were open at the ends, are relatively uniformly affected by corrosion (1).

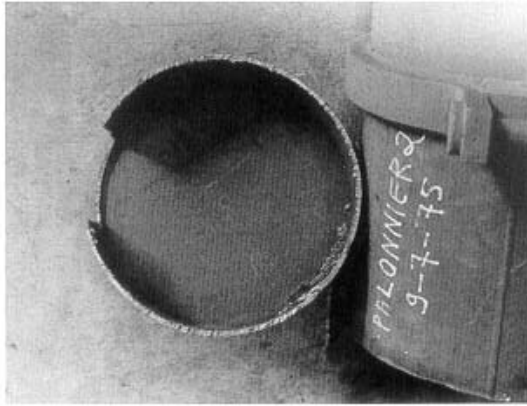


Figure 46: Lifting beam 2. View of the bottom plate at one of the ends.

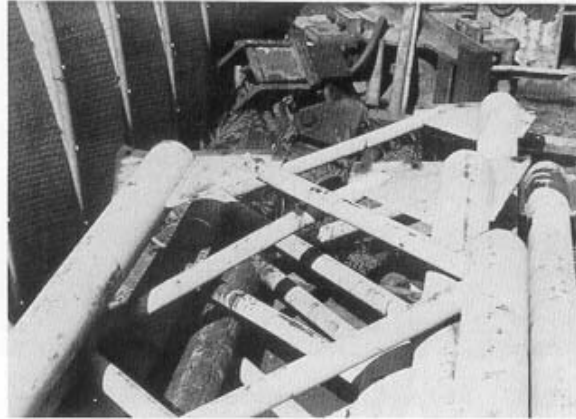


Figure 47: Wind girder 3 in the store.



Figure 48: Wind girder 3. Sample removed.

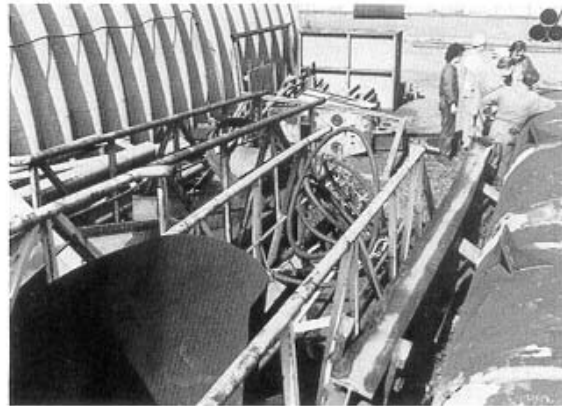


Figure 49: Gangway No. 4. as stored.

The external surfaces of both RHS are painted green over an undercoat of red-coloured anti-rust paint. The surface is corroded where the paint has flaked. On the other hand, the internal surfaces of these sealed hollow sections are in a satisfactory state, i.e. the surface still shows the mill-scale, though there are some traces of corrosion in places (1).

Single tube semi-portal of hall I: The single tube semi-portal No. 5, which was installed in 1962 in hall I, has been stored for three years in the open air, in an industrial atmosphere not far from the sea (Fig. 51). We are dealing here with a longitudinally welded circular hollow section 460 mm in diameter, and some 6 m long, bent in the middle. It was originally in a vertical position but has been lying in a horizontal position for three years. Both ends are sealed, welded to a plate. The laboratory sample (Fig. 52) about 100 mm long, had been cut from one end. The external surface is painted yellow over an undercoat of red anti-rust paint, and has a satisfactory appearance. The internal surface is covered, as normal, with a thin film of rust which cannot affect the quality of the hollow section, or indeed that of the structure (1).

5.2.4 Conclusions

Ten hollow sections have been cut and examined at the Laboratoire National d'Essais including four with an external diameter greater than 90 mm. Of these, eight with sealed ends have remained in a satisfactory condition internally, and unaffected from a structural point of view. The two with open ends show a deterioration of the internal surfaces due to corrosion, which, in their present state, does not appear to endanger the structure.

These hollow sections, some of which have been in service for more than thirteen years, under cover or outside, in industrial or marine atmospheres, show no deterioration to their internal surfaces when

their ends have been sealed. This applies to all the sealed samples regardless of structural location and atmospheric environment.

The only hollow sections in which corrosion was observed were the two which had open ends, thus permitted the ingress of moisture.

(Signed) M. Veaux
Head of Material
& Structure Dept.

(signed) P. Guillaume
Director of the Laboratoire
National d'Essais.

(1) Editor's note. The corresponding illustration of LNE Report is not reproduced in this document.



Figure 50: Gangway 4 - Cut sample



Figure 51: Hall I: single tube semi-portal.
Cutting out of the sample



Figure 52: Single tube semi-portal. Cut sample

5.2.5 Lesson to be learned from the results of this enquiry: The results observed were the same for the first series of samples cut out at Valenciennes for small size components (maximum diameter 90 mm) as for the second series carried out at Dunkirk on components of larger sizes (diameter up to 500mm) There is no possibility of corrosion inside hollow sections when these are sealed at both ends, whatever their size and length of service.

However, we noticed a slight difference in the surface condition of the components between the 1st and 2nd series. In the 1st series (maximum diameter 90 mm), we were always dealing with welded or

seamless hollow sections which were hot finished and were therefore covered initially with a coating of mill-scale, which was frequently found when cutting out the samples.

In the 2nd series (maximum diameter 500 mm) we were dealing mostly with cold formed welded hollow sections, i.e. products which left the production line without a coating of mill-scale. This difference in the manufacturing process is the reason for the superficial film of rust found on the Dunkirk samples. This slight rusting occurred during the period between the manufacture of the sections and their incorporation into the fabricated structure.

The presence of uniform superficial coatings of rust as described in the report of the LNE does not affect in any way the conclusions reached as regards the protection afforded the interior of hollow sections. The differences in methods of production affect only the appearance of the interior; i.e. mill-scale or superficial rust.

5.3 General Report Of The Laboratoire National D'Essais, Paris

Following these two investigations carried out in 1974 and 1975, the LNE was asked to write a general report which was handed to CIDECT members as well as the Chambre Syndicale des Fabricants de Tubes d'Acier. Figure 53 reproduces in facsimile the first page of this report No. 601.084-DMS/3-302 dated 19th March 1976 [13], which we reproduce hereunder in full.

We have merely renumbered the photographs (which have been reduced in size) as well as the tables and paragraphs to ensure the continuity within the present work.

LABORATOIRE NATIONAL D'ESSAIS, PARIS: TEST REPORT No. 601.084 - DMS/3-302.

5.3.1 Aim of the investigation

The "Groupement d'Interet Economique, COMETUBE" acting respectively, as has been stated, for the Chambre Syndicale des Fabricants de Tube d'Acier and the Comite International pour le Developpement et l'Etude de la Construction Tubulaire, has sent to the Laboratoire National d'Essais some samples which were cut out in the presence of the latter from old tubular structures.

The Laboratoire National d'Essais was asked to observe the state of the internal surfaces in steel hollow sections used as components in these structures. The investigation included cutting two series of samples.

The first dealt with hollow sections of less than 90 mm diameter (Report no. 403 136 dated 22 October 1974). The second dealt with hollow sections some of which were larger than 90 mm in diameter (Report no. 507 055 dated 7 October 1975)

5.3.2 Observation method

The cutting out of the tubes was always undertaken in the presence of the client, an engineer of the Laboratoire National d'Essais and a bailiff. The tubes were numbered, then photographed on the site before, during and after the cutting operation. After their arrival at the Laboratoire National d'Essais, some were sawn open longitudinally.

For each sample the following was noted: the location, the type of structure in which it was located, its

C. N. A. M. - **LABORATOIRE NATIONAL D'ESSAIS**

TÉL. 532-29-89

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PARIS, LE 12 MAR 1976



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Société COMETUBE -

Construction Métallique et Tube d'acier

156, Avenue Parmentier

75010 - PARIS -

DUPLICATA

ESSAI N° 601 084
DMS/3-302.

PROCÈS-VERBAL

OBSERVATION DE LA CORROSION INTERNE DE PROFILS CREUX UTILISÉS
COMME ÉLÉMENTS DE CHARPENTE MÉTALLIQUE

I - But de la demande -

Le Groupement d'Intérêt Economique COMETUBE, agissant respectivement comme il nous l'a précisé pour le compte de la Chambre Syndicale des Fabricants de Tube d'acier et du Comité International pour le Développement et l'Etude de la Construction Tubulaire, a fait parvenir au Laboratoire National d'Essais des échantillons prélevés en présence de ce dernier sur des constructions tubulaires anciennes.

Il s'agissait pour le Laboratoire National d'Essais de constater l'état des parois internes des profils creux en acier utilisés comme éléments de charpente métallique. Cette enquête a comporté deux campagnes de prélèvements :

. La première concernait des profils creux de dimensions inférieures au rond de 90 mm (Procès-Verbal N° 403 I36 en date du 22 Octobre 1974).

. La seconde était relative à des profils creux dont certains étaient de dimensions supérieures au rond de 90 mm (Procès-Verbal N° 507 055 en date du 7 Octobre 1975).

2 - Méthodologie des observations -

Les prélèvements de tubes ont toujours été effectués en présence du demandeur, d'un Ingénieur du Laboratoire National d'Essais et d'un Huissier de Justice. Ces tubes ont été répertoriés, puis photographiés sur chantier avant, pendant et après leur découpage. Après leur réception au Laboratoire National d'Essais, certains d'entre eux ont été ouverts longitudinalement par suifage.

Pour chaque échantillon, on a précisé son lieu de prélèvement et le type de structure dans laquelle il se situait, sa date de mise en service, l'environnement dans lequel il était placé et sa provenance de fabrication.

Le Laboratoire s'interdit de communiquer à des tiers les résultats des essais. Si le demandeur désire les publier avec référence du laboratoire, il ne peut le faire que par reproduction intégrale du procès-verbal. Toute infraction à cette règle rendra le Laboratoire responsable des résultats complets des essais.

P. V. - 20 80 88.

Figure 53: Facsimile of first page of Laboratoire National d'Essais report no. 601.084 – DMS/3-302

date of installation, the environment in which it was situated and its origin.

For each of the samples, which had been cut longitudinally, a note was made of its geometrical properties, the type of assembly and the position in the structure.

The main comparison between the hollow sections concentrated on the appearance of the internal surface in relation to that of the external surface, depending on whether the tube had or had not been sealed at the ends (assembly by welding or flattening at the ends).

5.33 General conclusions of the enquiry

Of the 110 tubular samples, 58 were examined at the Laboratoire National d'Essais (see table 3)

It was observed, as could be expected, that the 45 hollow sections which showed no alteration inside were those whose ends had been suitably sealed when installed. Some of them had been in place for more than thirteen years in a particularly hostile industrial or marine atmosphere, being:

on the outside of the buildings (Figs 54 and 55),

along side the sea (Fig. 56),

on the inside of the buildings (Fig. 40)*

**Editor's Note: This figure has been taken from Report No. 507.055 (enquiry carried out in Dunkirk in July 1975) [12]*

Table 3: Distribution of the tubes examined according to the state of their internal surface

| Type of tube | Series no. | Number of tubes in good condition | Number of tubes in altered state |
|----------------------------------|------------|-----------------------------------|----------------------------------|
| Column | 1 | 25 | 11 |
| Tubes larger than 90 mm diameter | 2 | 4 | 0 |
| Other tubes | 1 & 2 | 16 | 2 |
| Total | 1 & 2 | 45 | 13 |

Among the 13 tubes whose internal surface had been altered by corrosion, 6 were tubes which were open at their extremities. As regards the other 7, on the other hand, the quality of the seal had deteriorated during service.

Figures 57 to 63 represent characteristic examples of the two phases of the enquiry.

Figure 57 shows a circular tube sealed by flattening at the ends; its internal surface has remained in a satisfactory state in spite of the corrosion on the external surface.

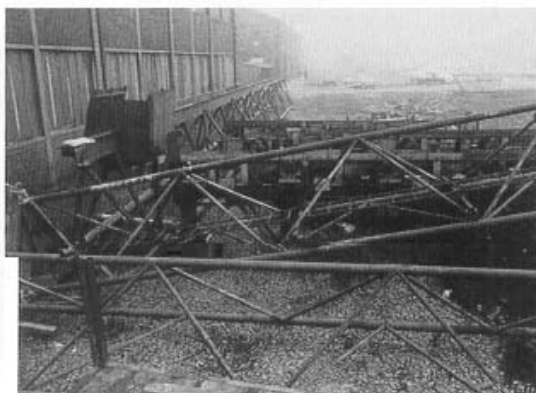


Figure 54: View of lattice column in storing area (first programme)



Figure 55: View of lattice column in storing area (first programme)

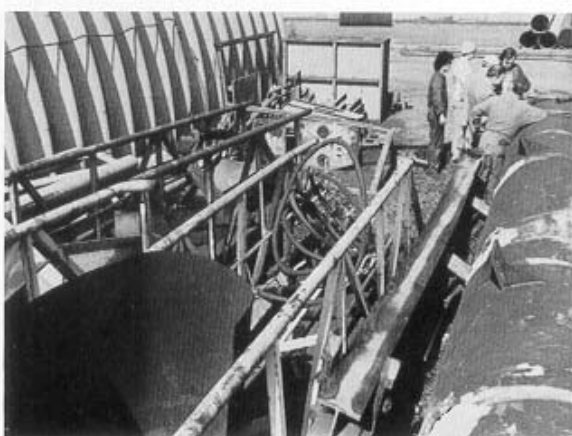


Figure 56: View of the samples in storing area (second programme)

The original mill-scale was found to be virtually intact in the case of a hot-finished RHS whose ends had been sealed (Fig. 58) by being welded at one end and bolted at the other.

Figures 59 and 60 represent two tubes of more than 90 mm diameter; one is a circular seamless tube with its ends welded to the external face of another tube, the other is a circular welded tube whose ends were welded to end plates. In each case, the internal surfaces are covered, as normal, with a thin coating of rust which could not affect the performance of the structure.

The substantial internal deterioration in one of the tubes in Figure 61 is due to the open weld over this part of the section which exposed the interior to the hostile external environment. On the other hand, the other tube in Figure 61, which was properly sealed in the same environment (column of Figs .54 and 55), has a satisfactory inside appearance.

Figures 62 and 63 show the welded junction of open ended tubes (RHS in one case and CHS in the other) and one or two tubes sealed at the ends. The deterioration of the internal surface of the open ended tubes only is due to the ingress of aggressive agents (or simply moisture), which lead to corrosion. This is only possible in the case of tubes which have not been sealed, or where openings have occurred, such as cracks or holes. These conclusions remain valid whatever the location and type of assembly of the hollow sections within the structure, whatever the geometrical properties or the method of manufacture.



Figure 57: Flattened end tube (First inspection programme)

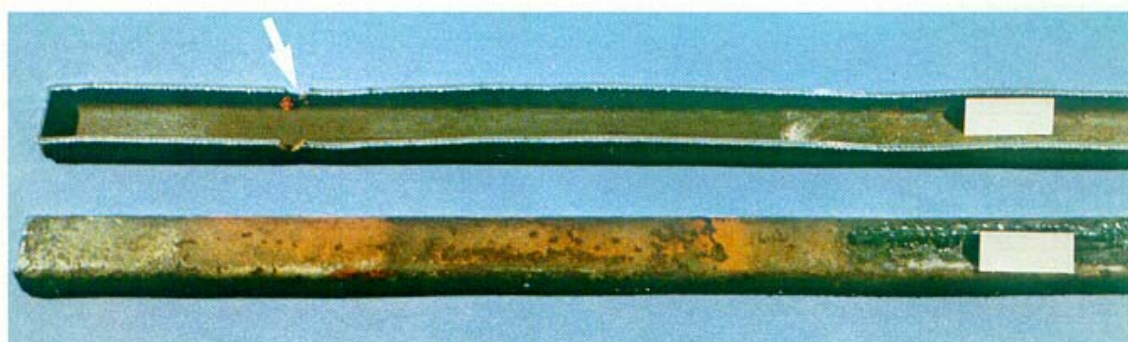


Figure 58: Tube with closed ends, one of which is bolted (First inspection programme)

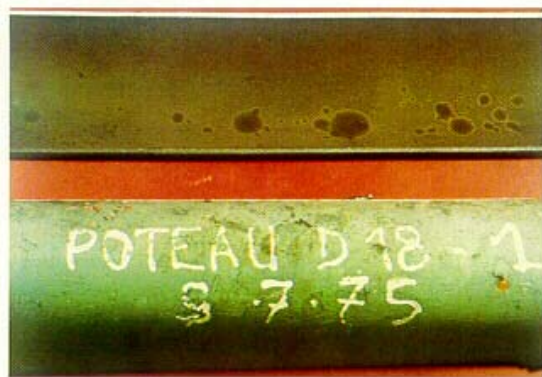


Figure 59: Tube with ends welded to the wall of another tube (Second inspection programme)



Figure 60: Tube with ends welded to a bottom plate (First inspection programme)



Figure 61: Tube(A) sealed and Tube(B) showing damage going back to original fabrication (First inspection programme)

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and Structures Dept.
M. Veaux.*

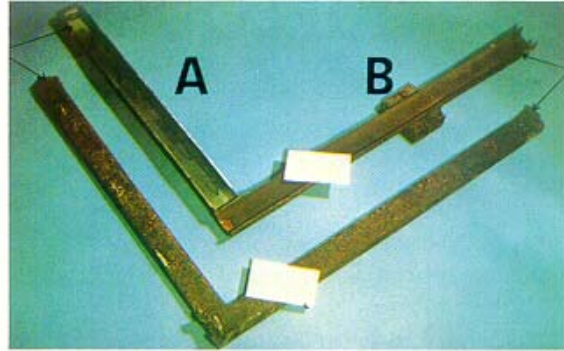


Figure 62: Joint between open Tube (A) and closed Tube(B)

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6 SOME SPECIAL CASES

All the investigations mentioned above are concerned with external structures exposed to the elements, or industrial buildings situated in a particularly corrosive atmosphere. Wherever the investigation has been carried out, the conclusion drawn from it is always the same:

‘It is sufficient to seal the ends of hollow sections to avoid internal corrosion’

However, there are other ways of using hollow sections, where the sealing of the ends is not necessary and even, in some cases, strongly inadvisable.

It is impossible to examine, or even merely to mention, every type of structure that can be encountered, and we shall limit ourselves to studying a few of the particular cases which appear to be especially significant,

- steel structures inside heated spaces (normally referred to as "warm structures")
- galvanised structures,
- concrete filled columns.

6.1 Steel structures in heated interior locations (controlled environment):

Examples of steel structures situated in a non-corrosive atmosphere are often encountered, and for these the precautions taken for industrial buildings or exposed frameworks are not applicable. Typical examples are housing blocks, office blocks or commercial premises, hospitals, some schools. To simplify the picture, a distinction can be made between concealed and visible frameworks.

6.1.1 Concealed frameworks: Let us examine the case of the framework of a steel girder placed between the ceiling and the slab in a dwelling block, which is constantly heated (Fig. 64)

As indicated in the figure, the lower chord, which does not extend to the column, is not sealed as part of the structure. With this type of construction, there is generally only a slight possibility of air renewal.

In order to be able to dispense with the usual precautions with regard to the sealing of the ends, it is sufficient to assure oneself that, in normal use, this closed space, which is not ventilated, will meet the following conditions: a relative humidity rate lower than 30% and a temperature equal to or higher than 18°C.

Though these conditions are usually met in dwelling blocks or offices, it is of course the relative humidity rate which is the significant criterion.

In the case of a hidden structure it is also necessary to check that no condensation can occur in the steel structure. Such condensation could for example be due to: a thermal bridge or the running of cold water piping in the enclosed space or even within the lower chord itself.

If these 3 conditions (humidity rate, temperature, lack of condensation) are fulfilled, it is not necessary to hermetically seal the ends of the lower chord. One can then either provide simple stoppers in plastic material, or even leave the ends open, if for example one wishes to run electric or telephone cables through the chord.

6.1.2 Visible structures: This type of structure can assume a load carrying function, a decorative function or a combination of the two.

We are dealing here, in most cases, with ceiling structures (see Fig. 65) but it is also possible to imagine a facade structure or even an internal staircase.

In contrast to the previous case, there is here a possibility of air renewal, but there is much less fear of condensation, since the whole of the steel structure is situated in the atmosphere of the dwelling or office area.

It is therefore necessary to check that the two above-mentioned conditions are met, namely that the

relative humidity rate is less than 30% and the temperature is equal to or higher than 18° C.

If these conditions are satisfied, as in the previous case, it would be possible either to close the ends with simple stoppers of plastic material, or to leave the ends open, with the possibility of using the lower chord as a duct.

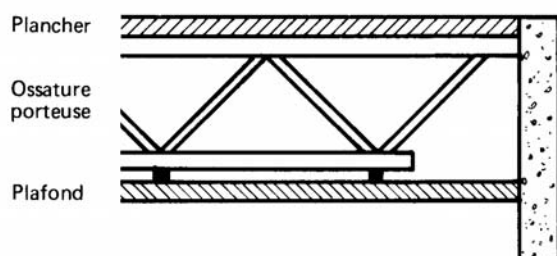


Figure 64: Concealed steel framework situated in a heated space. Framework floor supporting deck and ceiling

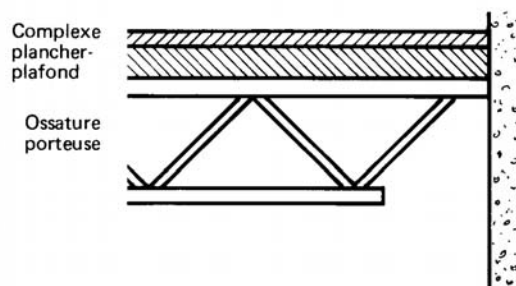


Figure 65: Visible steel framework situated in a heated space, framework supporting deck

6.2 Galvanised structures

There are two very different ways of using galvanising in steel structures:

- 1 – galvanising the individual components and then fabricating the units or assemblies
- 2 – fabricating the units/assemblies and then galvanizing the complete assembly

In the first case, the problems of internal protection are solved since firstly, the internal surfaces are galvanized and secondly, the ends of the members are sealed so no subsequent attack is to be feared.

On the other hand, in the second case, it is necessary to provide openings which make it possible to carry out both the pickling and the rinsing operations and the final galvanizing (see Figure 66)

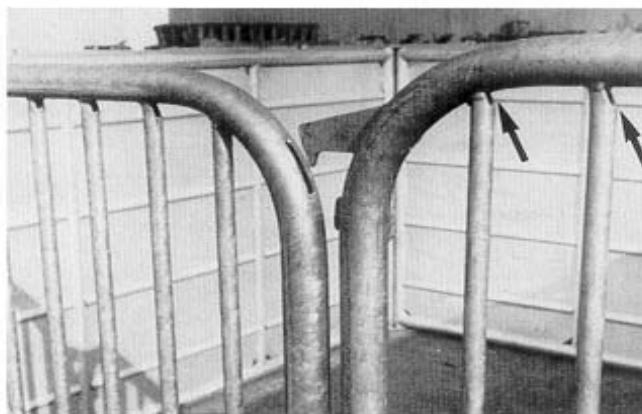


Figure 66: This partition fence in a cattle rearing installation has been galvanized after fabrication. Note the openings at the ends of the vertical infills (arrowed).

It should be remembered that galvanizing consists of dipping the object to be protected in a molten zinc bath at 460° C. This means first of all that the units fabricated in the workshop must be smaller in size than the galvanizing bath. The sizes of these baths vary a great deal and the first concern of the designer will be to make himself familiar with their limitations, so that the assembly can be suitably designed. The next thing to be considered is the other aspect of the operation, dipping.

As we are dealing here with hollow sections, (whether or not they are associated with open sections),

we must remember that a member hermetically sealed at both ends would constitute a 'float" which

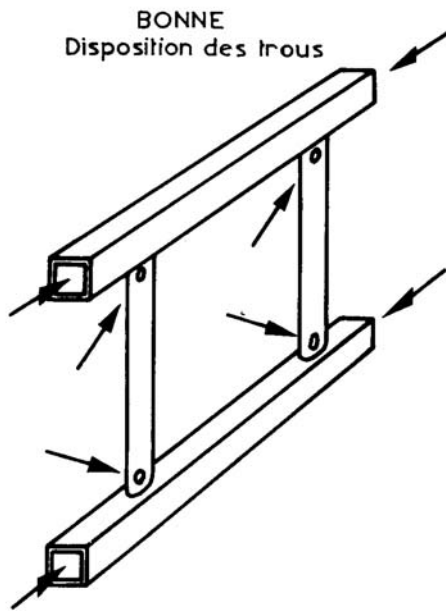


Figure 69: Diagram showing the position of recommended openings for a good circulation of pickling acid and molten zinc. (GOOD location of holes)

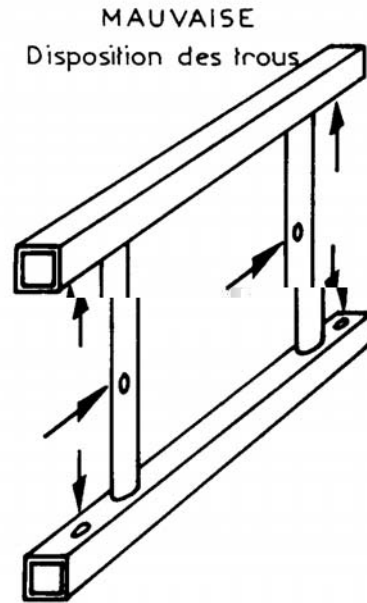


Figure 70: Diagram showing an un-recommended arrangement of holes for the circulation of the pickling acid and molten zinc (BAD location of the holes)

6.3 Concrete filled columns

In the case of concrete filled columns, some precautions must be taken. They are given in the recommendations to be found in CIDECT Monograph No. 5. (Part 1 of September 1977) [15]. Among these recommendations two concern the present investigation: the preparation of the hollow sections and the preparation of concrete used for filling

More recent information can be found in CIDECT Design Guide No. 5. 1995 [18]

6.3.1 Preparation of the hollow sections: As well as the considerations regarding the maximum allowable length of column (30 times diameter of the side - or 12 m), the recommendations give the following details concerning the holes to be made.

“Small sized holes are made in the walls of the sections, generally in groups of two (see Fig. 71). These holes are to be provided on each single length, and on each floor in the case of columns for buildings.

They are situated between 100 and 200 mm from the end of each length, but it is necessary to introduce two intermediary holes if the length exceeds 5 m.

These holes are intended to prevent the bursting of the column as a result of the steam pressure generated due to the boiling of the water within the concrete in the case of fire. The diameter of these openings should be between 10 mm or 15 mm for hollow sections of usual construction sizes.”

6.3.2 Preparation of concrete for filling: Monograph 5 recommends:

“The concrete shall be prepared in such a manner as to be sufficiently plastic; the wall effect of small size hollow sections will have to be taken into account, which will mean increasing the proportion of sand and cement. The materials (sand and gravel) must be of good quality and properly washed. The maximum size of the gravel should not exceed one sixth ($1/6$) of the internal diameter or side of the section.

Any additives likely to cause corrosion of the steel are forbidden, in particular setting accelerators with a calcium chloride base (Cl_2Ca). The addition of plasticisers, which allows a reduction in the volume of the mixing water, is recommended".

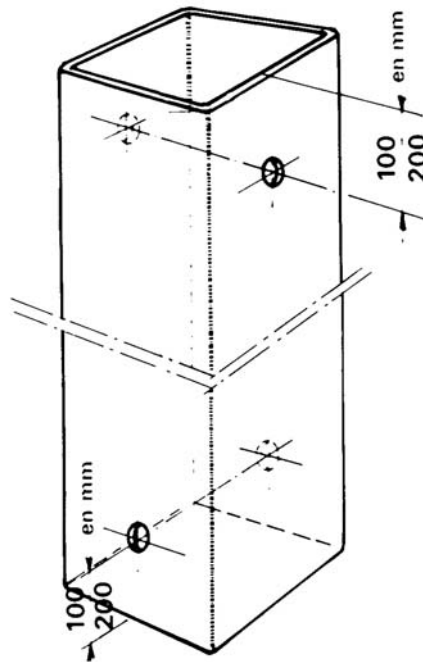


Figure 71: Hole positions in the walls of a concrete filled column.

It can thus be seen that, providing certain elementary precautions are taken with regard to the additives, there is no great fear of corrosion on the internal walls of concrete filled hollow sections.

7 CONCLUSIONS

On the basis of these investigations; originating from very different quarters, there can be no doubt with regard to the protection of the inside of hollow sections.

There is no possibility of internal corrosion in hollow sections, when these are sealed at both ends, whatever the environment in which they are found.

It has also been noticed that in certain structural cases the sealing of the ends of hollow sections could be superfluous (structures situated in heated premises), or even strictly inadvisable (structures galvanised after welding, and concrete filled columns).

Many more examples could have been mentioned; more cases could have been investigated, but we think that the examples chosen here are sufficiently convincing. We hope that this selection has contributed in some measure to a better understanding of the problems of protection of steel structures against corrosion. We are convinced that by keeping to simple rules, when fabricating hollow sections, it will be possible to obtain a protection against corrosion which is both efficient, permanent and nevertheless economical.

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