# Painting & Corrosion of Welded Structures

## 1. THE NATURE OF RUSTING

Any steel surface* will gradually and progressively rust if left unprotected. For this reason it is important to keep most steel structures painted.

Most of us are so familiar with the rusting of steel that we fail to recognize several important facts about this:

$$\underset{\text{(steel)}}{4\,Fe} + \underset{\text{(air)}}{3\,O_2} \xrightarrow[\text{(moisture)}]{} \underset{\text{(rust)}}{2\,Fe_2O_3}$$

1. Most chemical reactions will come to a stop if just one of the required elements or compounds is not supplied, or if one of the products is not removed from the reaction.

2. A moist condition (water) is required for steel to rust in the presence of air (oxygen). Steel will not rust in dry air.

3. Under ordinary conditions, there is a continuous supply of air (oxygen) and moisture, so this reaction never comes to equilibrium. The result is a continuous rusting action, unless prevented by some protective coating.

## 2. PROTECTION OF TUBULAR AND OTHER CLOSED SECTIONS

It is believed the inside of closed-in hollow box structural sections can be left unpainted. This is because any slight oxidation of the steel would soon come to equilibrium, since there is no continual supply of air and moisture.

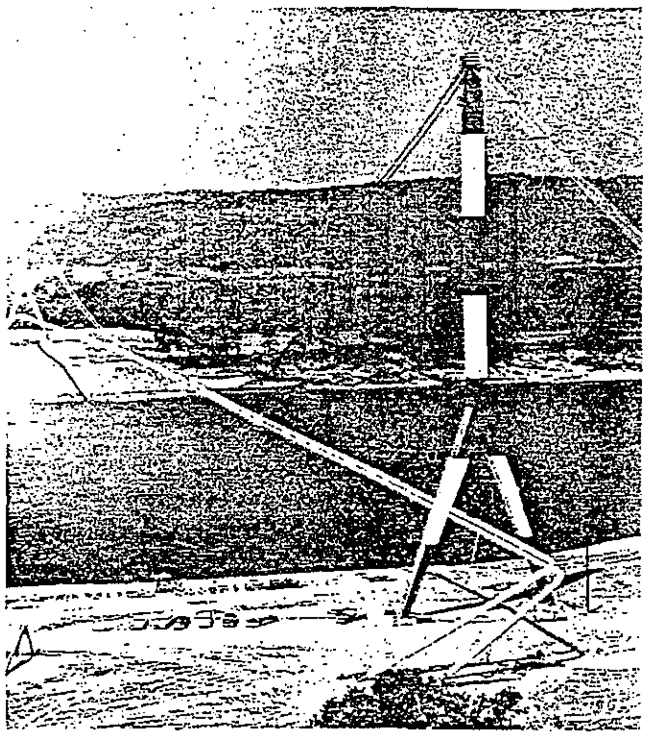
The question is whether box sections must be made airtight, merely protected from rain, or left completely open. If airtight, should any precaution be taken to dry the air before sealing, and should any unusual test methods be taken to insure complete tightness?

To shed more light on these questions, comments were solicited from several leading authorities in the structural field in the United States, Canada, and Europe. Foreign reaction is particularly significant since the adoption of welded box-section structurals has progressed further there than in this country, notably in German bridges built in the past 15 years. What follows is a symposium of their replies.

* The rusting of certain proprietary steels produces a thin protective oxide layer that inhibits further corrosion. Such steels (for example, A242) are often used unpainted.

• From an article, "Corrosion Prevention Inside Closed Hollow Bodies, by Seils and Kranitzky, in DER STAHLBAU (Germany), February, 1959, pp 46-53. (Translated in abstract form.):

Investigations on behalf of the German railroads are reported on six groups of welded structures: Four railroad bridges; three highway bridges; hollow supports on a Munich railroad station; a locomotive turntable; traveling platform on a rail car; and one experimental weldment.



These welded steel towers carry two 30" pipelines ½ mile across the river. The 273′ towers are hermetically-sealed box-section members internally reinforced to keep skin from buckling. They will stand for many years without concern for internal corrosion.

Detailed inspection substantiated the present assumption that condensation in hollow steel sections is very slight. Inaccessible or difficult-to-reach sections should always be welded airtight. Any manholes should be closed with rubber gaskets. With these precautions, corrosion protection of inner parts becomes unnecessary.

Wherever possible, large, accessible hollow weldments should be made as airtight as is practical. Closure does not lead to any observable tendency for water condensation and resulting corrosion. If sections are to be ventilated, adequate numbers of openings should be provided on the front and side walls to allow for some circulation of air. Openings in the floor are not very suitable for ventilation, particularly when sidewalls have no openings. Under this condition humidity could be higher.

If water pipes have to pass through hollow sections, there should be an opening in the hollow member to allow water to escape in case the pipe should later develop a leak. This opening, however, can be provided with a type of relief or check valve which will automatically open when required and later reseal. Areas in the vicinity of any of these openings should be particularly well protected. The pipe system itself should be insulated to avoid possible condensation.

Experience has shown that if any condensation does occur in the interior of sealed sections, the upper cover plate is the most vulnerable area.

In contrast to the outside coatings, a simpler corrosion protection can be applied to the inside surfaces. Areas subject to frequent use, such as manhole openings or in some cases the bottom side of a cover plate, should be given additional protective coating.

A recent type of corrosion protection for the interior of hollow sections is zinc powder paints. They have two important properties: First, they are largely unaffected by the welding heat; and, secondly, they do not influence the quality of the weld metal.

• Several of the new multi-span German bridges across the Rhine make use of welded orthotropic (orthagonal anisotropic) plate decks, with savings in dead weight of steel as high as 50% over conventional bridges. In this section, floor beams and longitudinal ribs are shop welded to the top deck plate, the latter thus serving as a common top flange.

Many times torsionally rigid ribs are used, either U-shaped or trapezoidal, forming a closed box section with the top deck plate. Thickness seldom exceeds $\frac{5}{16}''$, and occasionally is as little as $\frac{3}{16}''$. The box-shaped ribs are either butt welded to the webs of the floor beams at each intersection, or pass through them and are attached with fillet welds.

Orthotropic plate decks naturally have many sealed sections. They are not given any special corrosion protection inside. It is felt that after the initial minor corrosion resulting from entrapped moist air, little further advance will be experienced, and even under the most adverse conditions could not detract from the strength of the section.

• From a structural engineer at Eindhoven, Netherlands, representing an American international construction company:

"All modern fabricators make completely closed sections. There are a few which have taken some precautions for corrosion protection, probably at the insistence of the customer. One has used a normal type of manhole in large girders, for inspection purposes. The girders were not painted on the inside.

"Another company is using this construction in columns. Near the bottom of the column is a hole about ¾" diameter, drilled and then closed with a plug. The hole is used in two ways. First, before the column is shipped, pressure is applied to the inside to determine whether welds are airtight. If they are, the plug is replaced, the column erected and then inspected after a few years by removing the plug, to see if any water has collected. Until now, there has never been any water found inside the columns.

"E.D.F. in France has in use a large number of long welded steel columns closed at both ends, with no access holes.

"It is bad practice to completely close columns filled with concrete. Holes should be punched or drilled to avoid the possibility of explosion in case of fire. Water in the concrete may vaporize under heat, causing tremendous pressure on the inside if no escape hole is present."

• From a London structural engineering director, active with one of the largest companies in the field there:

"This 'bogey' of internal corrosion in hollow sections is constantly cropping up. . . In general, in order to be absolutely certain of the absence of internal corrosion, it is always preferable to insure that the structure is sealed completely."

• The paper, L'ENERGIA ELETTRICA (Italy), July, 1953, discusses the mechanics by which water can enter an imperfectly sealed structure—condensation, breathing resulting from heating and cooling, capillary infiltration, etc.

A passage from this research study is worth quoting for its basic information.

"To produce internal corrosion, one essential condition must be fulfilled, i.e., an aperture of appreciable size in order that water and oxygen can be present in sufficient quantity and a lack of either will delay corrosion. In the case of a closed tube, chemical equilibrium between water, oxygen and rust is reached as soon as a practically imperceptible layer of oxide has been formed.

"Tests we have made indicated that corrosion was unlikely to occur through holes having direct access to the atmosphere, provided they were shielded from actual films of water. The test, of course, refers to structures under ordinary atmospheric conditions where no artificial agency was tending to draw air into the structure.

"We would prefer that a hollow welded section be airtight, and if this is done there is no need to dry the air before sealing unless, of course, a slight initial corrosion must be avoided."

• From the chief structural engineer of an eastern structural fabricator and erector:

"On light structures such as schools, we have observed many designs which use tubular sections. Some are filled with concrete and many are not. Some require sealing and others do not. Apparently no concern is shown in regard to the rusting of the unsealed sections.

"If tubular sections are used and moisture is apt to accumulate, provision should be made to drain them. To seal fully tubular sections does not appear a feasible proposition."

• A consulting engineer in Phoenix, Ariz., now active on highway work in Alaska has this to say:

"There has always been a question in my mind as to the feasibility of closing the box sections so as not to permit the circulation of air through the member. I believe that if air is allowed to circulate, rusting will take place, but any good paint should take care of that and will last considerably longer if not exposed directly to the air and light.

"Some of the states have used a galvanized pipe or square section for a (bridge) railing member; however, galvanizing would be impracticable for a large bridge member. I have placed some hopes on the new epoxy resin which apparently has characteristics making it an almost permanent protection coat."

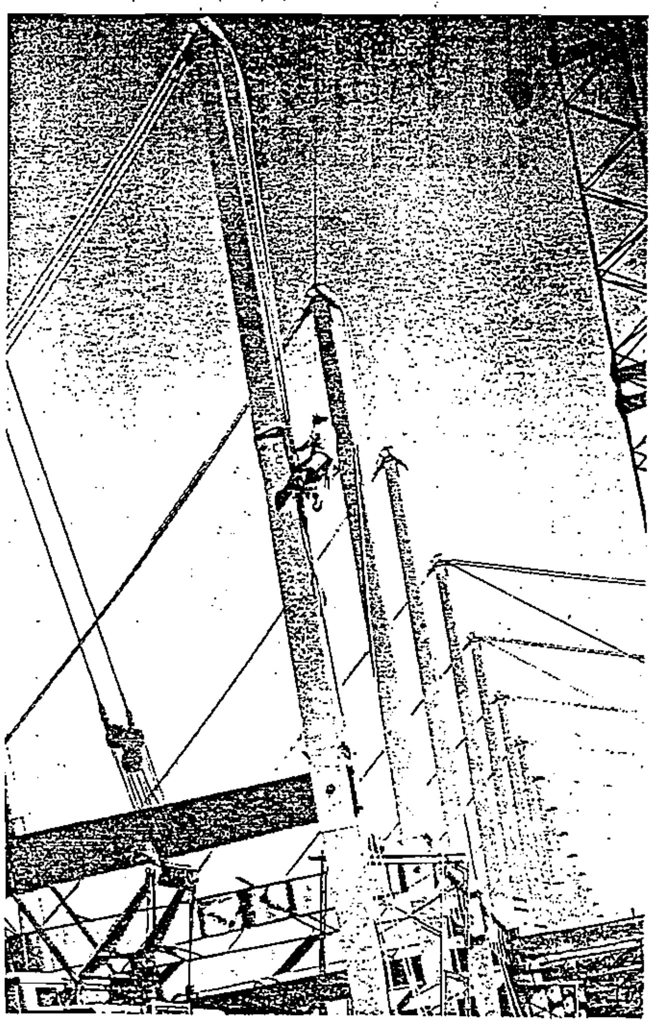
• From the assistant chief engineer of a major steel producing company:

"Our own corrosion experts have assured me that if the box member is completely sealed, any moisture or other corrosion causing substance will soon react and become neutralized, so that after a very slight amount of corrosion there will be no further action. However, if there is any opening to permit any air circulation, there will be new un-neutralized moisture from condensation, etc., and corrosion will be continued.

"If, however, sealed members are used, then some provision should be made for frequent checking of the seal by testing the tightness of the box under air pressure."

• From the general secretary of the American Welding Society:

"For many years elevated storage tanks in this country have been supported by towers consisting of closed tubular members. Companies in the structural field have had extensive experience in the use of such closed sections in which normally the internal surface receives no special treatment. Some of these have been sealed sections and some not sealed. Service generally has been entirely satisfactory in both cases. Where the section has been sealed, no effort has been made to dry the contained air before sealing."



Tower masts, roof girders and haunched frames for the Tulsa (Oklahoma) Exposition Center are box sections, entirely weld fabricated. Members such as these are capped to prevent entry of water; otherwise receive no special protection against internal corrosion.

• From a partner in a New York city consulting engineering firm:

"Closed box sections should be sealed, but if possible should be covered with a protective interior paint beforehand. The use of higher alloy steels, such as weldable A242, adds a measure of protection at low additional cost, and the added strength may offset the extra cost.

"I have seen no general applications in this country. However, some of the older bridges using the old Phoenix shapes (arc form with ends bent up at right angles) have been sealed and have stood up well.

"The subject of interior corrosion is very important, not only for columns but also for large closed box girders which at some future time may become popular in this country."

• From the manager of technical research for a Canadian bridge company:

"One of our erection engineers who has worked on bridge erection in England, India and other countries states that bridge box chords, either welded or riveted, are often sealed to avoid air movements. This sealing is accomplished by gasketing the manway openings into the chords. When this is done, painting on the inside can be a single coat or can be eliminated entirely. Sealing of box sections to avoid rusting on the inside is increasing in popularity.

"It is presumed that where welding is continuous to seal any box section completely, rusting will be inconsequential, being limited by the amount of air present when sealed."

• The chief engineer of the same company's Vancouver, B.C., plant adds:

"The practice of hermetically sealing structural members to avoid inside painting and corrosion originated in Europe when closed welded sections were introduced. No type of closure short of hermetic sealing is dependable. In such structures, no manholes were provided and no paint was applied on the inside."

"Completely logical" is how this engineer describes the practice of hermetically sealing closed welded members.

• The Port Mann arch bridge in British Columbia uses an orthotropic deck. The longitudinal stiffeners are U-shaped and when continuously welded to the deck, form a closed tubular section. The ends of the stiffeners have openings for field bolting. At a distance of 15" from each end of each stiffener, diaphragms are continuously welded inside to seal off the remaining length from the outside. This sealed portion of the stiffener was not painted on the inside.

## 3. PAINTING OVER WELDS

There may be an occasional problem with paint discoloring, flaking, or blistering over welds or in an immediate adjacent area. There are several possible reasons for this. Dust, smoke film, iron-oxide film, grease and similar materials on the surface of the weld and immediate adjacent area prevent the paint from coming in contact with the surface of the steel and properly bonding to it. These materials form a barrier between the paint and the steel surface. A surface that has been burnished very smooth with a power wire brush might also prevent proper bonding.

Elements in the fumes of welding, when deposited in the slag as a film on the steel surface, may combine with moisture in the air to produce an alkaline solution that reacts with paint. This may cause discoloring and blistering. This problem increases with increasing humidity.

Submerged-arc welds are relatively free of paint problems because the slag is nearly always removed and the process leaves no film of smoke or iron oxide on the adjacent plate.

Cleaning is the obvious first step. Removing slag, spatter, smoke film, iron-oxide film, and other similar materials, helps eliminate both causes of problems. First, it provides a clean surface to which the paint can bond. Secondly, it removes from weld deposits most of the chemicals that might react with a paint. In most cases, cleaning will eliminate paint problems, but don't burnish the surface with a power brush.

If discoloration or blistering prevails after normal cleaning, two additional steps will help. First, a wash in a mild acid solution, such as boric acid, followed by a good rinse with clear water will neutralize the alkaline solution so that it won't affect the paint. Secondly, a more alkaline-resistant paint may be substituted. Paints with a vinyl, epoxy or chlorinated rubber base are the best.

Just wiping the surface with a shop rag will remove much of the film and improve paint bonding. Painting with a brush instead of a sprayer helps the paint get under the film and make a better bond to the surface. Painting the affected area as quickly as possible after welding will prevent the chemicals in the deposited film from picking up mueh moisture. Therefore less alkaline solution will be formed to attack the paint. Two coats, including an alkaline-resistant primer put on as soon as practical, is usually better than a single coat.