IVd. Maintenance of metal structures

IV d 1

The rust proofing of steel bridges

Der Rostschutz von Stahlbrücken

Protecção contra a ferrugem de pontes de aço

Protection contre la rouille des ponts en acier

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This paper deals with metal spraying as a method of rust-proofing steel bridges. Once a bridge has been erected in a non-rust proofed condition, metal spraying is normally the only feasible method of rust-proofing it in situ. Because of the large size of bridge members it is also frequently the only way of rust-proofing before erection.

The process involves blasting with sand or chilled iron shot to remove all rust, scale and other contamination from the surface of the steel and to roughen it slightly. For blasting in situ, air blasting is always employed because it is so flexible a process. The abrasive is loaded into a pressure vessel and is then entrained in a stream of compressed air, the operating pressure normally being about 80 lbs. per square inch. The particles emerge at high speed from the blasting nozzle and readily remove all scale and contamination down to the bare steel. On some types of bridges it is possible by a suitable arrangement of tarpaulins to collect about 50 % of the abrasive for re-use. In other difficult locations it is not possible to collect any for re-use.

Figure No. 1 shows open blasting in progress on the Oddesund Bridge, Denmark.

Where it is possible for the bridge steel work to be rust-proofed before erection, there are in existence a number of factories specially equipped to do this and in some of these very large items can be handled readily. Figure No. 2 shows what is thought to be the largest blast room in Europe in a metal spraying works in London. A considerable tonnage of bridge steel work is regularly treated through this room. In such an installation all the abrasive is of course collected for re-use.

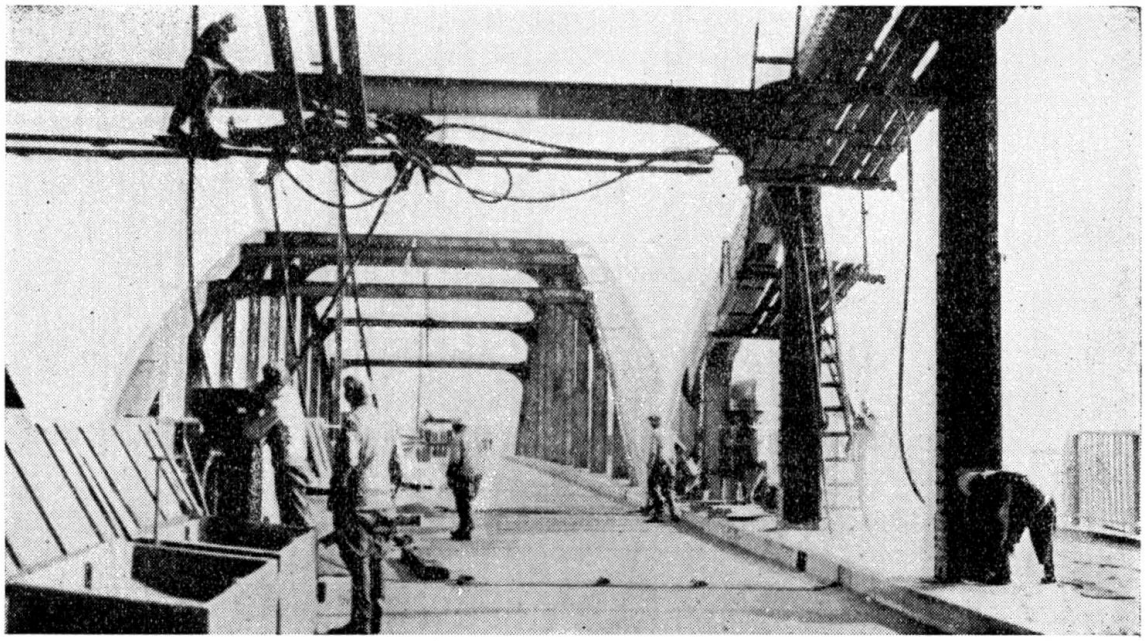

FIG. 1. Open sand blasting in progress on the Oddesund Bridge, Denmark

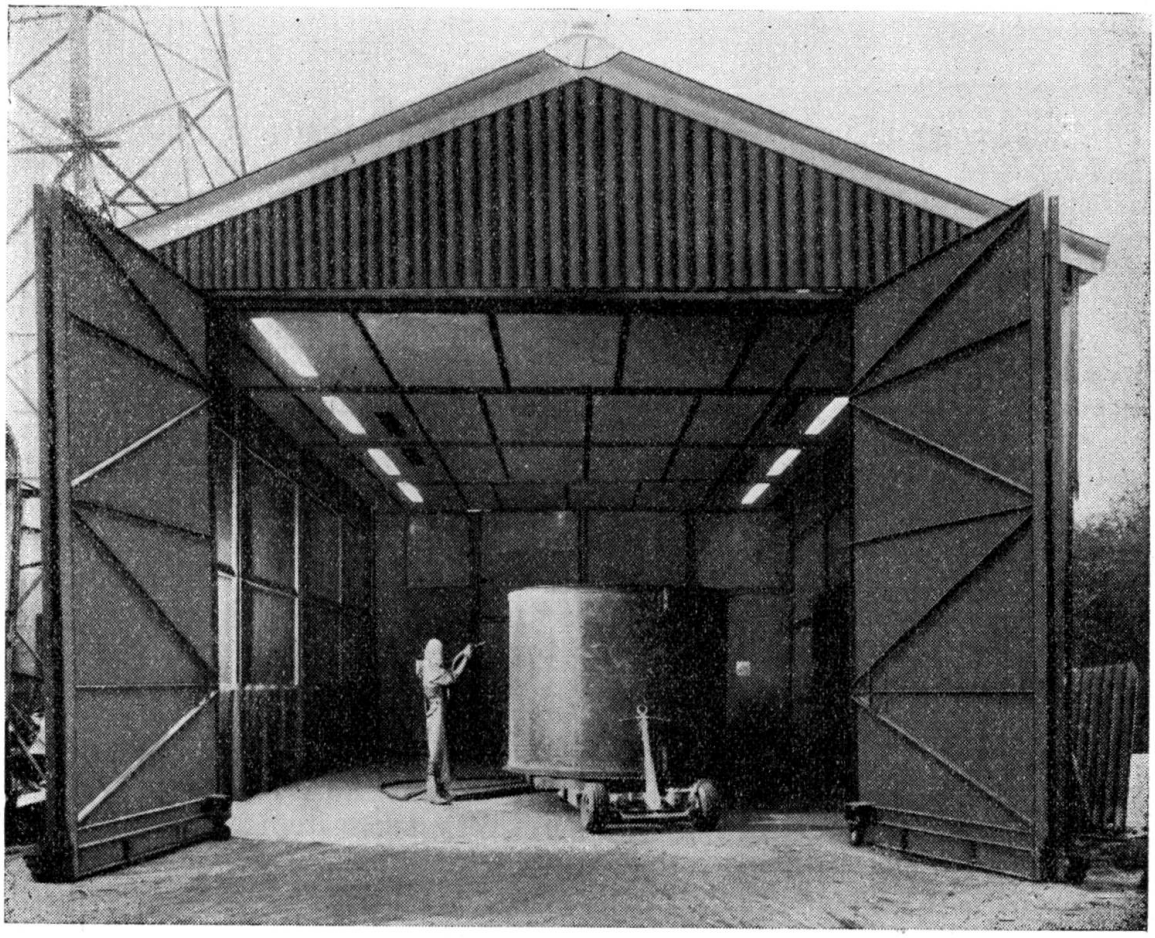

FIG. 2. A shot blast room in London, England thought to be the largest in Europe

Metal Spraying

After blasting the steel work must be metal sprayed before condensation or rust can form on the clean surface. Several types of metal spraying equipment are available. In the author's opinion the Schori gun which is also known as the Berk gun is the simplest and quickest

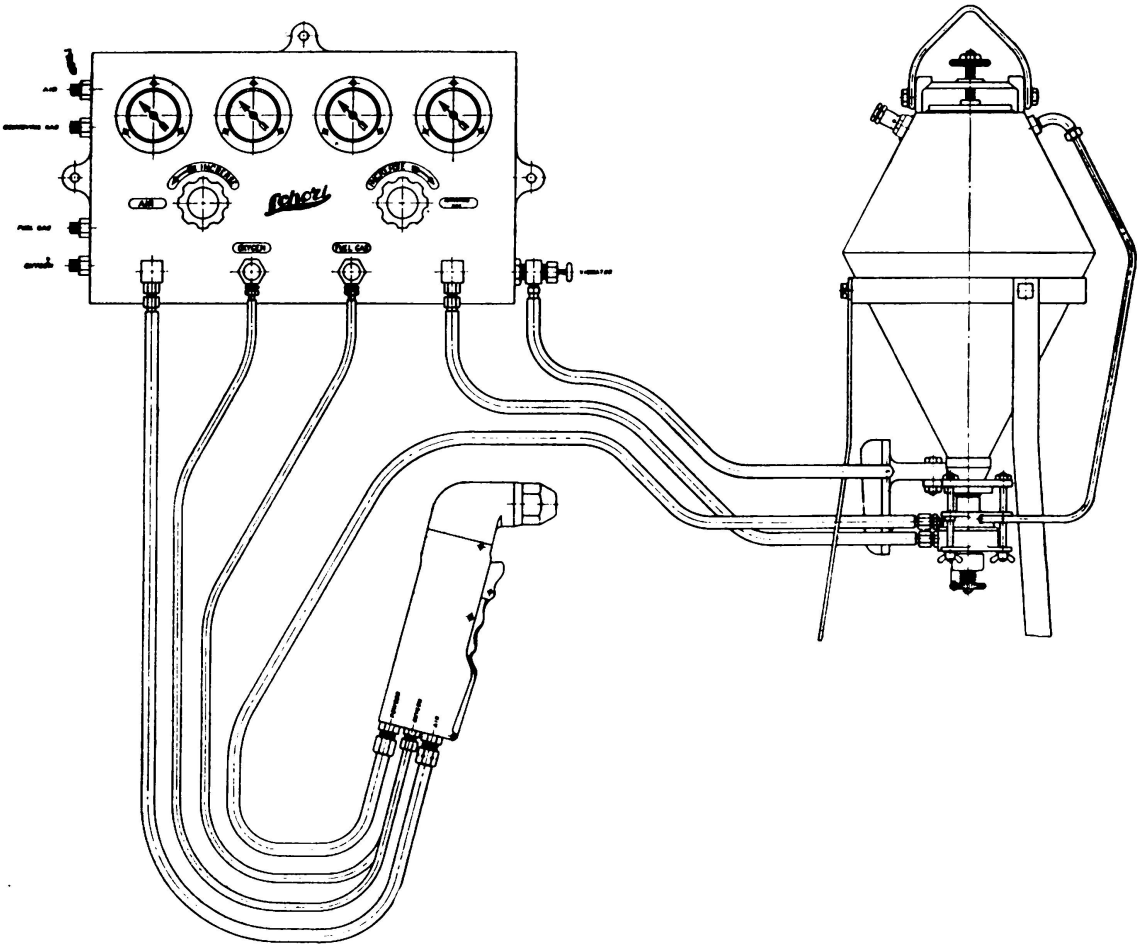

FIG. 3

as well as the most flexible equipment for spraying in awkward situations which frequently arise on bridge work. Basically the gun consists of a pressure feeding device whereby some 40 lbs. per hour of Zinc can be fed through a flame and firmly attached to the surface to be rust proofed. Figure No. 3 shows a layout of the complete equipment including the pistol, the powder feeder and the gas pressure control panel. The gun, which has no moving parts, is a very light and easily handled piece of equipment the weight being 2 $^1/_2$ lbs.

The Pistol

Figure No. 4 shows a cross section through the pistol.

Figure No. 5 shows metal spraying in progress on the Jubilee Bridge, Barrow in Furness, England owned by the Corporation of Barrow. The Consulting Engineers were Messrs. Freeman Fox & Partners, London.

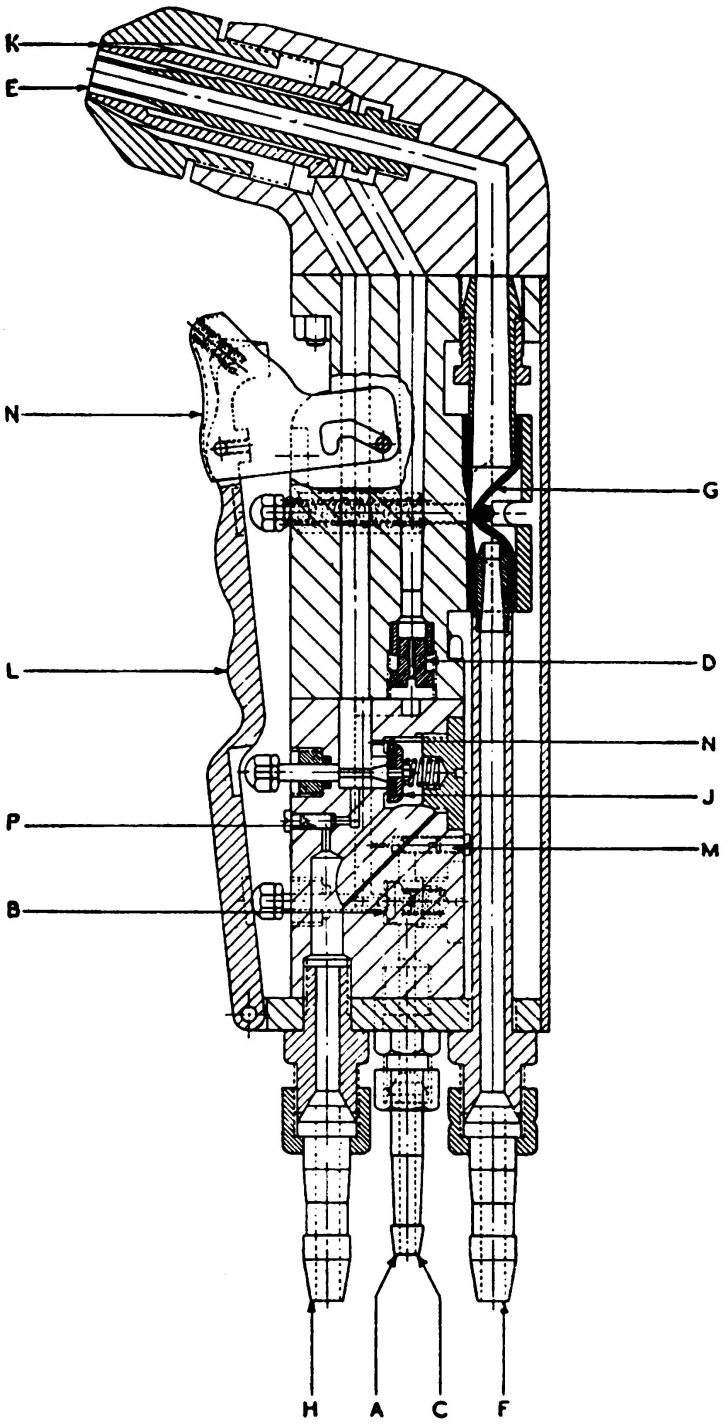

FIG. 4

Paint Systems

A sprayed metal coating is normally painted with whatever paint system is favoured by the Consulting Engineers. Zinc chromate priming paints are considered best both for sprayed Zinc and for sprayed Aluminium which is sometimes used to rust-proof bridges. The paint has to be formulated in such a manner as to incorporate small amounts of oxide to neutralize any acid which may be present in the vehicle.

Both Zinc and Aluminium which are the only sprayed metal coatings used on any large scale for rust-proofing bridges, are anodic to steel. This means that they will attract to themselves any corrosive ions which may be present thereby sacrificing themselves to protect the under-lying steel. As is well known, failure of paint systems applied to non-rust proofed bridges

normally arises through moisture penetrating the paint system and causing rusting beneath the paint which is then pushed off. Metal spraying prevents such under rusting and as a result a very long life of the paint system on the bridge is achieved. The only attack on the paint system on a rust-proofed bridge is from the effects of ultra-violet light, rain etc. on the top coat. This will ultimately become powdery and need replacing. If this is done at intervals the under-coats and the metal sprayed layer will remain intact for an indefinite period. This is

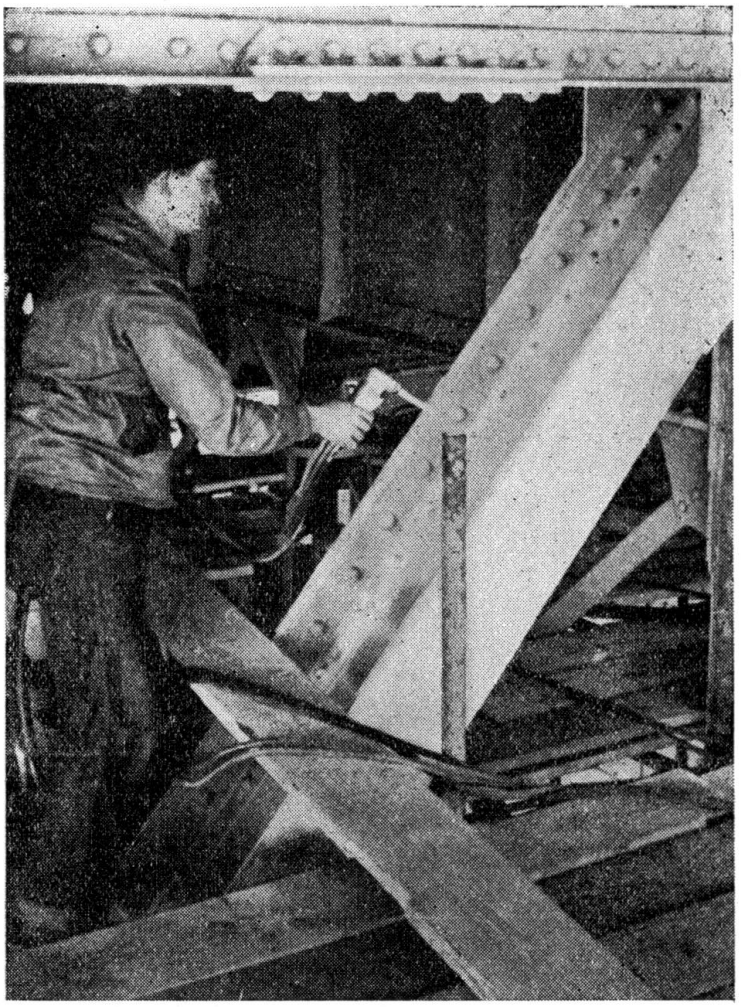

FIG. 5. Zinc spraying the previously sandlasted surface of the Jubilee Bridge, Barrow in Furness

illustrated by the excellent behaviour of the Menai Straits Bridge. Figure No. 6 shows the blasting and Zinc spraying of the suspension lengths of the Menai Bridge in progress in 1939. The Consulting Engineers were Sir Alexander Gibb & Partners and the Contractors Messrs. Dorman Long & Co. Ltd. It is exposed to severe marine conditions with high wind speeds. The paint applied to the rust-proofed links in 1939 is still in excellent condition after 17 years and provided the top coat is

replaced when necessary, the rust-proof system should have an indefinite life. The deck which was not rust-proofed has had to have very frequent attention.

Figure No. 7 shows the blasting and Aluminium spraying 0.006 inches thick of the large welded girders for the Black Bridge, Hook in the

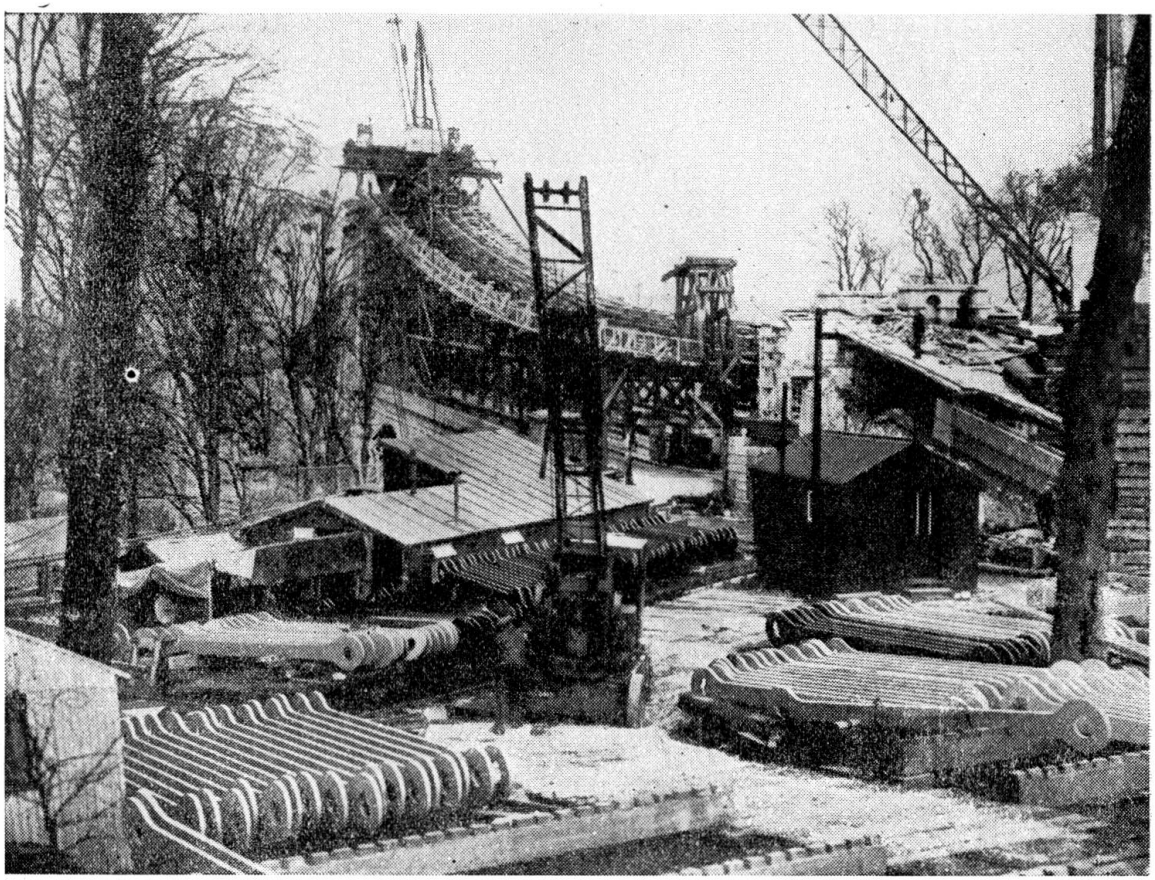

FIG. 6. The sandblasting and zinc spraying of the suspension links of the Menai Straits Bridge in 1939

workshops of The Butterley Engineering Co. Derby, England. The Consulting Engineers were Messrs. J. S. Wilson & J. Mason.

In certain conditions particularly in Chemical Works a duplex coating of sprayed Zinc followed by sprayed Aluminium has been found, after prolonged testing, to give excellent protection where a coat of Zinc or Aluminium by itself is attacked. A steel bridge in a Chemical Works in Britain is now being treated in this way.

The Economics of rust-proofing bridges

Steel bridges were always expensive structures and this is more than ever true today. They are normally expected to last a very long time and maintenance costs become of prime importance. The justifi-

cation for metal spraying is that a bridge treated in this way needs no attention for very many years and then only minor attention to replace the top paint coat. An eminent firm of Consulting Engineers has worked out that the maintenance cost of a metal sprayed bridge is less than one quarter of the maintenance cost of the same bridge non-rust proofed. Pediodic obstruction of the roadway by scaffolding is also avoided. Be-

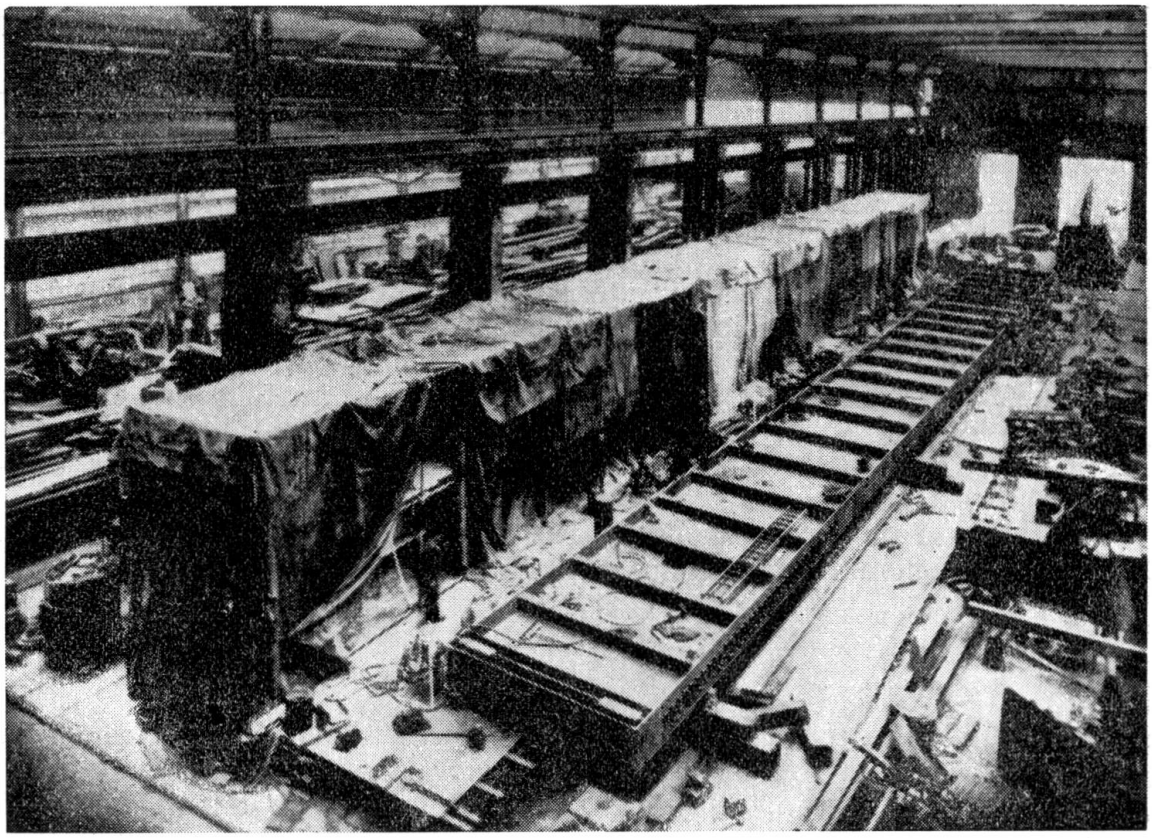

FIG. 7. The aluminium spraying of the main girders of the Black Bridge, Hook in the Works of The Butterley Engineering Co. Derby, England

cause of the good results obtained the use of the process on bridges is increasing. The mobility of the equipment allows it to be used on new or existing bridges in any part of the World.

SUMMARY

This paper describes the experience with the rust-proofing of steel bridges by sand blasting and metal spraying dating back to 1939, the Menai Straits Bridge then treated still being in excellent condition. Methods of blasting are described and a speedy, flexible and cheap method of metal spraying is detailed and work in progress on bridges in Great Britain and Scandinavia is described.

The advantages to be achieved by rust-proofing are described with the economy in the virtual absence of maintenance costs.

ZUSAMMENFASSUNG

Dieser Aufsatz beschreibt die Erfahrungen, die bei Rostschutz von Stahlbrücken durch Sandstrahlung und Metallspritzüberzug seit 1939 gesammelt wurden; in jenem Jahre wurde die Menai Straits Brücke behandelt, die sich noch immer in ausgezeichneter Verfassung befindet. Es werden Sandstrahlmethoden beschrieben und eine rasche, anpassungsfähige und billige Methode für Metallspritzverfahren wird erläutert; Bilder zeigen Arbeiten an Brücken in Grossbritanien und Skandinavien.

Die Vorteile, die durch den Rostschutz nach dem erwähnten Verfahren erreicht werden, liegen insbesondere im Wegfallen aller weitern Unterhaltskosten.

RESUMO

Descreve-se a experiência adquirida na protecção contra a ferrugem de pontes de aço por meio de jacto de areia e pulverização de metal, desde 1939, estando a ponte do estreito de Menai, que foi tratada nessa data, ainda em excelente condição. Descrevem-se métodos de limpeza por jacto e dão-se pormenores de um método de metalização barato, prático e rápido, bem como de trabalhos em curso em pontes na Grã-Bretanha e Escandinávia.

Indicam-se as vantagens que trás a protecção contra a ferrugem, incluindo a economia devida à ausência virtual de despesas de conservação.

RÉSUMÉ

Les auteurs décrivent l'expérience acquise dans le domaine de la protection contre la rouille de ponts en acier, au moyen du jet de sable et de la pulvérisation métallique depuis 1939, le pont du détroit de Menai traité à cette époque étant aujourd'hui encore en excellentes conditions. Ils décrivent les méthodes de nettoyage par jet ainsi que le détail d'une méthode économique de métallisation pratique et rapide et des ouvrages en cours sur des ponts en Grande-Bretagne et en Scandinavie.

Ils décrivent les avantages obtenus au moyen de la protection contre la rouille, dont l'économie due à l'absence virtuelle de dépenses de manutention.

IV d 2

The protection of bridges and structural steelwork by metal spraying by the wire process

Schutz der Stahlkonstruktionen durch gespritzte Metallüberzüge

Protecção de pontes e estruturas metálicas pela metalização por fio

Protection des ponts et charpentes métalliques au moyen de la métallisation par fil

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Dudley

In this present time it is realised that much can be done in the case of new steel structures to prevent corrosion by careful attention to design, but however carefully bridges and similar structures are designed, from the very nature of their basic material of construction, they must be subject to corrosion and hence require provision for maintenance.

It is a truism to state that all over the world labour costs are increasing. Fifty years ago it would probably have been right to state that the cost of materials was often a major factor in maintenance, but this is not always true today. One has to consider carefully, the cost of labour and in many parts of the world, its availability. Maintenance of structures is often an engineering exercise which can be influenced by the weather and the cost of long periods of waiting may be very considerable. It is recognised everywhere that if anything can be done to new structures to make the periods between maintenance much longer, then such methods should be critically examined.

Ideally, maintenance should be considered when structures are being designed but it is an unpleasant fact that it also has to be considered in those cases where the structure has been in use for many years. Repainting over existing paint is not recommended and the cost of cleaning on site is often quite considerable. In a programme on the British Radio recently it was stated that a team of about fifty men were continuously employed

on the maintenance of the famous Forth Bridge. If this statement is authoritative then it is obvious that costs must be rising quickly in proportion to the increase in wage rates. It is the purpose of this contribution to suggest that the use of metal coatings would be entirely justified for all cases of new structures and in many cases when structures are already erected.

One needs at first to consider the case for metallic coatings, and it will be realised that for purposes of corrosion resistance, there are only two coatings which demand serious attention. They are those of zinc and aluminium. Zinc is protective to underlying steel as is shown by its position in the electrochemical series, because it is strongly anodic to the steel, and so provides protection by sacrificial action. The life of zinc coatings under many types of exposure has been examined by numerous workers throughout the world, and two indisputable facts have emerged — they are —

1) That the life of such a coating under any given set of conditions is proportional to the weight of zinc applied. This would be expected as the deposit is protecting by sacrificial action.
2) That the methods of deposition of the zinc, whether by hot galvanising, spraying or electrodeposition, have little to do with the life.

While there are many processes capable of applying zinc, there is only one which is applicable to large structures such as bridges, that is by metal spraying.

Aluminium coatings are very protective against certain industrial atmospheres, particularly those containing sulphurous gases and they have given good service in atmospheres containing salt spray. In the case of these deposits, spraying is the only method for deposition that can be used commercially for coatings of fair thicknesses. Many workers have taken the view that this metal also protects largely due to sacrificial action because it is generally anodic to steel. Nevertheless there is some evidence that while sprayed aluminium acts sacrificially at damaged areas, over the general surface it collects an insoluble corrosion product which forms a complete and impervious seal which is an added advantage.

Another advantage of metal sprayed coatings is their matte surface which is extraordinarily receptive to paint and in this differs from the hot galvanised surface which usually requires etch priming.

It may be thought application of paint to a metallic coating is in the nature of gilding the lily, but in effect this is not so. The matte surface of sprayed zinc and aluminium easily picks up dirt, and the fact that both metals are protecting by sacrificial action means that they themselves are destructable and therefore will give corrosion products. In the case of zinc, these show as streaks of «white rust» and in the case of aluminium, sometimes brownish stains. Furthermore the dark grey colour of weathered zinc or the pale grey of weathered aluminium coatings, does not always fit in with the aesthetic requirements of the architect and it is advisable to use a paint as the final covering. The metal beneath protects the paint and its life is increased. It is usual to use a priming coat and

one or two finishing coats. The author is of the opinion that a paint could be developed for use on these sprayed coatings which would require only one coat.

There can be no doubt that if metal coatings could be applied as cheaply as those of paint, then they would be universally used. They are generally more expensive in initial outlay than painting, although as shown by the present author in a recent paper given to the Society of Chemical Industry's Symposium on Steel Structures (Chemistry & Industry, December 1955 pp. 1606-1611), there can be little doubt that over a period of fifty years the metal coating will show very material economic gain. In that paper the author gave actual analysis of costs of both painting and metal spraying, but it is not proposed to do so in this contribution which is intended for an International Congress. Labour rates, material costs and prices of power differ so much in each country. Anyone interested, could refer to the original paper and sufficient information is given for a translation to be made to fit the conditions at any particular site. As an indication it was shown that in a period of fifty years, savings on maintenance costs of between five and twenty-three pounds sterling per ton of steel, could be expected by using metal spraying in place of a straight four coat system.

If a decision is about to be made that protection of a structure is to be undertaken by metal spraying, there are two processes which may be used. They are that using wire as the material and seondly the process using powder. The paper by Mr. Rivett deals with the powder process and hence this contribution is confined entirely to consideration of the author's experience using the wire process. All recent experimental work has shown that it is necessary to clean the steel structure thoroughly before any paint is applied, and it can be very well understood that it is far more important to get an absolute clean surface before depositing metal. It is impossible to apply a sprayed coating of zinc or aluminium unless the surface of the steel is really clean and is roughened to a certain degree. The necessary preparation is by grit blasting with angular grit.

In the case of jobs carried out in works, steel grit is used, but on some site work, where other operatives can be excluded from the area, silica in the shape of crushed black flint is cheaper. This grit blasting represents in most cases, a major cost in the protective scheme. It is becoming recognised that grit blasting is a preferred process for cleaning the original metal before erection even if paint is going to be used as a protective measure. While it is a process with many objectionable features it is much cheaper as a rule than pickling or flame cleaning for structures such as bridges. The only alternative which, while suitable for painting, is unsuitable for receiving sprayed deposits, is that of weathering followed by mechanical or hand brushing. Grit blasting has the advantage that it can be continued until all scale is removed, and the surface is completely free from all foreign matter.

The original grit blasting process now largely used, depends on the abrasive being fed into a stream of compressed air and being carried to the working point through rubber hose and being directed on to the work from a hard nozzle usually made of tungsten carbide. The spent abrasive is collected by some means and is returned to the machine.

More recently the airless grit blasting apparatus has been invented. In this machine the abrasive is fed into a wheel rotating at 2,500 revolutions per minute and the grit is thrown on to the surface to be cleaned. The spread of the grit is considerable and the process is much cheaper and is more efficient. Unfortunately as yet developed, the process requires heavy machinery of high capital cost, and can therefore only be considered for structures which can be built up from material which is suitable to be passed through the machine.

More recently still a method has been developed which shows some promise. In this, the grit is blown on to the job as is usual, but the work nozzle is surrounded by a second nozzle connected to a type of industrial vacuum cleaner. The bottom edges of the outer nozzle are provided with a brush. As more air is sucked by the vacuum cleaner, than is blown by the nozzle, none of the abrasive escapes under the brush and the operation, which is normally dirty, can be carried out on such sites as food factories etc. Unfortunately the working head is heavy and cumbersone, with the result that human fatigue plays an important part, and makes this new and attractive process, rather expensive and slow. It is to be hoped that developments in the future will overcome these initial difficulties.

It will be appreciated that in treating a steel structure, there are three possibilities.

1) That the structure is built from members which are pre-metallised. This enables the cheapest method of metal coating to be used — the passage automatically of the straight members through an airless grit blaster and then their transfer to a mechanised metal spraying machine, where the surfaces are presented to numerous metal spraying nozzles which may be static or mobile, in order to get a complete evenly covered surface. There can be little doubt that the logical situation for this type of plant is at the stock yard of the steel maker producing the sections.

2) Where such objects as fabricated plate girders are to be sprayed they are treated in large cabinets or in temporary structures in the metal spraying works. Here the blasting is usually carried out by the compressed air method. The newer method of the vacuum return is not usually applicable, owing to the cost.

In either of the two methods mentioned, the work is metallised and goes forward on to the site for final erection.

3) When the structures are erected, if they have been pre-metallised, any damage and uncovered joints, can be sprayed on site, or if the structure has not been metallised, the blasting is done in temporary erections on the job itself using the compressed air system, or by the newer vacuum method.

In other words, the blasting and spraying are adaptable to any set of conditions.

The wire metallising process is well known, so that a full description of the tools used would be out of place here. Wire is fed through a central passage in a nozzle and round this are flutes or ports through which a mixture of high pressure fuel and oxygen are fed. When the mixture is ignited, it gives a blow-pipe flame and if the wire is passed through the centre of this, it is melted in the hot zone. Surrounding the gas ports

there is arranged an annular nozzle through which compressed air is fed and this compressed air catches the molten metal as it is formed and divides it into a fine spray. In the case of hand tools, which weigh between 3 and 4 lbs. the wire is drawn into the tool (which is called a pistol), by means of rollers actuated through a train of reduction gears, by a compressed air motor. It should be noted that the raw material of the process is wire which is easily transportable and is not easily damaged. The loss in spraying is lower than with other systems. Heavy duty tools are now constructed with large nozzles capable of spraying 5 mm. diameter rod, but in this case the power for feeding the wire is provided by an electric motor. In automatic plants several nozzles may be banked together and the wire feed arranged so that power for the whole of the nozzles is obtained from a small electric motor.

The process is applicable to all those metals which can be drawn into wire and which can be melted in an oxy-acetylene blowpipe. One of the most common fuel gases used today is propane from cylinders. While the metal must be melted in order to be sprayed, the comparatively large volume of compressed air used in the pistol — about 20 cu. ft. per minute — cools the spray as it is formed and so the process is virtually cold and the work does not get hot. This is another advantage of the metal spraying process.

No contribution on this subject could be considered complete unless some few notes were given as to the practical use to which the process has already been put. Those interested often enquire as to the probable life of metallic coatings, but this is an almost impossible question to answer. All that can be said with absolute certainty is that under any set of corrosive conditions, a metal coating will give the best form of protection yet known. If the coating be given a final painting scheme then the life of the paint and of the structure will be greatly prolonged. In 1922 the Société Nouvelle de Metallisation of Paris sprayed the large rivetted lock gates of the St. Denis Canal with zinc, and the coatings were not painted, the zinc coating being about 1/10th mm. in thickness. In 1939 an examination was made of these gates and they were found to be in reasonably good condition and it is reported they were still not very rusty after the war. Now similar structures in France are being sprayed regularly. This particular experience is mentioned as being an example of the life of a zinc sprayed coating.

In 1939 it was decided by the British Air Ministry that all balloon barrage cylinders made of a low nickel/chromium steel should be metallised with aluminium on the outside. These cylinders were subject to very rough usage and to exposure in all sorts of conditions during the war, both in Great Britain and other parts of the world, in industrial and in marine atmospheres. In all 200,000 cylinders each about 10 feet long were treated and at the end of the war, the behaviour of the aluminium as a protective medium, had been proved, in that there was no severe corrosion in any one case.

This experience led to aluminium coatings being used on the largest constructional job that has been treated by spraying. This involved the treatment of all the steel structure above crane level of the building of the Steel Company of Wales at Margam. The first contract necessitated

the spraying with aluminium of 29,000 tons of constructional steelwork varying in size from 8″ channels to 3″ angles. Sufficient aluminium wire was used in this contract to encircle the equator of the world five times. Where possible the steel was pre-metallised by passing through an automatic plant erected at the works of Metallisation Ltd., Dudley. The plant

FIG. 1. View of suspension chains «Clifton Bridge». The cradle for metallising is clearly shown. Courtesy of Bristol Metal Spraying & Welding Co. Ltd.

consisted of a four wheel airless blasting machine and a mechanised spraying plant capable of using up to 28 nozzles at one time. The coating, 1/10th mm. in thickness was very uniform. The completed work was slung by crane on to ordinary railway trucks and transported 120 miles to the site. No very special precautions were taken in erection, but it was worth while to note that the damage caused was comparatively small, and touching up on site was by no means excessive. Where the spraying of straight members was not possible, as in the case of roof

frames, these were treated in a temporary building on the site. The design of the structures called for welding and no coating was applied where welds had to be made. Each joint was grit blasted and sprayed in position. After the building had been completed the sprayed surface was given one coat of aluminium paint, largely for the purpose of obtaining maximum reflection of light. It was felt the spraying of the structures above crane level would be justified because of the difficulties of maintenance at heights, in a continuous steel mill above working machinery. The atmosphere was not only industrial, but the works are situated on the coast. The work carried out was entirely successful and as a result, further contracts were placed.

A different type of structure which has proved the advantages of metallic coatings can be cited as in the case of the penstock at Pangani Falls in Tanganika. This was metallised with aluminium of a minimum thickness of 1/10 mm. The site is in jungle country and the water is contaminated with organic material. A similar line untreated, had given very short service. The inside of the penstock was sprayed under somewhat difficult conditions some six years ago, by Metallisation (S. A.) (Pty) Ltd. and a recent investigation has shown that protection has been very good and further work is now being undertaken. Penstocks of the Clunie and Pitlochry Power Stations in Scotland were sprayed with zinc. With regard to bridges, several new structures for Iceland, New Zealand and Australia have been and are being metallised by the wire process by the engineers.

An interesting job now being sprayed is the Clifton Suspension Bridge over the Avon Gorge near Bristol. The work of metallising this old bridge necessitates grit blasting and spraying at a great height above the gorge.

In conclusion one must also refer to the use of these metallic coatings for structures of light alloys. There is a tendency in many cases to use light alloys where possible for structural work, because of the saving of weight. It is unfortunate that the very strong light alloys are not those that resist corrosion very well, and some difficulties have been experienced owing to fatigue corrosion. There is definite evidence that an aluminium coating of 99.5 % purity, sprayed on such structures is the cure for these difficulties, and large contracts have been carried out on the complete spraying of Bailey Bridge panels for this reason. Not only can the metal coating in this case, be used as a protection but by throwing the pistol out of adjustment the metal is deposited on the surfaces in comparatively large lumps giving a rough surface which prevents the slipping of pedestrians or vehicles.

Reverting now to light alloy structures, these are often rivetted or bolted on to steel members and there is a danger under some circumstances of electrolytic action being set up. If the joint between the steel and the light alloy be sprayed with aluminium, such danger is completely eradicated.

SUMMARY

Metal spraying of bridges and other structures with zinc or aluminium is described as the most economical method of protection against

corrosion. Most of the work should preferably be carried out in a mechanized plant for which the wire process is particularly suitable. Final coatings are applied at the site.

ZUSAMMENFASSUNG

Es wird festgestellt, dass der gespritzte Metallüberzug mit Zink oder Aluminium für Brücken und ähnliche Bauwerke als Schutz gegen Verrostung die weitaus wirtschaftlichste Methode ist. Die Arbeit sollte soweit als möglich mittels einer mechanisierten Anlage ausgeführt werden, wofür sich das Schmelzdraht-Verfahren besonders gut eignet. Ferner werden Beispiele von Schutzanstrichen auf dem Bauplatz beschrieben.

RESUMO

A metalização de pontes e outras estruturas com zinco ou alumínio é indicada como sendo o meio mais económico de protecção contra a corrosão. A maior parte do trabalho deve executar-se em oficina sendo então mais indicado o processo de metalização por fio. As últimas camadas são aplicadas no local da obra.

RÉSUMÉ

La métallisation de ponts et autres structures à l'aide de zinc ou d'aluminium est décrite comme le moyen le plus économique de protection contre la corrosion. La plus grande partie du travail doit être exécutée en atelier, le procédé de métallisation par fil étant alors le plus indiqué. Les dernières couches sont appliquées sur place.