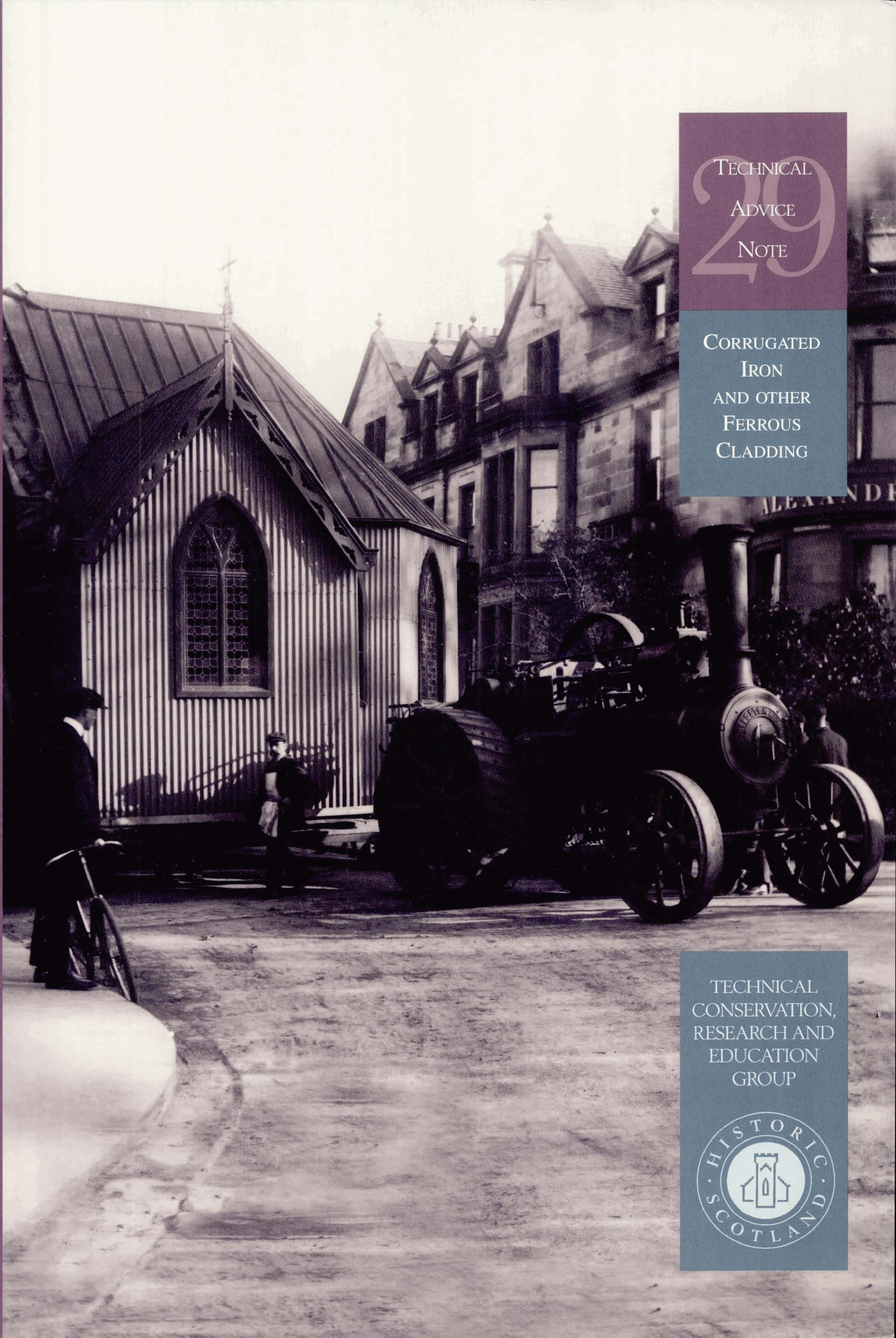
TAN 29

CORRUGATED IRON AND OTHER FERROUS CLADDING



Technical Advice Note 29

Corrugated Iron and other Ferrous Cladding

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TECHNICAL

ADVICE

NOTE

CORRUGATED IRON AND OTHER FERROUS CLADDING

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Prepared by
University of Dundee

Published by
Historic Scotland

ISBN 1 900168 83 9

Edinburgh 2004

Commissioned by
TECHNICAL CONSERVATION RESEARCH AND EDUCATION GROUP

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Prepared by the University of Dundee

Commissioned by:
Technical Conservation Research and Education Group Historic Scotland

ISBN 1 900168 83 9

Design and origination by The House (12/04)

ACKNOWLEDGEMENTS

The authors are indebted to a number of individuals who have assisted with the accessing, collection and understanding of the data contained in this publication.

Noha Akiki, Education Librarian, UNESCO, Paris; Jacqueline Demause, Leominster; R Fitzgerald, UMIST, Manchester; John Gall, North of England Open Air Museum, Beamish; David Hendrie, Historic Scotland, Edinburgh; Dr Catherine Higgitt; John Hume, Neil Lynch, Billy McColm (all formerly Historic Scotland); J Marsh, UMIST, Manchester, Michael Walker, Paris.

Special thanks to:

Audrey Morrison, University of Dundee for preparing the text for publication.

Cover illustration: Moving the old Catholic Church, St Andrews, 1909.
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FOREWORD

Invented and patented in Britain in 1829, corrugated iron was to become so widespread that it is difficult not to think of it as a "traditional building material". As manufacturing and production techniques developed, so did the market, both home and abroad. International demand grew to such an extent that countries as far afield as Argentina, Brazil, Canada, Chile, India, Italy, Manila, New Zealand, South Africa and Uruguay were regularly being supplied by Britain in the 1890s. Editing the 1891 Fourth edition of *The Book of the Farm*, James MacDonald also observed that with the construction of farm buildings in Britain *"One point however, deserves notice, and that is the greatly increased and steadily growing extent to which iron is being employed in the formation of buildings. Corrugated iron is now very extensively used in covering cattle-courts, hay-sheds, cart-sheds and other buildings on the farm; and in many cases the entire building is constructed from iron .... This is step in right direction for iron is both cheap and durable."*

As an indication of the export level, almost 40,000 packages of corrugated iron were imported into Victoria, Australia between 1853 and 1855 during the peak of that State's demand. Whilst a larger building, such as a church, constructed entirely of the material might consume 60 packages, many hundred of other buildings were constructed from these self-build flat-pack units. As associated manufacturing skills and techniques developed, continued production was assured by greater agricultural, domestic, industrial and war-time demand. Diversity of use followed these technical developments.

In 1932 the *"Architects and Builders Pocketbook For all persons interested in the design, erection and equipment of various classes of structure"* was indicating that *"Corrugated Iron is pressed or rolled into a series of corrugations from 3 to 5 inches wide; the sheets are then coated with zinc, to protect them from rusting. The amount of coating can be tested by holding a sheet over a gas jet and noting the amount of fused metal that flows off. The sheets vary in length from 5 to 10 feet and in width from 27 inches to 30 inches"*

Whilst methods of testing performance and quality control might have been limited initially, functional performance was less so as the various sheet profiles and sizes were put to ever increasing imaginative uses.

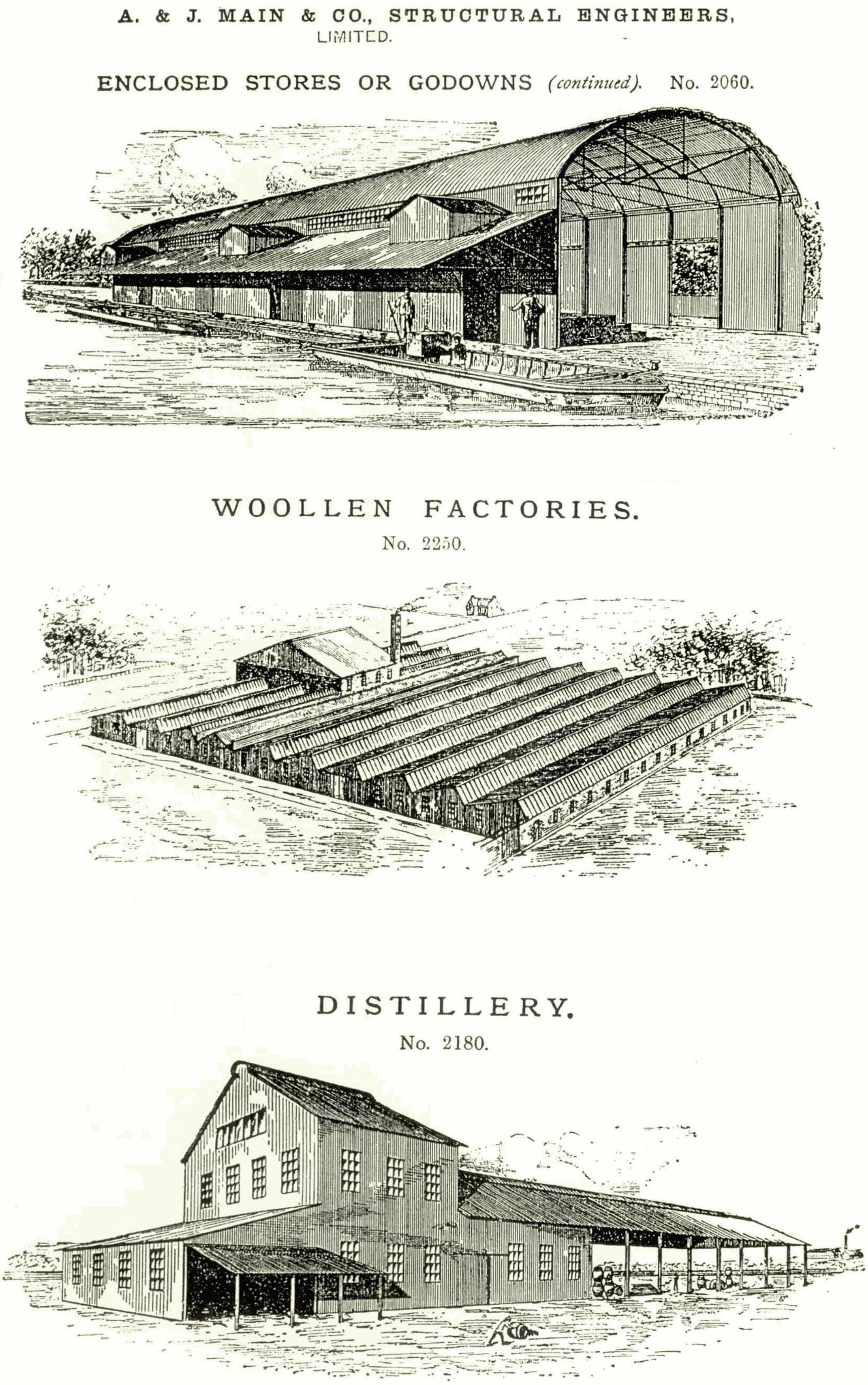
In a forthcoming Research Report volume *"Ferrous Metal Cladding in Scotland. A History and Guide to Traditional Components"* Dr Bruce Walker offers an in-depth explanation of this diversity and expansion in the use of the material. Here, in this Technical Advice Note, he explores the outline issues behind the conservation dilemmas of dealing with this more modern "traditional material".

However, a detailed awareness of how to do this effectively is still in its infancy, both in the UK and abroad. Key questions such as how and when to repair, or to replace, corrugated iron sheets have no definitive answer at this time. Similarly, an analysis of its degradation and decay, achieved through closely observing the emerging rust stain patterns on the surface of the sheet reveals more about the inadequacies of the original manufacturing processes of protective coatings than addressing how the failings can be resolved. Temporary holding measures such as sandwiching a covering sheet on top of the sheet that is failing, or patching with bituminous felt, often emerge. Beyond that lies complete sheet replacement, or the more demanding recoating.

Unlike our International colleagues we have not yet come to fully recognise the intrinsic value, or significance, that exists in our continuing reliance on "ageing" corrugated iron sheeting on our Scottish buildings. Consequently, we are somewhat behind in our exploration, thinking and adoption of relevant sympathetic solutions to the inevitable deterioration of the material.

This TAN attempts to increase that awareness of need, and to sensitively promote an understanding of the complexities involved in dealing with what remains. We have much that we can learn from others in countries which imported considerable amounts of the material from Scotland in the first place. It is to be hoped that this volume might assist in revisiting these original supply routes so that we might gain from the international experience of others now facing similar problems.

Ingval Maxwell, OBE
Director, TCRE
Edinburgh
January 2005



Illus 2 Prefabricated industrial buildings from A J Main & Co. Catalogue

SUMMARY

The history of the use of ferrous metal as a cladding for buildings is poorly documented, and as a result is largely misunderstood by building professionals and historians. It is considered by many historians and the majority of professionals as an inexpensive modern building material usually associated with industrial estates and temporary structures. This could not be further from the truth since many of the early applications were associated with some of the most prestigious structures of their eras.

The author, in association with Historic Scotland, has tried to change this perception by producing a research report which provides a skeleton history which may eventually be fleshed out by other studies into a complete history of the subject.

The modern history of ferrous claddings dates back to the second half of the eighteenth century, when improved techniques of rolling made iron available in sheet form at a price comparable to other building materials used for prestigious structures. Improvements in casting techniques followed but it took a further century to reach the stage where ferrous claddings could compete with vernacular materials in areas where there were no established building industries. The material always had an advantage in situations where there was spectacularly rapid new growth.

The concept of metal-clad structures being inferior or ugly stems from the writings of prominent members of the Arts and Crafts Movement at the end of the nineteenth century. These writers were trying to counteract the effects of the Industrial Revolution by maintaining former values without regard to economic pressures. In the first ever technical pamphlet produced by the Society for the Protection of Ancient Buildings, William Morris (1890) listed the following 'Bad Roof Coverings'.

'Milled lead

Broseley mechanically-made tiles (thin, brittle, always weathering, ugly).

Thin Welsh blue slates (one of the greatest curses of our age).

Corrugated galvanised iron and zinc (now spreading like pestilence over the country).'

It is difficult to imagine any current SPAB member or conservation officer making an argument for the rejection of any of the first three 'bad roof coverings', but many still have difficulty with the concept of conserving or renewing corrugated iron.

Prior to the change in attitude brought about by writers such as Morris and Ruskin, most of the innovative architects and engineers of the nineteenth century including:

Sir Charles Barry (1795-1860):

Isambard Kingdom Brunel (1806-1859):

Charles Robert Cockerell (1788-1863):

Thomas Leverton Donaldson (1795-1885):

(Alexandre) Gustave Eiffel (1832-1923):

Augustus Welby Northmore Pugin (1812-1852): and Robert Stephenson (1803-1859) were involved with metal clad or metal roofed structures often on particularly prestigious buildings. All except Eiffel were on the committee that proposed a corrugated iron clad dome over the central pavilion at the Great Exhibition of 1851; a proposal that proved to be too expensive and was replaced by the cheaper Crystal Palace. This confidence and enthusiasm for metal claddings has returned with examples such as: the Lloyds Building, London; the Pompidou Centre, Paris; the Guggenheim Museum, Bilbao; and the Clyde Auditorium at the Scottish Exhibition and Conference Centre, Glasgow, indicating the diversity of form, cladding types and methods of application that is possible.

The aim of this document is to provide sound technical advice to the conservator but since the conservation of complete ferrous metal clad structures is still in its infancy, particularly with regard to flexible sheet and corrugated iron, much of this will be in the form of warnings and pleas for caution rather than direct instructions.

Experience and expertise exist in some aspects of ferrous structure refurbishment such as the cold stitching of damaged cast-iron components or the conservation of ferrous artefacts taken from archaeological and other sources for museum display. It is hoped that by highlighting these activities, particularly the larger museum conservation exercises such as the conservation of the first Royal Navy submarine (BAKER et al: 1997), a certain amount of experience and expertise may be transferred from the archaeological/museum conservators to building conservators.

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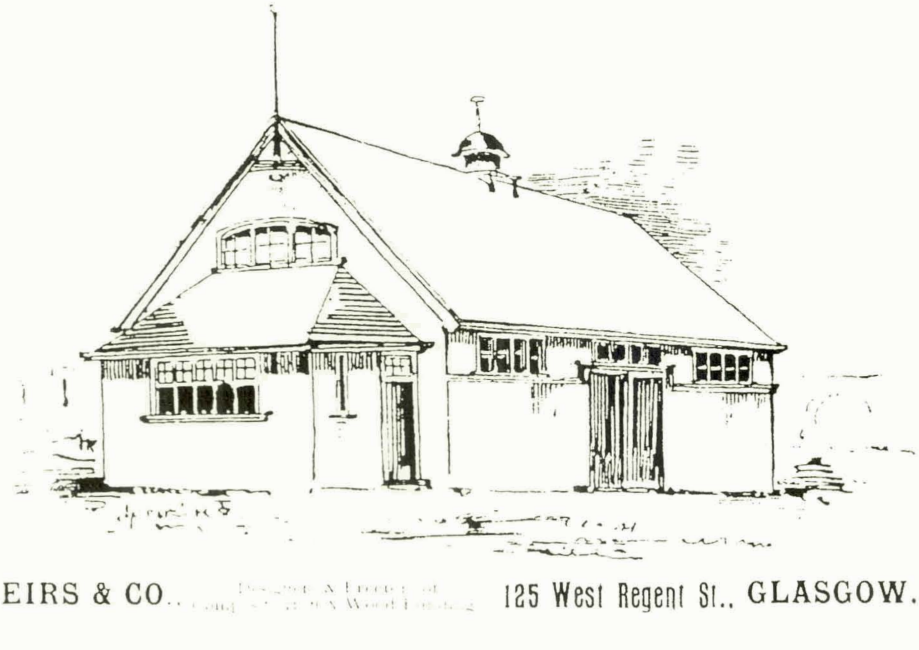


SPEIRS & CO.. 125 West Regent St., GLASGOW.

Illus 3 Prefabricated small public buildings from Spiers & Co. Catalogue

1.0 INTRODUCTION

Metal-clad buildings have been known since the Bronze Age when it was easier to enrich a timber or masonry structure by the application of polished metal plates than by carving the base material with stone or soft metal tools. Descriptions in the Bible refer to King Solomon's Palace as being 'brazen' suggesting a cladding of polished brass, bronze or copper plates. These were possibly applied as a pattern of flat sheets with decorative bands of repousse-work forming cornices or friezes in places where there was less chance of damage. Similarly the original temple at Delphi, erected in 1263 BC 'was of brass' (Hazlitt, 1851). This probably refers to a cladding rather than solid brass since archaeologists working in the Middle East have long recognised the patterns of nail holes used to attach these plates to the walls of masonry structures.

Harder metals, such as iron, are much more difficult to work and only began to be used for roofing and cladding purposes after the invention of the plate mill reduced the cost of the product to a level where it could compete with other materials used for the same purpose. This development took place in the late eighteenth century, but this is still early enough for ferrous metal cladding to be a potential roofing material for at least ninety percent of our current building stock.

The idea of using corrugation or buckling to stiffen sheet iron and allow it to be self - supporting over greater spans helped to reduce both the cost and the weight of the roof. This had a significant effect on the construction of metal buildings from the 1820s onwards. The whole of our industrial history is, from then on, linked to the ability these materials offer to enclose large workspaces cheaply and effectively thereby allowing works, that had hitherto been subject to the effects of weather when they were carried out in the open air, to proceed uninterrupted by such changes. Ferrous metal cladding also met the demands for inexpensive housing, religious and social gathering places, hospitals, and other structures, generated to meet the needs of the population migrating from the countryside to the town.

Considering their economic, industrial and social importance it is surprising that ferrous metal claddings have not been the subject of a comprehensive study. Why have they been ignored in architectural, engineering, ethnological, economic, military and social terms? It is this question and its possible answers that may be addressed in future research commissioned by Historic Scotland.

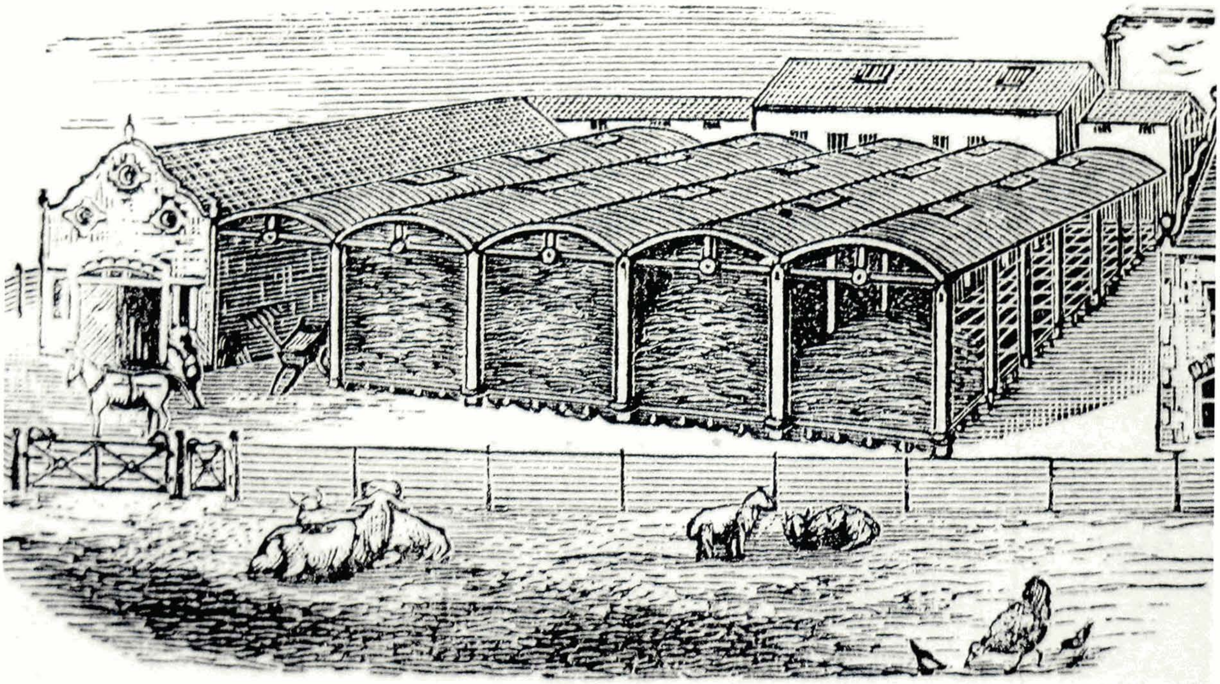
The primary aim of this Technical Advice Note is to provide sound technical advice to the conservator or to conservation organisations involved in the conservation of wrought ferrous metal cladding, but since the conservation of complete ferrous metal clad structures is still in its infancy, particularly with regard to flexible sheet iron or steel and corrugated or profiled iron or steel, much of this will be in the form of warnings and pleas for caution rather than in the form of direct instructions. Cast iron cladding has been omitted from this publication. As with other subjects, Historic Scotland is committed to producing relevant case studies as these become available and to updating the technical advice as new expertise develops.

Experience and expertise exist in some aspects of ferrous structure conservation and refurbishment. One such area of expertise is in the cold stitching of damaged cast iron components. Another is in the conservation of ferrous metal artefacts from archaeological and other sources for museum display. Many of these objects are extremely small and spend their museum life in environmentally controlled surroundings. Some of the conservation technology is extremely expensive and would be prohibitive on large scale structures but it is hoped that by highlighting these activities, particularly the larger museum-based conservation exercises such as the conservation of the earliest Royal Navy submarine (Barker et al: 1997), a certain amount of the skill and expertise developed in the museum environment may be transferred to the conservation of ferrous metal clad buildings in a natural environment.

Susan Maltby, a conservator based in Toronto, Ontario, Canada, summarises the problem (Maltby, 1998) in the following terms:

"Buildings are essentially large, immovable composite objects maintained in an uncontrolled and often inhospitable environment. Their conservation and preservation requires the expertise of a number of heritage professionals including architects, engineers, historians, skilled restoration tradespeople and conservators".

When dealing with metal cladding, an imaginative skilled conservator is absolutely essential.



Illus 4 Illustration for Iron Farm Buildings: Stephens Book of the Farm Vol 3 Fig 769. 1891

Illus 5 Sheriffston Farm Cottage, Elgin. Half roofed with single sheets of corrugated iron. © Ingval Maxwell

2.0 FERROUS METALS

Metals fall into two categories and are described as being either *Ferrous*, that is containing a substantial proportion of Iron (Fe) or *Non-Ferrous*.

The tonnage of ferrous metals produced annually is more than ninety per cent of the total production of metals.

In general, ferrous metals are strong and inexpensive compared to non-ferrous metals but if they are not properly and continuously protected they may corrode and suffer serious loss of strength.

2.1 Iron (Fe)

The table below shows the relationships between the various forms of ferrous metals.

- IRON
  - CAST IRON
    - ORDINARY
    - HIGH DUTY
  - WROUGHT IRON
  - STEEL
    - CARBON STEELS
      - eg Low Carbon Steel
      - Mild Steel
      - Medium Carbon Steel
      - High Carbon Steel
    - ALLOY STEELS
      - eg Stainless

This publication will concentrate on the various types of wrought iron and steel but excluding alloy steels.

Iron is a silver-grey metallic element, symbol Fe, atomic number 26, and relative atomic mass 55.847. It is the fourth-most abundant element and second-most abundant metal in the Earth's crust.

Iron occurs in concentrated deposits in the form of ores although it sometimes occurs as a free metal, occasionally as fragments of iron or as iron-nickel meteorites.

The common iron ores are: haematite (Fe_2O_3), magnetite (Fe_3O_4), limonite ($-2Fe_2O_3-3H_2O$) and siderite ($FeCO_3$). These ores require processing to produce a recognisable and usable metal.

2.02 Types of Iron

The nomenclature used to describe iron and steel is far from standardised and has caused considerable misunderstandings. It was not until 1901 that a committee was appointed by the International Association for Testing Materials to establish uniform nomenclature. There findings were published in 1907. These were not universally acceptable and a further group of definitions was developed, classified and published in 1912. That publication is the basis for many of the terms defined in section 9.0 Glossary.

Very broad terms have been used throughout the text since many different varieties of iron and steel are being discussed.

There are three main types of iron used in buildings. These are wrought iron, steel and cast iron.

2.2.1 Wrought Iron

The production of wrought iron has a long history and has been traced back at least 4000 years when it was being made in the Middle East. The technology gradually spread across Europe and reached Britain by 450BC where the primitive beginnings of iron making had begun some 300 years earlier.

Wrought iron typically contains 99.59-99.95% Fe. and has a very low carbon content (0.030-0.226%). Wrought iron melts at 1500°C (2732°F) but below this temperature it can be readily impact-welded. Impact welding of wrought iron can be carried out more readily than with any other form or alloy of iron.

The recipes and manufacturing techniques for many of the early forms of wrought iron have not survived but wrought iron in its purest form can be made by removing carbon and other non-metallic impurities from cast iron or pig iron. This produces a material which is strong, extremely ductile, resistant to shock and possessing a relatively good resistance to corrosion.

Skelton (1924.132) stated that the essential characteristic of wrought iron, which has been puddled, is that it consists of an immense number of elongated elastic iron crystals (fibres), each protected by a slight film of slag, interlaced and knitted together by 'welding' under pressure into a compact mass.

Wrought iron is expensive to produce and its use reached its zenith in 1889 in the construction of the Eiffel Tower, Paris. Production of wrought iron has now ceased in Great Britain, except in museum situations such as the Ironbridge Gorge Museum.

Old wrought iron can be recycled by heating the scrap to welding temperatures then hammering the pieces together on the anvil of a steam or air hammer. The hammered lump is then rolled into a bar in the grooves of a rolling mill. All wrought iron scrap to be considered for rewelding should be free from any metal coatings such as tin or zinc. Care must also be taken not to include steel in the scrap.

Wrought iron scrap can be graded into three categories:

a) Wrought iron plate and sectional material 9mm thick and over, reasonably clear of rivets, without flanged end plates or circular angles and plates; chain cable scrap and chain scrap not less than 12mm diameter.

b) Heavy wrought iron scrap not less than 6mm thick including horseshoes, rivet and bolt scrap from the manufacture of rivets and bolts and chain scrap not less than 6mm diameter.

c) Wrought iron scrap under 6mm thick and including 'country' iron scrap.

Traditionally wrought iron made from scrap was held in high esteem since the scrap involved was the crop ends of bars, plate shearings and so on. This was considered as equivalent to best iron (see 2.3.1 below) from that particular plant.

However, today scrap can consist of scrap iron collected from a wide range of sources, and can contain iron of varying character. Each iron type has its own welding point. This results in some of the iron welding before others and the poorer irons will be burnt before the better irons reach welding heat.

Should the reworking of wrought iron scrap be considered, it is important to obtain the scrap from a single source and to have it tested before and after rewelding.

Information on the testing of wrought iron is given by Skelton (1924, 189-213).

2.2.2 Carburized Iron (Carbon Steel)

Although technically a steel, carburized iron was made in the same way as wrought iron but with a higher carbon content. The carbon forming 0.5 - 1.5 per cent of the mass.

Carburized iron has a similar long production history to wrought iron. and was used in toolmaking and for weapons: it could be hardened by heating it to a bright red colour before quenching in water.

The different characteristics of wrought iron and carburized iron have been recognised and understood for many centuries but it was not until well into the twentieth century that the metallurgy of the difference was fully exposed.

2.2.3 Steel

Steel can be described as a ferrous alloy which is produced by first removing most of the impurities from pig iron then accurately controlling the proportions of all the ingredients added to the pure iron.

Carburized iron is a form of carbon steel and was often described as 'steel' in early publications. The means of producing steel on a large scale dates from 1856 when Henry Bessemer, attempting to make wrought iron on a large and economic scale, invented the Bessemer Converter. Bessemer succeeded in producing a metal which was chemically similar to wrought iron but physically different. This metal is known as mild steel and from then onwards the term 'steel' is generally reserved for the bulk product, unless qualified by an adjective, such as carbon steel or stainless steel.

Wrought iron continued to be the principal metal used in tensile structures until 1889. In that year the Eiffel Tower was constructed using wrought iron. The Forth Railway Bridge (1882-1890) used mild steel and its success appears to have established steel as the principal ferrous metal for large-scale civil engineering projects.

2.3 Methods of Production

It is impossible to list all the historic methods of production for the various types of ferrous metals but a summary of the main methods employed in the recent past is included below. This is of necessity simplistic but it should serve to illustrate why it is essential to have historic metals analysed before proceeding with a maintenance or restoration project.

2.3.1 Pig Iron

All ferrous metals are now made from pig iron (see 2.3.2). This is produced in a blast furnace where a mixture of iron ore, coke, and limestone (to separate the iron from the earthy material) is subjected to heat. A blast of hot air injected into the base of the furnace reacts with the coke to smelt (reduce) the iron ore to form molten iron. Some carbon in the coke combines with oxygen in the iron and is given off as gas, whilst some of it combines with the molten pig iron, which is thereby deoxidised and acquires a high carbon content, that is, up to about three to four per cent.

Molten iron is run off into moulds to form pigs, or taken in liquid form to make steel.

2.3.2 Wrought Iron

Historically, wrought iron was made by direct reduction in a bloomery furnace, without the iron ever becoming molten. Direct reduction of pelleted iron ores is a modern equivalent of that process, which is an alternative to the use of the blast furnace (see section 2.3.1).

The first stage in the production of wrought iron is the preparation of puddled iron. This is achieved by melting pig iron with mill scale (iron oxide) in a puddling furnace in which the impurities in the iron, including carbon, react with the oxygen in mill scale to produce a slag within the iron. The molten iron has the appearance of boiling. During the period when the iron is 'boiling' the metal is stirred continuously by the puddler, and as more impurities are removed the iron becomes stiffer. The boiling stage ends when carbon monoxide no longer bubbles through the iron. The spongy mass of iron is then said to have 'come to nature'. The iron is then formed into balls by the puddler. The production of these iron balls is not scientifically controlled but depends to a great extent on the skills and experience of the puddler.

The iron balls are then removed to a steam or air 'shingling' hammer where they are hammered to expel most of the slag. This process is known as shingling and is completed in minutes and the finished product takes the form of a bloom approximately five inches by five inches by thirty six inches. The bloom, still at bright red heat, is then passed through the rolling mills to form a long bar. The product - 'muck bar' - still contains some slag and is cut into pieces which are then made up into 'Piles' which are reheated to welding heat and then rolled. Tiles for making plate have the bars arranged to form a mat three bars thick with the central bars set at right angles to the upper and lower bars.

The first rolling produces 'Crown Iron', the lowest but most commonly used grade for making ferrous cladding. Additional heating and rolling produces better grades - Crown Best, 'Best Best', 'Best Best Best' and 'Treble Best'. The range of standard sections produced includes plate iron, coated iron (tin or lead) and corrugated sheet iron.

2.3.3 Bulk Steel

The various types of carburized iron or carbon steel are described in the *Edinburgh Encyclopedia* (Brewster: 1830: XVIII: 385-388).

The main processes used for making mild steel have historically been:

a) Converter Processes (or Basic Oxygen Converter Process)

b) Open Hearth Furnace

c) Electric Furnace

d) Spray Steelmaking.

In modern steel production the carbon, silicon, phosphorus and other elements present in pig iron are reduced in quantity by oxidation.

Today the vast bulk of mild steel is made in oxygen converters. The open hearth process is obsolete, and electric furnaces are used only for special steels.

All these processes are described in *Mitchell's Building Construction* (King Everett 1970, 192-193).

2.4 Properties of Iron

The properties of iron vary according to the era in which it was produced, the area, the method of production and its treatment since production. It is impossible to describe all the variants particularly of early wrought irons and carburized irons since these were made by intuitive methods, the quality depending on the skills and expertise of the man in charge of production. In the *Edinburgh Encyclopedia* (Brewster, 1830, XVIII, 385-388) the properties of 'Damascus Steel' were fully appreciated but at that time all attempts to replicate the metal had been unsuccessful.

It is therefore extremely important that older irons be fully analysed before conservation works are agreed.

2.4.1 Wrought Iron

Wrought iron has the lowest carbon content of all the commonly-used ferrous metals. Its main properties are:

Corrosion: relatively good resistance to corrosion

Economics: costly to produce

Strength: strong, resistant to shock, very ductile - elongation at failure is 25-40 per cent.

Workability: ideal for working at low temperatures, best material for hand-wrought work, can be impact-welded, cannot be cast.

2.4.2 Carburized Iron (Carbon Steel)

The properties of carburized iron are similar to those of wrought iron but with greater strength. The increased strength is offset by the material being slightly more prone to corrosion than wrought iron. Low-carbon mild steels (up to 0.15 per cent carbon) are soft and suitable for thin sheet or tinplate manufacture.

Mitchell's Building Construction (Everett 1970, 197) provide a useful diagram showing how the treatment of carbon steel during manufacture affects the properties of the material and its subsequent uses. When the basic material is heated to 'red heat' it can then be:

a) quenched in water, brine or oil to produce a material referred to as 'hardened'

b) retained at 'red heat' temperature then gradually cooled in air to produce a material referred to as 'normalised' or

c) retained at 'red heat' temperature, then cooled very slowly to produce a material referred to as 'fully-annealed'.

Both normalised and fully-annealed steels are then suitable for cold working, the normalised steel being slightly harder and stronger than the fully-annealed steel which is soft.

2.4.3 Mild Steel

The metallurgy of steels is complex, and experts should be consulted about proposed treatments.

The carbon steels have been included under carburized iron, while alloy steels are described here.

All steels contain carbon, but the description 'plain carbon steels' is used to distinguish those which do not contain a significant proportion of alloying elements. The others are known as alloy steels. It is dangerous to assume that all early steels are 'plain carbon steels' since alloying elements may have been included without a full metallurgical appreciation of what was happening, hence the high reputation of some of the early carburized irons. The presence of other metals in alloy steels results in a huge variety of physical properties, and can produce corrosion resistance and increased hardness or toughness. The added metals in alloy steels produce a surface film (of metal oxides) which is impervious to water, for example, stainless steel protected by a film of Cr_2O_3.

Plain carbon steels can be subdivided into four categories:

a) Low carbon steels (up to 0.15 per cent carbon)

b) Mild steels (0.15 – 0.25 per cent carbon)

c) Medium carbon steels (0.25 – 0.50 per cent carbon)

d) High carbon steels (0.50 – 1.50 per cent carbon)

In addition to carbon steels and alloy steels, steels can also be distinguished as:

Structural steels.

Sheet steel (under 3mm thick).

Alloy steels.

The types of steel of most interest to those dealing with ferrous cladding are structural steel plate and sheet steel, although many of the newer claddings involve the use of alloy steels.

2.5 Deterioration of Iron

2.5.1 The Corrosion Process

'It is a melancholy reflection that an important structure like the Forth Bridge if not adequately protected by paints or preservatives of some kind might decay and perish within the lifetime of an average man' (Skelton, 1891, 1924).

Deterioration or degradation of iron usually results from chemical, electrochemical and mechanical

Illus 6 Forth Bridge © Crown copyright Historic Scotland

actions. Corrosion is the term used to describe the slow wearing away of the iron by chemical or electrochemical attack.

i) Rusting or Oxidation

Iron undergoes chemical deterioration processes, or corrosion reactions, with water, oxygen and other substances in the environment in a process of reversion: this is called rusting.

Rusting of iron is an oxidation process involving the formation of hydrated iron (III) oxide, Fe_20_3 xH_20 (or $Fe(0H)_3$ or $Fe0(0H)$). Rusting is initiated by an electrochemical or redox reaction, where different parts of an iron structure act as cathodes and anodes. At an anodic region, the iron is oxidised to iron (II)cations (oxidation number of 2).

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$$

A second electro-chemical reaction occurs at the cathodic region:

$$0_2\,(aq) + 2H_20(l) + 4e^- \rightarrow 40H^-(aq)$$

The resulting $Fe\,(OH)_2$ is oxidised in air to rust, hydrated iron (III) oxide =

$$2Fe\,(0H)_2\,(s) + \_0_2\,(aq) + H_2\,0(1) \rightarrow Fe_2\,0_3.x\,H_20(s)$$

$$[\text{or } Fe\,(0H)_3 \text{ or } Fe\,0\,(0H)]$$

The electrolyte is required to provide a pathway for the electron current, and in the presence of dissolved acids and salts its conductivity is increased and nesting is speeded up.

Rusting can occur between different crystals in the iron, between different qualities or conditions in the iron, and between areas of different aeration in the electrolyte layer. Differences in the qualities of the iron may be due to additional working at joints, anntaling of edges, the amount of stress to which the metal has been subjected, and so on.

ii) Other Electrochemical Deterioration

Corrosion will occur when a difference of electrical potential occurs between two points on a wet surface. This can result from contact of iron with a different metal, the two metals being connected by a film of water (an electrolyte).

While the Electrochemical Series lists elements in the order of the electrode potential which is developed under standard laboratory conditions (immersion in a solution of molar ionic concentration), it is not always possible to predict when, nor what type of, a reaction will occur. In practice tables, known as *'galvanic series'*, are constructed which list metals in order of increasing reactivity in a given medium. The table below shows the galvanic series in sea-water, with the anodic metals at the top and the cathodic metals at the bottom. The metals at the top of the table corrode in preference to those below and the more remote the two metals are on the scale, the greater the reaction.

ANODIC END - NEGATIVE - BASE METALS	
magnesium	Mg
zinc	Zn
aluminium	Al
cadmium	Cd
aluminium-magnesium-silicon alloys	Al-Mg-Si
copper-aluminium alloys	Cu-Al
iron & mild steel	**Fe**
chromium	Cr
lead	Pb
tin	Sn
nickel	Ni
brass	Cu (65%) - Zn (35%)
stainless steel	
bronze	Cu (85%) - Sn (15%)
copper	Cu
silver	Ag
CATHODIC END - POSITIVE - NOBLE METALS	

This series has a fundamental bearing on the choice of metals for flashings and fixings in any situation where a film of moisture can form an electrolyte.

In practice, therefore, certain metals should not be used together in any position where they may be linked by a film of moisture, whether this be rain or condensation.

Thus copper and copper alloys will attack cast iron, mild steel, cadmium-plated steel, galvanised steel, zinc and aluminium. Similarly, mild steel will attack aluminium, galvanised steel and zinc.

Corrosion will be particularly severe where the area of the anode is small compared with that of the cathode.

Corrosion is more rapid where strong mineral acids or their salts, for example, chlorides or sulphates, are present in the electrolyte. This is the case with acid rain or chemical fumes, or in marine environments.

Temperature also has a bearing. In the case of zinc and steel, a reversal of polarity occurs at about 70°C when a normally-protective zinc coating will tend to corrode the steel it should be protecting.

It is not essential to have two different metals to set up electrochemical deterioration. The same action can be set up between different crystals in the iron, between different qualities or conditions in the iron, and between areas of different aeration in the electrolyte layer. 'Waterline' corrosion, where metal exposed to air meets metal below ground or under-water, is a common and potentially dangerous phenomenon.

Differences in the qualities of the iron may be due to additional working at joints, annealing of edges, the amount of stress to which the metal has been subjected, and so on.

Galvanic corrosion is also influenced by the relative areas of the metals and resistivity of the surface films.

iii) Mechanical Deterioration

There are several physical processes which will cause the deterioration of metal.

a) Abrasion: caused by the rubbing of other materials against the surface of the metal may cause the removal or damage of the protective layers thereby exposing the underlying metal to corrosion.

b) Fatigue: caused when a metal is repeatedly stressed beyond its elastic limit. The usual cause in buildings is insufficient allowance for thermal expansion and contraction in sheet metal roofs but it can occur in other situations.

c) Heat: usually in the form of fire, will cause many metals to become plastic, distort under load, and then fail. Cast iron performs well in situations like this since it has a higher softening point than most metals, and contrary to popular opinion does not explode when hit by a fire crew's jet of water.

2.5.2 Connection Failure

All of the above-mentioned processes of deterioration (2.5.1) can cause the breakdown or reduced effectiveness of structural metal fixings and connections.

Iron connections which trap water are particularly susceptible to corrosion.

2.6 Repair and Maintenance

Generally, accepted conservation policy is to retain and repair as much of the historic fabric of any building as is possible, and to replace on a like-for-like basis only when there is no other option. The historic importance of any constructional element must be identified at an early stage. The merit of the structure or cladding in terms of age, association with historic events or figures, design qualities, exceptional workmanship, materials, scale, technological achievement, and uniqueness must all be understood before decisions regarding maintenance, presentation and repair can be made. The conservation issues associated with these considerations are discussed in section 6.0.

Whatever the importance, the principal aim of any work must be to halt or slow down the process of deterioration, and to stabilize the condition of the cladding.

Unfortunately, when dealing with ferrous metals, decay often occurs at points on the cladding or structure which normal maintenance fails to protect. Joints that are subject to the penetration of moisture are the most common failure points, and to rectify problems in this situation it may be essential to dismantle, conserve or repair, and then reassemble, as this may be the only method of achieving a satisfactory level of protection.

In the approach to the conservation of a ferrous metal cladding it is essential to consider the following good practices.

a) Retain as much existing material as possible - repair and consolidate rather than renew.

b) Use traditional materials and techniques.

c) Identify replacement items - unobtrusively but positively.

d) Use reversible processes whenever possible.

e) Record in detail before, during and after work.

When assessing the problem include the following:

a) Identify the sequence of original assembly.

b) Identify primary, secondary and decorative components.

c) Assess how the cladding and supporting structure are behaving at present.

d) Assess the condition of structure and cladding as a whole, and the condition of individual components.

e) Pay special attention to vulnerable areas such as connections to footings, fastenings, interlocking parts, water traps, bolts and rivets.

f) Check levels for structural movement. If settlement has occurred check the reaction of the structure and cladding to establish whether the components, joints or fastenings have failed.

2.6.1 Wrought Iron - repair

When the gauge is sufficiently heavy, most grades of wrought iron can be welded satisfactorily. The Welding Institute can carry out tests on iron samples to determine the best welding parameters and filler rod for the type of work to be undertaken. Rivets should not be replaced by welded joints, nor should welding be carried out in close proximity to rivets since distortion of the metal caused by the heat of the welding process may stress the rivet holes and form a gap. This destroys face friction within the rivet joint, and may allow water to penetrate by capillary action thus forming a trap for water.

Wrought iron can be successfully welded to steel and stainless steel although this may result in corrosion (see section 2.5.1.ii) Other Electrochemical Deterioration).

With wrought iron sheet it may be necessary to replace individual sheets. This creates problems, since for many years the only source of wrought iron has been recycled material. Whilst it may cost more to re-roll old wrought iron for a replacement sheet than to produce a replacement unit in carbon-steel, historical authenticity and durability, may make this worthwhile. Wrought iron sheets should not be replaced with mild steel since mild steel will accelerate the corrosion of any wrought iron in contact with it.

It must be borne in mind at all times that 'corrugated iron' is a generic name for all forms of corrugated wrought iron, corrugated carbon steel, and corrugated mild steel, and **tests must be carried out to establish the type of material being considered on each individual job.**

2.6.2 Carburized Iron - Carbon Steel

See section 2.6.1 *Wrought Iron - repair*

2.6.3 Mild Steel - repair

See section 2.6.1 *Wrought Iron - repair*

2.7 Surface Protection

Ferrous metals require to be protected from corrosion. In its simplest form the protective coat must prevent the atmosphere from coming in contact with bare metal since even the slightest amount of condensation combined with air will result in rust. In many instances a double or triple protection is employed, for example galvanising or tinning can be used to protect the ferrous metal, then paint is applied to protect the non-ferrous coating.

Metalwork in an external environment, or exposed to chemical fumes, must be carefully designed. This is not always easy to achieve, particularly in conservation work, where the original design and finish must be respected. This may conflict with the requirement that all welds should be ground smooth, pockets and crevices in the surface, which might trap water, must be avoided particularly in marine environments or in polluted areas or rural areas subjected to acid rain. It should be noted that the washings from trees such as oak and chestnut also contain acids which may be harmful.

A good protective system may seem expensive but provides an excellent base which, if well maintained, will last for a very long time. Any owner who accepts a poor specification for preparation, materials or application of the protective coating, simply to save on the initial cost, will find that not only are the maintenance costs considerably higher but also the protective coat may develop defects resulting in the destruction of the underlying metal.

It is important to follow the traditions of each region or

Illus 7 Sunnybrae Cottage, Pitlochry ©Bruce Walker.
A corrugated iron roof was used to overlay and protect the underlying thatch

the original paint colour scheme for the building being conserved. Gloss paints are often used and although these may appear harsh and unpleasantly shiny when first applied, they give good protection and soon weather to a more acceptable finish.

Whatever paint is used it should be applied thinly if the original profiles of the metal are to be appreciated. Thick, leathery, paint finishes not only blunt detail but also protect the work less well than properly applied paints. Freshly-applied thick paint tends to crack and blister in summer, and these cracks and blisters will eventually allow damp to enter and rust the metal beneath the paint.

2.7.1 Paint

Since very early times, paint has been used to protect iron from the effects of water and air. Initially it formed a simple barrier in the form of an impervious film between the iron and the elements. The main difficulty with paint application is to make sure that the resultant protective film is of even thickness and is free from flaws and blemishes. It was quickly understood that several thin coats gave a better result than one thick coat, since each thin coat had the opportunity to oxidise and set. During the nineteenth century various different qualities began to be recognised in the paints and gradually each coat, in a three or four coat paint system, developed a specific purpose. The priming coat can contain rust-inhibiting ingredients, the undercoats builds up the thickness of the protective film and the finishing coat provides the tough resilient external skin.

The problem with traditional paint systems is that the labour costs, plus the on-costs associated with safety factors and access to the work, greatly exceed the cost of the paint. Traditional paints have a comparatively short life span and any form of reduction in the preparation of the surface or quality of the paint system will be heavily penalised by reincurring these on-costs within a shorter period. Rather than contemplating any form of saving by skimping on preparation or using a cheaper type of paint, consideration should be given to improving the life span of the paint system by strict supervision of the preparation and painting contract, giving an extra coat of paint in traditional paint systems or even changing the specification completely to one of the new types of paint with a longer life span.

On the same theme, it makes sound economic sense to reinstate the surface of a paint film before it has deteriorated to the extent that it becomes necessary to remove the whole film and go through the complete exercise of preparation, priming and painting the ferrous metal. Paint systems that are monitored carefully and are reinstated prior to the deterioration of the undercoats and primer are much less expensive, and the additional thicknesses of paint should extend the lifespan of the system even further than that of the original surface, since the reinstated paint system will be considerably thicker. Applying fresh coats of paint on top of existing surfaces may also avoid problems in disposing of paint particles containing heavy metals.

Today a wide variety of paint systems is available for painting ferrous metals, and these go far beyond the abilities of traditional oil-based paint systems. These new paints can provide a superior protective layer, which, although not historically accurate, may provide longer lasting protection in particularly difficult environments.

But new types of paint systems should not be specified without a full analysis of the problems. These problems may not only be affected by the composition of the original ironwork but also by the existing protective system.

The analysis of existing paint layers on ironwork should be a part of any repainting programme. This is necessary since many of the paint systems currently available are incompatible with some of the earlier systems and it is essential to be aware of the chemical composition of all the underlying layers. Paint analysis of this type should be undertaken by a person with expertise in this field. Samples for microscopic examination should be carefully removed by scalpel from the most protected areas of the structure where a good representative sample of all the previous coatings may survive in a reasonably intact form and therefore yield full information to the sampler.

Ordinary ferrous metals are particularly difficult to protect from corrosion. The essentials to a good paint system are a very thorough preparation of surfaces to remove any corrosion that may be present, and a specially formulated paint system, including rust-inhibiting primer, followed by thick and impervious undercoats and finishing coats, all prepared and applied by a skilled operative in dry, dust free conditions.

As a general rule, painting should not be undertaken in the following conditions:

in wet, damp or misty conditions

where the surface is affected by condensation

on surfaces below 5° Centigrade

in direct sunlight

in dusty conditions

Good ventilation is required to dry paint and sometimes to remove noxious fumes.

Humid conditions delay the drying of many paint systems, particularly the traditional types, and the entrapment of moisture reduces adhesion, durability and the formation of a gloss finish.

Ideal conditions are seldom achieved on the building site and unfortunately, although possible in a factory, they are not always achieved there either due to dirt and bad practice.

Whatever paint system is adopted, the final results will depend on backing up a good specification with good practice and good supervision.

All paints require a binding agent to hold the pigment or rust inhibiting particles whilst at the same time forming a complete and uniform thickness of protective film over the ferrous metal to protect it from the elements, chemicals, salts and other impurities in the atmosphere. The materials selected for this binder are fundamental to the performance of the paint.

Linseed oil was possibly the most commonly-used binding agent in the nineteenth century. It was used in various forms described as raw, boiled, double-boiled and heat-treated, each providing a slightly different characteristic to the paint. With binding materials such as linseed oil the paint has to set between each successive coat. The coats then continue to harden, by oxidation, throughout the life of the paint. Towards the end of its useful life the binding agent becomes so brittle that breakdown is inevitable. Oil based paints only provide a low-to-medium life-span when compared with some of the late-twentieth century binders. Unfortunately not all the new binders are compatible with the early oil binders and, if applied over old paint, can react badly.

The individual layers of paint are normally described as:

a) The primer or priming coat.

b) The undercoat(s).

c) The finishing coat.

In ordinary mild, inland exposures, two priming coats and at least two further coats of air-drying paint with a minimum thickness of 0.125 mm are necessary.

In severe exposures, where heavy industrial pollution occurs or within two miles of the coast, no paint system will be effective unless applied in factory conditions on galvanised or zinc sprayed metal. Alternatively, vitreous enamelled or plastic coated metal may be used.

Mitchell's Buildings Construction: Components and Finishes (King and Everett: 1971, 346-363) gives detailed independent advice, as do the *BRS Digest 70 Painting Metals in Buildings - 1, Iron and Steel* and *CP2008: 1953 Protection of Iron and Steel Structures from Corrosion.*

Mitchell's Building Construction (King and Everett, 1971, 346) also gives a table outlining the performance of various paint types on a vertical surface. This is based on application in strict accordance with the manufacturer's instructions and the normally specified number of coats. A version of the above table, referring to paints for metal, is given below.

The shorter times given against the average life can be expected on south-facing facades or in severely polluted or marine environments. The average life is even shorter on backward sloping surfaces or where

Type of Coating	Background	Average Life
Long-oil alkyd-based paint system with suitable	ferrous metals	3 - 7 years
primers and undercoats	aluminium	3 - 8 years
Special protective paints eg. micaceous iron oxide aluminium coal-tar epoxy	steel - with thorough surface preparation	5 - 10 years
Thick PVC coatings	galvanised sheet	10 - 20 years
Thin PVF films	metals	
Vitreous enamel	steel cast iron aluminium	20 + years

preparation, materials and application techniques are poor.

When all of these life-reducing factors are found together one can understand the annual painting regime practised in many coastal and island communities.

2.7.1 i) The Priming Coat

The priming coat must be capable of adhering to the surface of the metal whether it be shiny or chemically aggressive. On metallic surfaces etching- and corrosion-inhibiting primers are important and their use may be considered to be more appropriate than the maintainance historical accuracy. Much will depend on the condition of the metal, the degree of exposure and the longevity required of the paint system.

On application, the priming coat should completely obliterate all sight of the original metal surface. If this is not possible in a single coat, apply two coats.

The priming coat in the nineteenth century would commonly contain one of the following:

2.7.1.i) (a) Red Lead: this is a bright orange oxide of lead. It has been in use as a protective pigment for over 2000 years and acts as a rust-inhibiting agent. Unfortunately, due to its high lead content removal or disturbance of this material has several health and environmental implications and must be treated with extreme caution. Despite this, it is still available for application to historic structures and is still one of the best rust-inhibiting substances available.

The Rural Industries Bureau (White, 1963, 94-5) recommended a mixture of red lead powder, japan gold size and pure turpentine as a reliable primer. This will dry quickly but will not crack. Properly mixed it dries matt and provides an excellent key to the next coat. The method of mixing recommended states that the japan size be added to the red lead powder until the mixture becomes as stiff as a very thick cream. It is then thinned gradually, using pure turpentine, to the consistency of thin cream and allowed to stand for one or two hours. It is then stirred vigorously, adding a little more turpentine as necessary. The paint should be stirred frequently as it is being applied. The primer should be applied so thinly that the colour of the metal shows through the first coat. The paint should be dry and ready for a second coat in three to six hours according to the temperature. This primer will not affect the profile or detail of the metal and will not readily chip or crack. No primer will be efficient if applied too thickly since it will bridge small pits and pores in the metal without entering them. Because of this characteristic it is preferable to apply two thin coats rather than one thick coat. The first coat must always be thin enough to fill all pores and crevices although it may not cover the surface of the metal opaquely.

2.7.1.i) (b) Zinc Dust: This came into general use as a rust inhibiting protective coating in the early nineteenth century but at that time had to overcome the reputation of red lead. Zinc has excellent rust-inhibiting qualities and this is now considered as one of the best protective coatings available.

Zinc-based paints are now available and these can be applied over rusty metal provided the rust is not loose, since the chemical reaction of the particles of zinc in the paint against the metal inhibits rust and prevents it developing between the paint and the metal. For this reason zinc paints are often described as 'cold galvanising' paints. Most oil-based finishing paints can be applied over zinc-based primers. There is at least one brand of zinc paint that can be applied to wet metal.

2.7.1.i) (c) Iron Oxide (Fe_2O_3): This is the most natural and stable form of iron and makes a reddish brown pigment. It enjoyed considerable popularity in the nineteenth century as a primer, although it had little rust-inhibiting effect. This may be due partially to its success as a preservative for wood, and partially to its colour which tends to disguise rust staining. Its lack of protective qualities for iron products was not fully appreciated at the time.

2.7.1.i) (d) Aluminium leafing paste: Some aluminium paints also make effective primers provided they are made from aluminium leafing paste. Unlike zinc paints, aluminium paints have no beneficial chemical action on any rust over which they are applied. Advice should be sought from the manufacturer or their agents before choosing a paint to cover an aluminium primer since some paints are manufactured with a base material which is detrimental to the medium binding the aluminium paint. If the finishing coats pick up the aluminium particles from the base coat, the whole job will be spoiled and the only way of rectifying the problem is to sand-blast back to bare metal and start again.

2.7.1.ii) Intermediate or Undercoat

The first undercoat should follow as soon as the primer has set. Like the primer, undercoats should provide obliteration. They should be compatible with, and adhere well to the primer and to each other. The undercoats should fill minute surface depressions and provide a good base for the finishing coat. Traditional paints require to be rubbed down between coats to obtain a key for the next coat. This is no longer necessary with paints containing synthetic ingredients but 'flatting' of undercoats, preferably 'wet' is necessary to obtain a first class finish. If in doubt consult the paint manufacturer rather than the painting contractor.

It is important to the production of an evenly-thicknessed film of paint that each succeeding coat should be easily distinguished. This highlights areas that have been missed or inadequately coated and helps both the painter and the supervisor. The colour of the last undercoat should however be near to, but lighter than, the finishing coat. This is due to the finishing coat often being less opaque than the undercoats since its primary function is to seal the surface from the elements, often by the production of a deep gloss finish, which is not always conductive to heavy pigmentation.

These are applied over linseed oil based primers to build up an evenly-thicknessed flexible coating over the metal. They normally vary in colour to make it easier for the painter to check that he has applied an evenly-thicknessed coat.

2.7.1.iii) Finishing Coat

The finishing coat forms the outer protection for the whole paint system against weather, chemical and mechanical damage and also determines the final colour and texture. The finishing coat is normally described as being: full gloss, semi-gloss, eggshell (lustre, satin, velvet or suede); flat or matt. Gloss paints reflect light directly and thus tend to accentuate the slightest irregularities in the surface. On the other hand they do not collect grime as readily as matt or textured paints and tend to give better protection.

This is applied over the intermediate coat(s) and normally contains an oil binder specifically designed to produce and maintain a deep gloss finish. The gloss finish is not absolutely necessary but it does add to the water repellent properties and to the effective life of the finishing coat.

2.7.2 Enamel

Vitreous enamel provides a tough, colourfast, easily cleaned, highly corrosion-resistant surface to ferrous metals. It is best suited to cast materials since sharp edges or corners tend to result in chipping or spalling of the surface. Vitreous enamel can only be applied in factory conditions. Enamel paints provide a similar surface and are applied in situ.

2.7.3 Pitch or Bitumen

Like red oxide, the use of pitch or bitumen as a preservative tends to come from the timber building tradition. Although pitch and bitumen are excellent water repellants their natural acidity causes metal to decay.

Their effective use on metal depends on their natural acidity being neutralised, usually by the addition of a proportion of lime.

When properly mixed with the correct proportion of lime they make a reasonably dependable coating for structures such as bridges and industrial premises.

Bitumastic paints developed from such a combination, and specific manufacturers have improved the basic mix to achieve remarkable results. Immediately prior to World War I, the German battle fleet had the bottoms of all its ships coated with Briggs Bitumastic Paint. William Briggs and Sons, the manufacturers of this paint, were based in Dundee. They continued in business until the 1960s when they were involved in a series of mergers and takeovers.

2.7.4 Galvanising

The galvanizing process is not a galvanic coupling of iron and zinc as was initially believed but the creation of an alloy of iron and zinc in an amalgam. Galvanizing involves dipping the cleaned object, to be galvanzsed, into a bath of molten zinc, with a flux to ensure that the object is evenly coated. The zinc forms a tenacious film of a zinc compound (oxide or carbonate) which hinders any further corrision. Even if the zinc is scratched the remaining zinc corrodes preferentially leaving the iron intact.

The effective life of a galvanised finish is difficult to predict. This is due to the range of variables combining to act upon its surface. The effective lifespan of a galvanised surface will depend on:

- The quality of the galvanising
- The type and quality of the ferrous metal
- The thickness of the sheet or plate
- The atmospheric conditions

Atmospheric conditions are extremely difficult to predict. In industrial conditions, particularly when there is a cocktail of chemicals in the atmosphere, galvanising will erode many times faster than in fresh country air. But in rural situations the surface of the galvanising may be subjected to acid rain or ammonia from animal urine condensing on the surface. Whatever the nature of the polluting chemicals, galvanising in humid conditions will not last as long as galvanising in dry conditions.

Particular care must be taken when there is a change of use or a change in the heating system since this may result in increased condensation on the surface of the metal in areas that are not generally seen.

When galvanizing begins to show signs of deterioration it is good practice to introduce a secondary protection system (such as paint) immediately, and to follow this up with a regular painting programme. The alternative is to dismantle the elements and have these re-galvanized in factory conditions.

See BS 2989: 1967 *Hot-dipped galvanised plain steel sheet and coil* and BS 3083: 1959 *Hot-dipped galvanized corrugated steel sheets for general purposes.*

The Engineers and Architects Guide to Hot Dip Galvanizing published by the Galvanizers Association provides authoritative information and advice on hot-dip galvanizing and its uses. Their telephone service line gives immediate answers to queries about the subject. They also monitor regulations and take a leading role in standards development and overseas research projects to support and develop the industry. P35 of the Guide also gives a worldwide list of Zinc and Galvanizing Associations.

2.7.5 Tin Plating

Tin (Sn) plated ferrous metals were in existence long before galvanising was perfected, although the practice tended towards domestic utensils rather than cladding. Some of the early galvanising firms tinned ferrous metal sheets before galvanising to improve the effectiveness of the product.

2.7.6 Other Metallic Coatings

Zinc is the metal used most extensively to protect ferrous surfaces from corrosion. The reason for this is that zinc is electropositive to ferrous metals and even if the coating is penetrated the zinc will deteriorate, due to electrochemical action, rather than the ferrous metal.

Coatings of other metals such as lead, tin, copper and nickel, all electro-negative to ferrous metals, when penetrated will add to the corrosion process through electrochemical action, causing the ferrous metal to corrode faster than if it were unprotected (see section 2.5.1.ii)).

Magnesium, aluminium and cadmium are all electro-positive to ferrous metals and theoretically can be used as alternatives to zinc.

Zinc-galvanizing is the commonest method of protection (see section 2.7.4). The technique is rapid, ensures a considerable thickness of zinc, and is comparatively inexpensive. The disadvantages are that the coating is not alloyed or amalgamated with the surface, that the sal-ammoniac used as a flux tends to help start corrosion, and that paint does not adhere well to the galvanized surface.

Metal coatings can be applied to ferrous surfaces in a number of ways. These include:

- Cladding
- Electroplating
- Hot-Dipping (Galvanizing)
- Spraying
- Sherardizing

i) Cladding

A thin coating of one metal such as aluminium, brass or nickel can be hot rolled onto a stronger, less durable and cheaper base such as iron or steel, so that a degree of alloying occurs at the interface.

ii) Electroplating

The ferrous metal forms a cathode in a bath and the non ferrous metal is deposited on it either from a reactive anode or from the electrolyte. A very accurate and uniform thickness of non-ferrous metal can be applied without any loss to the metal being plated.

The process is not economical for thick coatings, and coatings of zinc on ferrous metal are thinner than those of the galvanizing process. The normal electroplating thickness is from 0.01 to 0.03mm.

The coatings can also be applied to one side only if required.

See BS1706: 1960 *Electroplated Coatings of Cadmium and Zinc on Iron and Steel.*

Aluminium, cadmium, tin and zinc coatings on steel have the advantage that parts can be formed after being plated without damage to the coating.

iii) Spraying

A compressed-air gun is used to spray atomised metal onto the surface to be protected. The atomised metal is produced by heating aluminium or zinc, powder or wire, using either an electric arc or a gas flame.

Adhesion of the atomised metal is mainly mechanical and it is therefore desirable to roughen the surface of the ferrous metal beforehand by shot-blasting.

A skilled operator can achieve an even matt finish of a thickness suitable for painting, or a greater thickness for grinding and polishing.

iv) Sherardizing

Sherardizing, or vapour galvanizing consists of placing the ferrous metal in zinc dust or powder in a closed receptacle and heating for several hours at a temperature of several hundred degrees below that employed for the molten zinc process.

The zinc coating is evenly distributed and is amalgamated with the surface. The resultant surface is excellent for painting.

v) Oxide Conversion

As metals corrode they form layers of corrosion products. The stability of these corrosion products can protect the underlying metal against further corrosion if the layer is stable and uniform. This material is normally referred to as 'patina'.

The late-nineteenth century saw a number of experiments with the thermal oxidation of ferrous metals to produce so-called 'rustless coatings'. These coatings comprise stable oxidation films formed directly on the surface of the ferrous metal as an integral component.

Such a process was made commercially viable by Professor Frederick Barff, at Kilburn in 1877. Barff used a special oven or furnace to heat the metal to a dull or bright red heat thus producing red oxide (Fe_2O_3) on the surface. The heat was then maintained whilst superheated steam was introduced to convert the red oxide to magnetite (Fe_3O_4) and wustite (FeO).

George and Anthony Bower, St Neots took up the idea, but determined to convert all the red oxide to magnetite. They experimented with air as a substitute for steam but were unsuccessful. Ultimately they used producer gas, a mixture of hydrogen and carbon monoxide.

The coating is achievable in a range of hues from brown to blue-black, and in a range of thicknesses. It was extremely successful as an internal finish, as a self-colour or highlighted by polishing some of the metal prior to the process to produce steel-blue colours and by gilding parts of the surface.

2.7.7 Oils and Varnishes

The use of clear oils, waxes and varnishes to protect ironwork tends to be restricted to indoor use although it was used on some utensils intended for outdoor use.

Clean iron is coated in linseed oil, heated and wiped over with an emery cloth. A mixture of beeswax and boiled linseed oil is then rubbed into the surface.

An alternative treatment is to apply varnish or shellac to the clean iron. Goose fat and lamp black is another treatment traditionally used for door furniture.

2.8 Surface Preparation

Surface preparation of ferrous metals is extremely important and should be closely monitored. Fancutt and Hudson have shown that the life of a paint system can be increased by up to five times by thorough surface preparation.

Many claims have been made regarding the effectiveness of primers designed either to penetrate or react with rust to nullify its effects. Materials of this type should only be used by skilled conservators who are fully aware of the composition of the ferrous metal being treated and the chemical implications of the application for both the base metal and the paint system. For normal conservation work it is advised that the primer be applied to bright metal even although this may have a serious impact on the conservation procedures.

Various chemical processes can be used on iron that has not left the factory, but on an existing roof the sheets must either be removed for work by the conservator or must be prepared by chipping, wire brushing and polishing with an emery cloth. Pieces of loose scale left on the iron will, sooner or later, crack the protective skin. Mill scale which is not loose need only be removed for a bright metal finish: this is seldom associated with corrugated or profiled iron sheeting. Any rust on the iron must also be removed. There are several reliable brands of de-rusting fluid on the market and these are constantly improving. It is essential to have important ironwork examined by a metal conservator and to follow the advice given. The main agent in most derusting fluids is phosphoric acid, which converts rust that survives after wire brushing into a grey deposit of iron phosphate. The metal can usually be painted without further treatment but it must be stressed that the paint manufacturers' instructions must be followed at all times.

2.8.1 Grease

Before starting any other preparation it is essential to remove any oil or grease that might be contaminating the surface of the metal or any intermediate paint surface. Should any oil or grease be left, subsequent preparation may well spread the contamination over wider surfaces.

Large quantities can be scraped off the surface, taking care to scrape the outer edges of the contamination towards the centre to prevent its spreading.

Small quantities of grease, or the residue from large quantities, are more difficult to deal with since it is important that all trace of the contaminant be removed. Whenever possible, final degreasing should be carried out in factory conditions by operatives skilled in this process. On-site, clean swabs soaked in white spirit should be used. It is essential that the swabs be changed frequently to reduce the risk of spreading the grease to other surfaces.

Non-caustic degreasing agents are also available but these should only be used under the direction of a skilled conservator or with the prior agreement and approval of the paint manufacturer.

2.8.2 Mill Scale

Mill scale and tightly-adhering rust on a pitted surface can only be completely removed by acid-pickling in a factory or by grit- or shot-blasting (BS 4232: 1967).

When considering the course of action to be followed it must be remembered that grit or shot blasting can only reach exposed surfaces, and thus if there is corrosion in the joints between components it is essential to dismantle to provide access and allow the concealed surfaces to be treated.

Less-serious mill scale, rust or old paint can be removed in a number of different ways. These include:

i) Hand tool abrasion

ii) Power tool abrasion

iii) Flame Cleaning followed by brushing

iv) Pickling Jellies or Pastes.

i) Hand tool abrasion

The simplest form of surface preparation for ferrous metal involves a combination of chipping, scraping and brushing with hand-held tools. This is labour-intensive and although a surface prepared in this way may be bright or clean it may only have removed as little as thirty per cent of the mill scale and rust.

The use of hand tools may also result in the scoring of the surface and a loss of detail. However, the use of hand tools can be of considerable assistance in the first stage inspection since they can used on heavily-corroded components to clear corrosion deposits and allow the conservator to make informed judgements on a course of action.

Hand tools are also useful in areas where more sophisticated methods are not available.

ii) Power tool abrasion

Power tools for surface cleaning take a number of forms. The simpler tools such as grinders and rotary wire brushes only provide a marginal improvement over the results obtainable by hand tools, and rust and other deposits lodged in a pitted surface or in crevices are rarely removed.

Tools such as needle-guns break up mill scale and rust by the impact of a head of iron needles. These are more successful since they can reach into awkward corners and angles inaccessible to other equipment.

iii) Flame-cleaning followed by brushing

This involves the use of either oxyacetylene, propane or butane gas burners. It should be noted that a standard painter's blowlamp is insufficient for this process.

An oxyacetylene or oxypropane flame is passed across the iron. This causes both mill scale and rust to detach from the main body of the ferrous metal as a result of differential thermal movement. Immediately after the application of the flame, the loose mill scale, rust and remaining dust is removed by wire brushing.

Flame-cleaning provides a high level of cleanliness from paint, loose mill scale and rust. It is the most appropriate methods of cleaning wrought iron. Unfortunately, on larger iron structures it can be a relatively slow process.

The main advantage of this method is that it allows wrought iron structures to be examined carefully during the cleaning process. It is also very effective in removing loose scale, rust and other contaminants from localised areas such as water traps and inaccessible areas.

Wrought iron sections of less than 2mm thickness may warp during flame-cleaning unless the work is carried out very carefully.

The equipment is mobile and can be taken on site. It can be used in relatively wet conditions and helps to dry the surface.

A major disadvantage is that the method is a fire hazard. It can also cause unbonded scale and other materials to fuse to the surface of the metal if the flame is traversed too slowly.

Flame-cleaning is often used to ‘flash clean’ a ferrous surface to remove corrosion occurring after cleaning and prior to priming. It can also be used to create a dry surface for priming on areas which form water traps.

iv) Acid Pickling - Jellies or Pastes

Ideally acid pickling should be carried out in factory conditions - see item 2.8.6.

Various acid jellies or pastes can be used on site but only in very carefully controlled situations. It is extremely important to follow the manufacturers instructions and have the work carried out under strict supervision.

2.8.3 Old Paint

All existing paint which is loose, perished or flaking must be removed as part of the preparation process.

Sound, hard and firmly adhering paint that is known to be of the conventional drying-oil paint type may be left in situ unless a sophisticated modern paint system is to be applied. If in doubt, consult the manufacturer of the paint system to be applied.

Unless a change in paint system is proposed, sound paint surfaces may simply be rubbed down and refinished with one or two suitable coats.

Rubbing down should remove residual gloss from the top coat, as well as surface deposits and blemishes.

Damaged paintwork can be similarly rubbed down, ensuring that all loose paint is removed and that the surface under adjoining paint is free from corrosion. Locally-damaged paint areas should be rubbed down to a feather edge, but it can be difficult to achieve a visually-acceptable repair in situations where the chips have been removed from paint that has had many continuous layers.

New paint coatings must be compatible with those existing and should overlap the edges of any rubbed down chips by at least 50mm.

Thixotropic paint-strippers containing methylene chloride can be used to remove small areas of existing paint. Residues must be removed using white spirit or water as appropriate.

Flame-cleaning and hot-air blowers are also effective paint-removers - see item 2.7.2.3. They must be used with care on thin sections of metal since they can cause thermal stresses due to localised overheating.

2.8.4 Rust

Rust must be removed from the surface of the metal prior to the application of any form of protective coating. Very small amounts of rust can be treated with a rust-converter, but it is preferable to use the rust-converter as a back-up to other cleaning methods rather then to rely on it entirely. Any rust that remains after either cleaning or conversion will continue to corrode under the new paint system causing its eventual failure.

2.8.5 Soluble Salts

Water-soluble salts such as ferrous sulphate and ferrous chloride must be removed from pitted areas of the ferrous metal surface.

Tests for these corrosive soluble salts should be carries out on ferrous metal in marine or industrial environments both after cleaning and immediately prior to painting. A simple and effective method of carrying out this test is to use blotting paper dipped in a ten per cent solution of potassium ferricyanide (BS 5493). The dried strips of blotting paper are applied to a dampened surface and will change colour if soluble ferrous salts are present.

2.8.6 Acid-pickling

The acid-pickling technique works on the principle that a warm dilute acid will remove mill scale and rust before there is any risk to the surface of the sound ferrous metal.

The component is normally immersed in the solution. A dilute phosphoric acid solution has the advantage that it not only removes mill scale and rust but its reaction with the iron results in a protective layer of phosphates forming on the surface. These are known as anodic inhibitors. Dilute sulphuric acid is also commonly used. Hydrochloric acid and sodium hydroxide (caustic soda) should not be used since they deposit corrosive soluble salts - see item 2.8.5.

Acid-pickling must be carefully controlled to prevent damage to the sound metal. This makes it essentially a factory process. Before commissioning any acid pickling work it should be established that the company undertaking the work have sufficiently large pickling baths to accommodate the largest components being treated.

Site application of acid washes is not recommended - see 2.8.2.iv) above.

Various acid jellies and pastes (usually containing phosphoric acid) can be used on site but only in very carefully controlled situations. It is extremely important to follow the manufacturers' instructions and have the work carried out under strict supervision.

2.8.7 Dry Abrasion

Dry abrasive-cleaning is carried out by the impact of airborne abrasive particles on the surface of the metal. The impact of these particles tends to remove rust and loose mill scale but it also tends to change the character of the surface of the metal. Highly-skilled operators can often produce a satisfactory result but the metal will tend to lose its original cast, milled or wrought surface leaving a clean but roughened surface in its place. This makes it a questionable technique for conservation work.

Should this technique be considered it is essential to obtain the services of highly skilled operatives. Experiments should then be carried out to establish the right grits and the correct air pressure. It is advisable to start at a pressure of 6KPa with a fine grit, usually a copper slag. A satisfactory cleaning pressure is unlikely to exceed 8-10KPa.

Dry abrasive-cleaning produces considerable amounts of dust and debris on the surface of the iron. These must be removed prior to painting, preferably by vacuum cleaning.

The quality of the cleaned surface is usually specified in terms of surface cleanliness and surface roughness as laid down in BS 4232 and SIS 055900. These specifications are applicable to steel and they must be carefully interpreted and adapted before being applied to cast or wrought iron.

It should be noted that

(i) care must be taken to mask all surrounding surfaces

(ii) dislodged caulking must be replaced

(iii) operatives must be adequately protected

(iv) debris, dust and spent abrasive must be dealt with properly to avoid environmental pollution and

(v) wrought iron may be too soft for some of the more aggressive abrasive-cleaning treatments - use soft abrasives at low pressures.

2.8.8 Wet Abrasion

Wet abrasive-cleaning has many advantages over dry abrasive-cleaning. The wetness, which at first glance appears to be a recipe for corrosion, is especially useful in dealing with lead-based paints since it eliminates the harmful dust problem - see item 2.8.3. It is also useful in washing soluble corrosive salts from pitted surfaces - see item 2.8.5.

The equipment should be fitted with a nozzle which has independent control over abrasive, air and water. This is necessary to allow the operator to adjust the jet to suit different circumstances such as the removal of debris, being able to see the work surface, cleaning out crevices and ledges, and the removal of excess water.

The main disadvantage is unwanted water penetration at joints and junctions.

It should be noted that

(i) the technique is particularly suitable for cleaning ferrous surfaces in marine or polluted atmospheres

(ii) care must be taken to mask all surrounding surfaces

(iii) dislodged caulking must be replaced

(iv) operatives must be adequately protected and

(v) debris, slurry and spent abrasive run-off must be dealt with properly to avoid environmental pollution.

2.8.9 Mechanical Abrasion

See items 2.8.2.i) Hand Tool Abrasion and
2.8.2.ii) Power Tool Abrasion

2.8.10 Flame Cleaning

See item 2.8.2.iii) above

2.8.11 Rust Removal Solutions

Orthophosphoric acid is the basis for many proprietary rust removal systems.

Solutions which are described as being chemically neutral are based on a combination of acid and alkali material.

As with acid-pickling, the best results are normally obtained by immersion in the solution under factory conditions. Several solutions are available in gel form but the same care should be exercised with these as with acid pickling jellies and pastes - see item 2.8.2.4.

2.8.12 Re-rusting

Rust can begin to develop on freshly-cleaned ferrous metal surfaces within a few hours.

Where flame-cleaning or dry abrasive cleaning is adopted, the primer should be applied immediately the cleaning process is completed. If this is not possible the surface should be flash-cleaned immediately prior to painting to remove any particles of rust that may have formed in the intervening period.

After wet abrasive cleaning (which is necessary when materials such as red lead are being removed), a ferrous surface will re-rust relatively quickly due to the combination of the wet surface and the drying air. A rust inhibitor can be included in the final wash but this creates its own dangers. The amount of inhibitor incorporated in the wash is crucial, usually not more than 5000 ppm, because any excess will cause a deposit of salts which in turn will cause the paint to peel. Unfortunately, inexperienced operatives are often inclined to 'put in a little extra' to ensure there is no re-rusting, to the long-term detriment of the paint system.

3.0 COMPONENTS

Good design is an essential feature of any building, and good design in a corrugated iron building relies heavily on good detailing. Generally, conservation of historic structures is based on 'like for like' renewal but, when existing buildings are changing use as part of the conservation process, new requirements can be introduced into the equation which may demand underlying changes particularly in concealed details.

British Standard Code of Practice CP 143 Part 2 'Sheet Roof and Wall Coverings - Galvanized Corrugated Steel' can be used as a sound design guide.

When the conservation ethics for the building under consideration and the BS Code of Practice are in conflict it is essential to collect all available evidence and present this to the appropriate conservation authority at the earliest possible date. This allows decisions to be reached which at worst might mean the abandonment of the project owing to the lack of compatibility between the needs of the historic structure and the requirements of the future occupiers. But consultation at an early stage may at least prevent unnecessary work and frustration.

3.1 Roofing and Cladding

Iron or steel roofing and cladding, as manufactured and supplied by British ironfounders, take a number of different forms. These can be sub-divided into five principal categories - Plate Iron, Sheet Iron, Corrugated Sheet, Galvanized Iron Tiles and Buckled Plate.

3.1.1 Plate Iron

A plate is defined as an even-thickness, rigid or semi-rigid metal component capable of spanning between frames or purlins to which it may be bolted, riveted, screwed or welded.

Plate iron roofs and cladding can be formed in cast or wrought iron or steel, and tend to be designed for a specific function or particular application rather than being mass-produced speculatively. They therefore vary considerably in thickness and detail, particularly in the expression of the joints between the plates. These can be either extremely simple or elaborately moulded, especially when plates are cast with the intention of looking like carved masonry.

Illus 8 The Steading, Torosay Castle ©Bruce Walker. The use of profiled cladding sheets

Sheet metal components are normally specific to a particular building, designer or manufacturer, and consequently there are few general rules that might be applicable. The exception is corrugated sheet which became so universal that a degree of standardisation inevitably followed.

Thickness, detail and moulding aside, there are seven main methods of jointing plate metal, the butt joint; butt joint and cover strap; lapped joint; stepped lapped joint; stepped lapped and keyed joint; flanged butt joint; and welded butt joint.

i) Butt Joint

The sheets may be simply butt-jointed against the face of the structural or constructional frame. The fixing bolts, screws or rivets pass through the edges of the plate and into or through the frame.

ii) Butt Joint and Cover Strap

Here the cover strap serves as both a link between the plates and a cover to the joint. The fixing screws, bolts, or rivets can pass directly through both strap and plate or can be fixed to the back of the strap before application to form a type of concealed fixing secured from inside the building.

iii) Lapped Joint

Here the edges of the plate are allowed to overlap and the two plates are then secured by bolts, rivets or screws.

iv) Stepped Lapped Joint

This involves preforming the sheet to form along the edge of the plate a small step, that is intended to lap the other plate. The additional work involved is offset by the benefit of both plates being in close contact with the face of the structural frame.

v) Stepped Lapped and Keyed Joint

This is possibly the best form of joint for cast iron plates since it is relatively easy to form in that material and has the benefit of drainage channels within the joint to conduct any water that does penetrate back to the exterior.

vi) Flanged Butt Joint

This is one of the most secure ways of forming a butt joint, particularly in cast iron since additional secondary flanges can be formed at right angles to the main flange to strengthen the material especially to either side of the fixings.

vii) Welded Butt Joint

This is not an option with cast or wrought iron but rather is usually associated with mild steel. The strength and effectiveness of the joint depends on the quality of the weld between the two plates.

3.1.2 Sheet Iron

A sheet in this context is a flexible metal component of even thickness, capable of spanning short distances but better suited to being backed and supported on continuous boarding to which it may be bolted, nailed or screwed.

Sheet iron was supplied in either semi-rigid or flexible forms depending on the gauge. The thicker gauges

Illus 9 Houses in Dundee, Angus ©Bruce Walker. The use of sheet metal walling panels

were supplied flat whilst the thinner gauges were rolled in what was called a 'continuous' roll of 9 feet sheets, providing a total length of 25 yards (22.5m). The sheets were annealed, pickled and edged prior to packing and the packing for the rolls comprised an iron keg. The sheets were rolled into a cylinder before being placed in the keg, and sufficient one-inch (25mm) flat-headed galvanized iron slating nails were included in the core of the sheeting to secure the sheets to the roof. Continuous rolls were made in twenty-four and thirty inch (600mm and 750mm) widths and in six to nine foot (1800mm and 2700mm) lengths.

Continuous roofing sheets were manufactures in three gauges of iron. The thirty-one gauge metal was only available in twenty-four inch (600mm) widths whilst the twenty-six and twenty-eight gauge metal could be in either twenty-four or thirty inch (600mm or 750mm) widths.

3.1.3 Corrugated Sheet

Corrugated Sheet is sheet metal fluted in one direction to create stiffness in that direction, thereby allowing increased spans between frames or purlins. Corrugated sheet can be bolted, nailed, screwed or spiked to a frame or purlin.

Corrugated sheet manufactured in Britain tended to follow the rule that the depth of the corrugations should be one quarter of the pitch: the depth being the distance from ridge to trough, and the pitch being the distance from ridge to ridge. Although this was a general rule it was not until the late nineteenth-century that English manufacturers agreed to standardise the pitches to allow various manufacturers' sheets to be interchangeable. The pitch sizes agreed for wave profile iron were 1, 2, 2½, 3, 4, 5, 6 and 9½ inches but many manufacturers still offered a wider range and varying depths of profile.

Various manufacturers continued to produce non-standard sheets in addition to the agreed range of standard profiles.

i) Size of Sheets

Corrugated sheets can be obtained in multiples of one foot length (300mm). Traditionally the lengths varied from four to ten feet (1.2m – 3m). Twelve feet (3.6m) lengths were occasionally made in the late-nineteenth century but these were criticized for failing to hold the profile after manufacture. Longer lengths are now available but should only be used where there are compelling reasons to depart from the original sheet pattern.

Special lengths, within the four to twelve feet (1.2m – 3.6m) range, are available to special order and at additional cost.

ii) Gauge of Metal

Sheets vary in thickness from No 16 to No 26 BWG (British Wire Gauge) (1.6mm – 0.5 mm). In exceptional circumstances, and only for use on a very temporary structure, the gauge may be dropped to No 28 BWG (0.4mm). Generally, replacement sheets should match those already on the roof or walls.

iii) Pitch

The pitch of corrugations normally available varies from two inches (50mm) in light sheets to six inches (150mm) in heavy sheets. One inch (25mm) and one-and-a-half inch (37mm) pitches were available from some manufacturers such as John Lysagh Ltd, St Vincent's Iron Works, Bristol: Orb Iron Works, Newport, Monmouthshire: Swan Gorden Iron Works, Wolverhampton: and Osier Bed Iron Works, Wolverhampton.

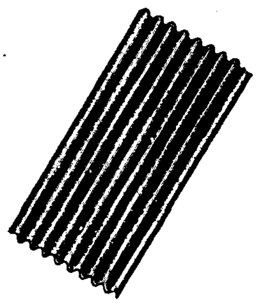
For most domestic purposes the three inch (76mm) pitch was accepted as standard. This gives a depth from crest to valley of 3/4 inch (19mm). Industrial applications occasionally use a five inch (125mm) pitch with a corrugation depth of 1¼ inches (32mm). This was also quite common in structures exported before the 1870s.

The standard pitches of corrugation are 1, 1½, 2, 2½, 3, 4, 5 and 6 inches (25, 38, 50, 63, 76, 102, 127 and 153mm). Pitches between 1 inch (25mm) and 4 (102mm) inches are normally made to cover a 2 feet (600mm) width. The 5 and 6 inch (127 and 153mm) pitches cover 2 feet 6 inches (750mm) but variants were available on the 3 inch (76mm) and 5 inch (127mm) pitches covering 2 feet 6 inches (750mm) and 2 feet 1 inch (625mm) respectively.

The dimensions given are normal and even at the end of the nineteenth century, after the major manufacturers had completely standardised their corrugation profiles, smaller manufacturers were still not completely integrated. Davies (1899) points out that a variation of one-sixteenth of an inch (1.5 mm) in pitch results in a half-inch (12mm) variation in sheet width and a resultant 25 inch (625mm) variation over 50 feet (15m) of roofing.

Unfortunately it is impossible to check all the manufacturers' catalogues of the period, for variations on these standards. This is partly due to the low survival rate and partly to the reluctance of many holding institutions or individuals to lend or copy.

HIGH-GRADE GALVANIZED CORRUGATED SHEETS.



THE life of a Galvanized Sheet depends upon the coating of zinc or galvanizing. Hence it is real economy to use High-grade Galvanized Sheets.

Our Sheets answer this description and we give the galvanizing of the Sheets our special care. All Sheets are well coated with zinc.

Having our own Rolling Mills and Galvanizing Plant we can regulate the quality from raw material to finished product ; the result is that our Sheets ARE WITHOUT A SUPERIOR ON THE MARKET.

We have the largest variety of corrugations and can produce sheets to suit any requirement.

Lengths, 4′ to 12′. **Widths,** 1′ to 4′. **Gauges,** 12 to 30 gauge.

Can be supplied Curved to any radius.

THE "BRABY" QUALITY MEANS LONGER LIFE.

Braby's "Sun" Brand=Very Best Double-Coated.

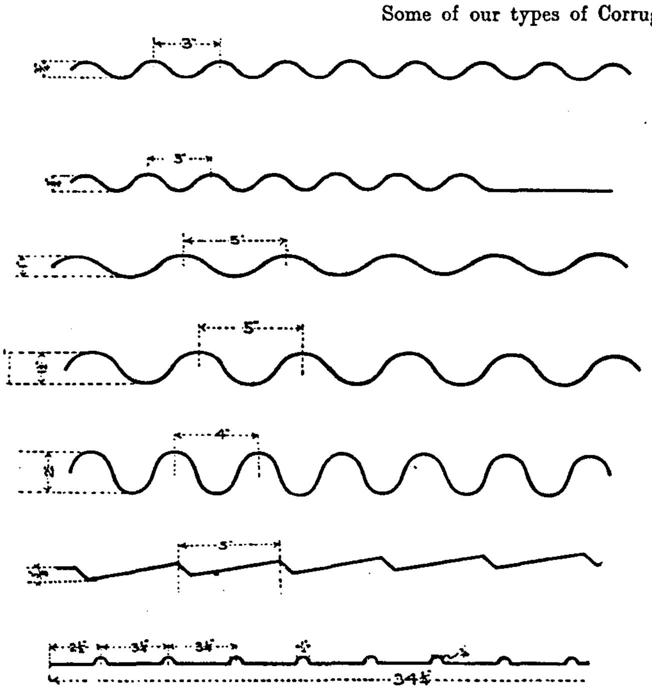
Braby's "Empress" Brand=Extra Heavily Coated.

Braby's "Eclipse" Brand=Extra Coated : Specially Selected.

Braby's "Castle" Brand=Good Ordinary Quality : Prime Sheets.

Braby's "Voxol" Brand=Good Ordinary Quality : Ex Liverpool Stock. VOXOL

Some of our types of Corrugation.



Corrugations.

Ordinary 3″ × $\frac{3}{4}$″ deep. Can also supply 3″ × 1″ deep ; 2$\frac{1}{2}$″ × $\frac{5}{8}$″ deep ; 2″ × $\frac{3}{8}$″ deep ; 2″ × $\frac{1}{2}$″ deep ; 1$\frac{1}{4}$″ × $\frac{1}{2}$″ deep ; 1$\frac{1}{4}$″ × $\frac{5}{16}$″ deep ; 30 m/m × 15 m/m deep.

3″ × $\frac{3}{4}$″ deep, but with flat edge.

5″ × 1″ deep.

5″ × 1$\frac{1}{2}$″ deep.

4″ × 2″ deep.

Weatherboard or Step Type, 5″ × $\frac{5}{8}$″

Small ribbed type, $\frac{1}{2}$″ × $\frac{3}{16}$″, 3$\frac{1}{2}$″ apart ; for ceilings.

Illus 10 Galvanised corrugated iron profiles from Messers Braby's Catalogue

For identification purposes the following table may be useful:

PITCH		DEPTH		CORRUGATIONS	WIDTH of COVER SHEET	
inches	mm	inches	mm	per sheet	inches	mm
1	25	1/4	6	24	24	600
1 1/2	38	3/8	9	16	24	600
2	50	1/2	13	12	24	600
2 1/2	63	5/8	16	12	30	750
3	76	3/4	18	10	30	750
3	76	3/4	18	8	24	600
4	102	1	25	6	24	600
5	127	1 1/4	31	6	30	750
5	127	1 1/4	31	5	25	625
6	153	1 1/2	38	5	30	750

iv) Lap

The customary lap of an end-to-end joint is six inches (150mm).

The normal side lap is a single corrugation although some manufacturers recommend 1 1/2 or 2 corrugation laps to increase waterproofness and stiffness. The increased lap often proves to be detrimental, particularly on coastal sites, as it forms an inaccessible area in which salt from spray may be deposited thereby accelerating the breakdown of the galvanised surface and the subsequent rusting of the iron.

A single corrugation side-lap, used in conjunction with an approved sealant along the crest of the side corrugation, provides the most waterproof joint. Should additional stiffness be required it is recommended to reduce the gauge and thus use a heavier sheet.

v) Weight

The approximate weight of a galvanised corrugated iron sheet with eight 3 inch (76mm) corrugations - to cover two feet (600mm) width when fixed is:

	5	**6**	**7**	**8**	**9**	**10feet long**
	1.5	1.8	2.1	2.4	2.7	3.0m long
26 gauge	**9.7**	**11.5**	**13.4**	**15.4**	**17.1**	**19.3 lbs**
0.5mm	4.4	5.2	6.1	7.0	7.8	8.8kg
24 gauge	**13.4**	**15.8**	**18.4**	**21.5**	**24.1**	**26.6 lbs**
0.6mm	6.1	7.2	8.3	9.8	10.9	12.1kg
22 gauge	**16.1**	**19.5**	**23.4**	**26.4**	**29.5**	**33.3 lbs**
0.8mm	7.3	8.8	10.6	12.0	13.4	15.1kg
20 gauge	**19.2**	**22.9**	**26.4**	**30.7**	**34.5**	**38.7 lbs**
1mm	8.7	10.4	12.0	13.9	15.6	17.6kg

The approximate number of similar type sheets per tonne is:

	5	6	7	8	9	10 feet long	
	1.5	1.8	2.1	2.4	2.7	3.0m long	
26 gauge	231	196	167	146	131	116	**0.5mm**
24 gauge	167	142	122	104	93	84	**0.6mm**
22 gauge	139	115	96	85	76	67	**0.8mm**
20 gauge	117	98	85	73	65	58	**1.0mm**

The range of variations in profiles is limitless and this can be illustrated by a group of profiles collected in the 15th Arrondissement of Paris in June 1998. These are quite different from the British profiles and give the surface an entirely different character, particularly when the sharply angled types are used. It should be noted that these particular patterns can also be found in aluminium and plastic.

Virtually all standard-profiled sheets can be curved longitudinally with a single or double radius or bent to one or more angles.

3.1.4 Galvanised Iron Tiles

These are flat sheets of galvanised metal with a roll of corrugation on each side and four semi-circular ribs in the centre. They are made up from flat sheets by pressing them between two dies which can be fixed to the corrugation machine. They are made from a sheet of galvanised metal large enough to make two tiles which are cut through after galvanising.

The roll on one side of the tile is slightly bolder than the other, and this ensures their being laid equally.

The larger roll is pierced by three holes. The price in 1899 was five shillings (25p) per ton over that of galvanised corrugated sheets.

Galvanised iron tiles were packed in skeleton cases.

The main market was in the West Indies.

3.1.4.(i) size

The size of the finished titles is 36 inches (900mm) by 24 inches (600mm).

3.1.4.(ii) Gauge

The tiles can be manufactured in any of the standard gauges used for corrugated iron sheets, 24 gauge (0.6mm) being the norm.

3.1.5 Buckled Plate

Buckled Plate is plate metal embossed in two or more directions to increase the stiffness of the plate.

3.2 Fixings and Flashings Components

Modern fixings and flashing components are set out in the trade literature issued by the principal manufacturers (see Appendix B).

Many fixing companies are capable of producing purpose- made flashings, and should be able to replicate most of the pressed metal types. Cast iron components would have to be specially cast.

3.3 Sealing Methods

Many traditional roofs relied entirely on a dry lapped joint between sheets. This often caused problems and various methods were tried to achieve a sealed joint.

Hayes Cladding Systems Ltd (formerly Bio Hove Ltd
Brindle Road (off Hadfield Road)
Cardiff CF 11 8TL
Tel 02920226088
www.haysengineering.co.uk
info@haysengineering.co.uk

Many of these were unsuccessful and resulted in damage at the lap. Sealants have improved significantly in the recent past, and modern practice is as set out in RCI Technical Note 52 (Roberts 1996).

Illus 11 Rosemay Cart Shed, Midlothian. © Ingval Maxwell

4.0 ON-SITE RECORDING

4.1 Basic Information

It is useful to collect the basic information on a special card or printed form which can be used as a check list on completion of the survey to ensure that all available information has been collected or identified.

The information should include:

i) *County or City*

ii) *Parish or Town*

iii) *OS Grid Reference*

iv) *Postal address including postcode*

In remote situations it may be necessary to give a brief description as to how to get to the site, linked to national road numbers, distance to nearest prominent feature such as church, village or crossroads, and so on.

v) *Personnel involved*

vi) *Date of Survey*

vii) *Film number or image file reference*

viii) *Persons interviewed*

- Possible source of records
- Owner
- Tenant

ix) *Brief description of building or structure*

x) *Orientation*

xi) *Degree of exposure*

xii) *Uses - present, recent, past*

xiii) *Materials - roof*
- *walls*
- *floors*
- *foundations*
- *doors*
- *windows*
- *shutters*
- *verandah*
- *ventilators*
- *chimneys*

xiv) *Condition*

xv) *Finishes*

xvi) *Colour - present, previous*

xvii) *Repeat sections xiii-xvi for interior*

xviii) *Wall filling*

xix) *Account of known history*

xx) *Manufacturer's name - nameplate may be attached to the structure (if so, identify location)*

xxi) *Type of corrugated sheet*
- *gauge*
- *profile*
- *pitch of corrugations*

4.02 Detailed information

i) *Measured survey*

ii) *Detailed description of basic structure*

iii) *Detailed description of jointing system for basic structure*

iv) *Detailed description of construction*

v) *Detailed description of materials*

vi) *Detailed description of fixing devices*

vii) *Assess condition of all elements*

viii) *Non-intrusive investigation of all cavities:*
- *roof space*
- *wall cavities*
- *floors*
- *solum*

ix) *Availability and condition of services:*
- *electricity*
- *gas*
- *telephone*
- *water*
- *drainage*

x) Photographic record

xi) Check site against 1st and 2nd editions of OS Maps

4.3 Cladding assessment and recording

i) Material(s)

ii) Finish

- external
- internal
- colours

It may be necessary to perform paint analysis to establish the above: check whether base metal is galvanised or not, and look for traces of other primer types.

iii) Gauge of metal

iv) Pitch of corrugations

v) Depth of corrugations

vi) Detail of corrugation profile

vii) Amount of side lap - one, one-and-a-half or two corrugations

viii) Amount of end lap

ix) Presence of cover straps and the like.

Illus 12 Whiteriggs Farm Cattle Wintering Courts. As previously open Cattle Courts were roofed over toward the end of the 19thC corrugated iron sheeting was a favoured material to use for the roof covering. © Ingval Maxwell

5.0 BUILDING HISTORY

A number of sources that can be checked to establish something of the history of any particular building or structure. There is no one source that will provide all the information, and each fragment of information must be used to help locate further material from other sources.

5.1 Maps

Estate maps, fire insurance plans, and early editions of Ordnance Survey maps can be used to establish an approximate date for the building being studied. Maps must be used with some degree of scepticism since only the plan form is normally given and different structures can be set on the same foundation.

5.2 Purchaser's Records

Many organisations, including businesses, church and social committees, estates, hospital boards, local authorities and school boards, keep minutes of meetings, catalogues, records of purchases, maintenance accounts, and other relevant information. These records may also indicate sales or purchases of buildings: some metal buildings are known to have occupied a number of sites, under different ownerships, over the lifetime of the structure. This is particularly relevant in the case of churches, since many congregations purchased a corrugated iron church as a temporary measure while they raised funds for a more substantial building. The temporary church could then be sold on to another congregation, disposed of to a new owner intending a change of use, or used as the church hall. Second-hand libraries, school classrooms and prefabricated houses are known to be in use as agricultural buildings on a range of farms in different parts of Scotland.

5.3 Manufacturers' Catalogues

Manufacturers' old catalogues are difficult to locate but can be extremely useful. The North of England Open Air Museum, Beamish, Stanley, County Durham has one of the best collections, but major reference libraries in all the main manufacturing areas tend to have just one or two examples.

5.4 Manufacturers' Records

If the name of the manufacturer of a particular building is known, it may be possible to trace the company or its successors and gain access to their archive. In many

Illus 13 Highland Folk Museum, Kingussie ©Bruce Walker

cases former corrugated-iron manufacturers have diversified successfully and may no longer be connected to the trade, but still retain their archives.

5.5 Transport Records

Port records have been found to be particularly useful in establishing the quantities of corrugated iron entering certain Australian ports. Scottish port records have not yet been accessed for this type of material. Rail transport records may prove equally rewarding.

5.6 Local Authority Warrants

Dean of Guild Warrants, Police Burgh Warrants and Local Authority Building Warrants should be able to be traced back to the third quarter of the nineteenth century.

5.7 National Monuments Record for Scotland

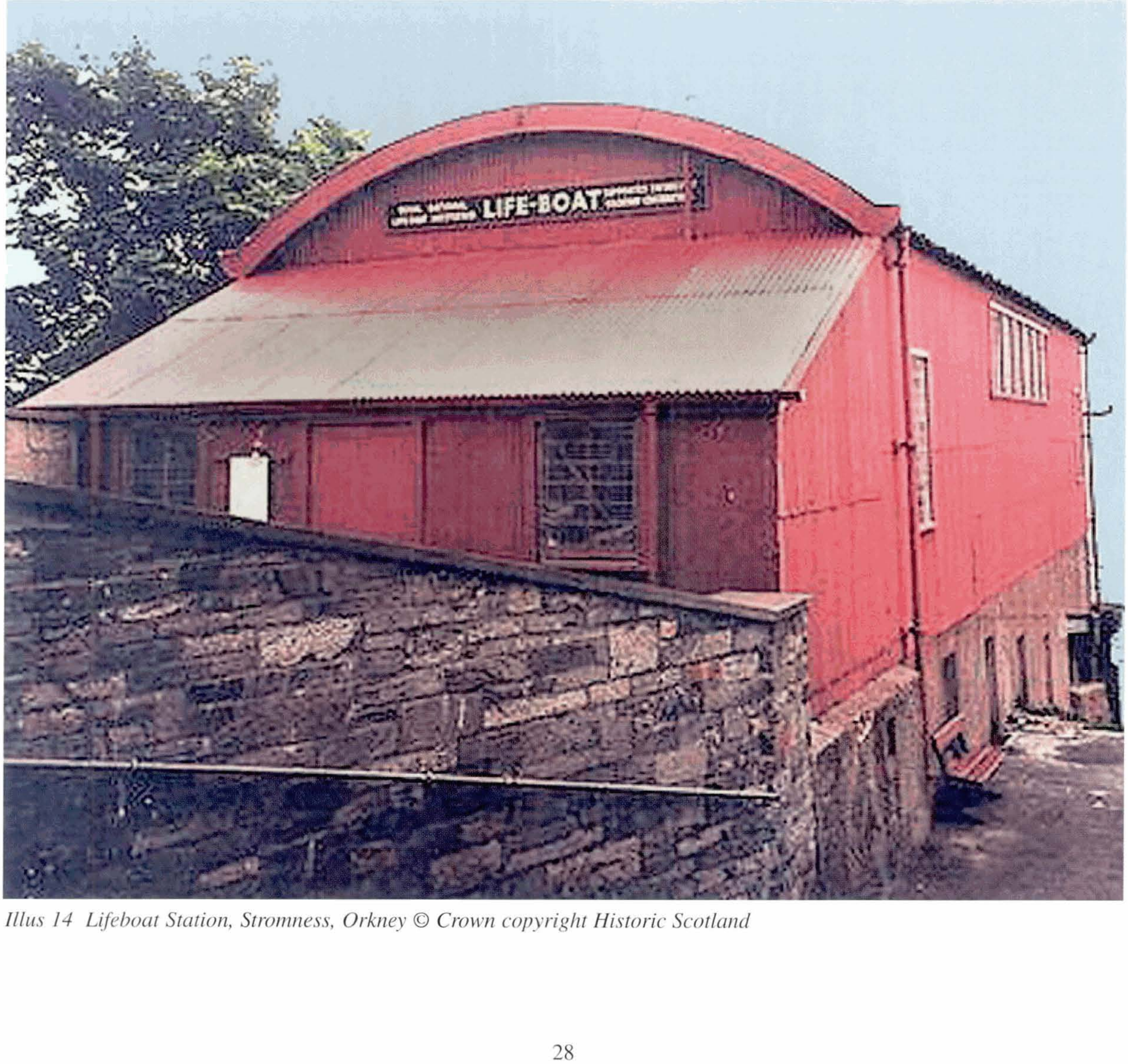
The NMRS keeps information on all types of buildings. These are filed by county and parish, and include drawings, photographs, specifications and descriptions. They also have a few catalogues for A & J Main & Co Ltd, mainly for fencing products.

5.8 Advertisements

Newspaper advertisements from the 1830s onwards give the names of manufacturers involved in the iron buildings trade. These are occasionally supplemented by advertising features describing either the extent of the firm's influence or the range of products ready for export.

5.9 Photographic Collections

Collections of photographs taken as an industrial record of buildings and plant can contain a considerable amount of detail. Social records of particular groups such as berry-pickers show iron encampments similar to the iron city near Blairgowrie, Perthshire. Photographs in the Imperial War Museum show various types of military camps, installations, aircraft hangers and other structures.



Illus 14 Lifeboat Station, Stromness, Orkney © Crown copyright Historic Scotland

6.0 CONSERVATION ISSUES

The term *corrugated iron* is generic and has included corrugated mild steel since its production. Modern replacements will therefore be some form of corrugated steel sheet unless a manufacturer can be persuaded to produce corrugated iron to match the existing.

6.1 Assessment

When replacing corrugated iron it is important to analyse the existing structure to ensure that the replacement sheets match the pitch and gauge of the existing and will be adequately supported by the existing structure.

When complete re-cladding is required or contemplated, it is essential to ensure that the replacement sheets are capable of spanning between the existing supports whilst still complying with current legislation regarding strength and stability.

It should be noted that 26 gauge (0.5mm) - 3 inch (76mm) corrugated sheet steel cladding with $1^1/_4$ ounce (350g/m^2) galvanized coating is the lightest gauge which can be used to qualify for an agricultural grant. This sheeting is available in 8x3 inch (76mm) and 10x3 inch (76mm) corrugations to cover widths of 2 feet (600mm) and 2 feet 6 inches (750mm) respectively. Lengths are available in 6 inch (150mm) increments up to standard lengths of twelve feet (3.6m) but longer lengths of sheet are available up to 25 feet (7.5m). The use of long lengths often enables a roof to be clad in one length from eaves to ridge without the need for end laps. This is particularly advantageous on shallow pitches as it removes the potential for water penetration at the end-lap joints, but since sheets of this length were not available at the time when many of the structures now being conserved were built, any contemplation of replacing short sheets with long should be discussed with the representatives of the appropriate conservation agencies prior to specification. The normal requirement for replacement of material on a historic structure is on a 'like for like' basis, but where recurring problems at end-lap joints can be linked to a certain amount of water penetration, (which was acceptable with regard to the buildings original function) and this is irreconcilable with the current or proposed function such a change of specification might be permitted.

When considering existing structures incorporating lighter gauges of corrugated iron which may no longer comply with current legislation, it may be worth considering the substitution of high-strength sheet steels such as Discus which is produced from lighter gauges but gives greater strength and performance.

Discus is normally sold on the justification of reducing weight on the structure, and a straight comparison of gauges on the basis of strength and span illustrates the potential of the material.

Ordinary		Discus	
22 gauge	0.8mm	25 gauge	0.5
24 gauge	0.6mm	28 gauge	0.35
26 gauge	0.45mm	29 gauge	0.33

The author stresses that the substitution of Discus for ordinary corrugated sheet steel is not being advocated as a general means of reducing weight but only as a replacement measure when the original gauge of material no longer complies with legislation.

Discus sheets are available in 8x3 inch (76mm) corrugations to cover a width of 2 feet (600mm). The sheets are galvanised with a $1^1/_4$ ounce coating and are available in lengths up to 12 feet (3.6m) in 28 and 29 gauge, and 25 feet (7.5m) in 25 gauge, respectively. Discus 28 and 29 gauge sheets may not normally be acceptable for agricultural grants but in appropriate circumstances may be considered for a conservation grant. It is essential that this is discussed with the appropriate conservation authority at the planning stage, that is, after the structural analysis, when all the particulars are available for consideration, but before the final approach is formulated.

Another modern corrugated sheet-steel product worthy of consideration is Everbright. This sheeting has a $2^1/_2$ ounce galvanized coating (twice that of ordinary galvanized sheet) and is produced from 26 gauge (0.5mm) rust-resistant steel in 10x3 inch (76mm) corrugation profile giving a 2 feet 6 inch (750mm) cover width. This is available in lengths up to 12 feet (3.6m) and can be supplied either curved or flat.

It is usual to paint galvanized corrugated iron either immediately after erection or at a later date. It is recommended that joints be painted prior to erection to ensure a protective layer in those areas not accessible after fixing. Galvaprime has been developed to meet these requirements. It is a high quality 1¹/₄ ounce (350g/m²) galvanized corrugated sheet with the weather side prepainted before packaging and despatch. The paint is a green colour and will have a life equivalent to that of any other normal paint system in the area: when required, it will readily accept further coats of any of the usual outdoor paints. Galvaprime is produced in 10x3 inch (76mm) and 8x3 inch (76mm) corrugations in lengths up to 18 feet (5.4m). The gauges available are 22, 24 and 26 (0.8, 0.6 and 0.45mm). Curved sheets, ridging and flashings are also available in the same finish. This material is worth considering even when a different colour is required immediately since it eliminates the risk of damage in prepainting sheets or joints prior to erection, and provides a factory-controlled primer.

The alternative pre-coated material Everclad has less potential for the conservation of historic corrugated-iron structures. This is a 26 gauge (0.45mm) 1¹/₄ ounce galvanized sheet steel coated on both sides. The topside or weathercoat is coated with a thick PVC plastic, and the underside with a grey protective paint. It is available in three British Standard Colours (BS 5-059, 9-101, and 4-051). These greys have been chosen in close collaboration with the various government bodies concerned with planning and agriculture. This does not automatically make them ideal for conservation projects where the aim may be to produce a historically correct colour scheme. Everclad is produced in two profiles but it is the ordinary 10x3 inch (76mm) corrugated sheets with a width of 2 feet 6 inches (750mm) that could be of interest to conservation architects. Standard lengths are from 6 feet (1.8m) to 12 feet (3.6m) in 6 inch (150mm) increments. Longer lengths are obtainable to special order. Tests on the coatings have shown that, for normal weather conditions, no maintenance costs can be expected for at least 15 years.

6.2 Strategy

Historic Scotland's preferred strategy is to conserve in situ with as little interference as possible to the historic fabric. Whilst this is eminently sensible when dealing with masonry structures, the conservation of ferrous metal cladding and structure may require a different approach.

The most difficult problem facing the conservator dealing with ferrous metals is how to control corrosion that may be occurring in the joints between the various components. There is, of necessity, a fine gap between all overlapping or butt-jointed components. No matter how well this gap is protected, it is possible that water or moist air will penetrate and result in corrosion.

Maintenance schemes can recommend filling the edges of these gaps and protecting all the exposed surfaces of the metal in the ways set out in this document, but due

Ilus 15 Cottage on Eriskay ©Bruce Walker

Illus 16 Dogton Farm Cartshed, Fife. Mid 19th C building roofed in corrugated iron. © Ingval Maxwell

Illus 17 Tromie Mill, Moray. Outbuilding roofed in corrugated iron. © Ingval Maxwell

to structural and thermal movement it is almost impossible to ensure that joints remain watertight. Once moisture has penetrated and corrosion starts it is almost impossible to control without considering the dismantling of the cladding or structure to allow the concealed surfaces to be cleaned, preserved and protected. This is not a new concept in conservation circles: the International Wood Committee of ICOMOS has for many years been discussing this approach to the protection of joints in structural timber.

The ICOMOS International Wood Committee argues that 'prevention is better than cure' and that in structures where there is a fundamental weakness in particular types of joint it may well be advisable to dismantle, treat the components in factory conditions, and then re-assemble, rather than to wait until corrosion has reached the stage that the component must be replaced.

This should not be interpreted as a charter to dismantle and re-erect at will. Each intervention of this type should be based on proper study and assessment. Problems should be solved according to relevant conditions and needs, with due respect to the aesthetic and historical values and physical integrity of the cladding or structure.

The Wood Committee recommended that a copy of the measured drawing of the building be used to highlight problem areas, since this helps all concerned to focus on potential trouble-spots.

The following points must be recognised and considered fully in the light of all available evidence:

- *Complete dismantling is often necessary to allow a thorough conservation process*
- *Where possible, revive traditional techniques, particularly if they have been successful over a long period of time*
- *Intervention should, where possible, be reversible*
- *Do not prejudice future work*
- *Do not impede access to evidence contained in the historic cladding or structure*
- *'Minimum intervention' should be retained as an aim*
- *Use like-for-like materials in any replacement components. This will require careful analysis of the composition of the ferrous metal being considered. Do not use bulk steel as a replacement for wrought or carburized irons.*
- *Bear in mind that traditional cladding and structural techniques are useful textbooks to the past and should be kept intact for future generations.*

6.2.1 Repair

Wherever possible the historic fabric should be repaired and conserved rather than being replaced.

Repairs should be identifiable to future conservators.

Repairs may be carried out in situ or in a factory after careful dismantling, labelling and recording to ensure that each part can be successfully relocated in its original position.

Care must be taken not to put undue stresses on structure or cladding during the repair or dismantling processes. To do this successfully the original erection procedure must be fully understood, and the limits of adjoining components must be respected.

i) In situ Repairs

The main concern with in situ repairs is the protection of adjoining components during cleaning and repair works.

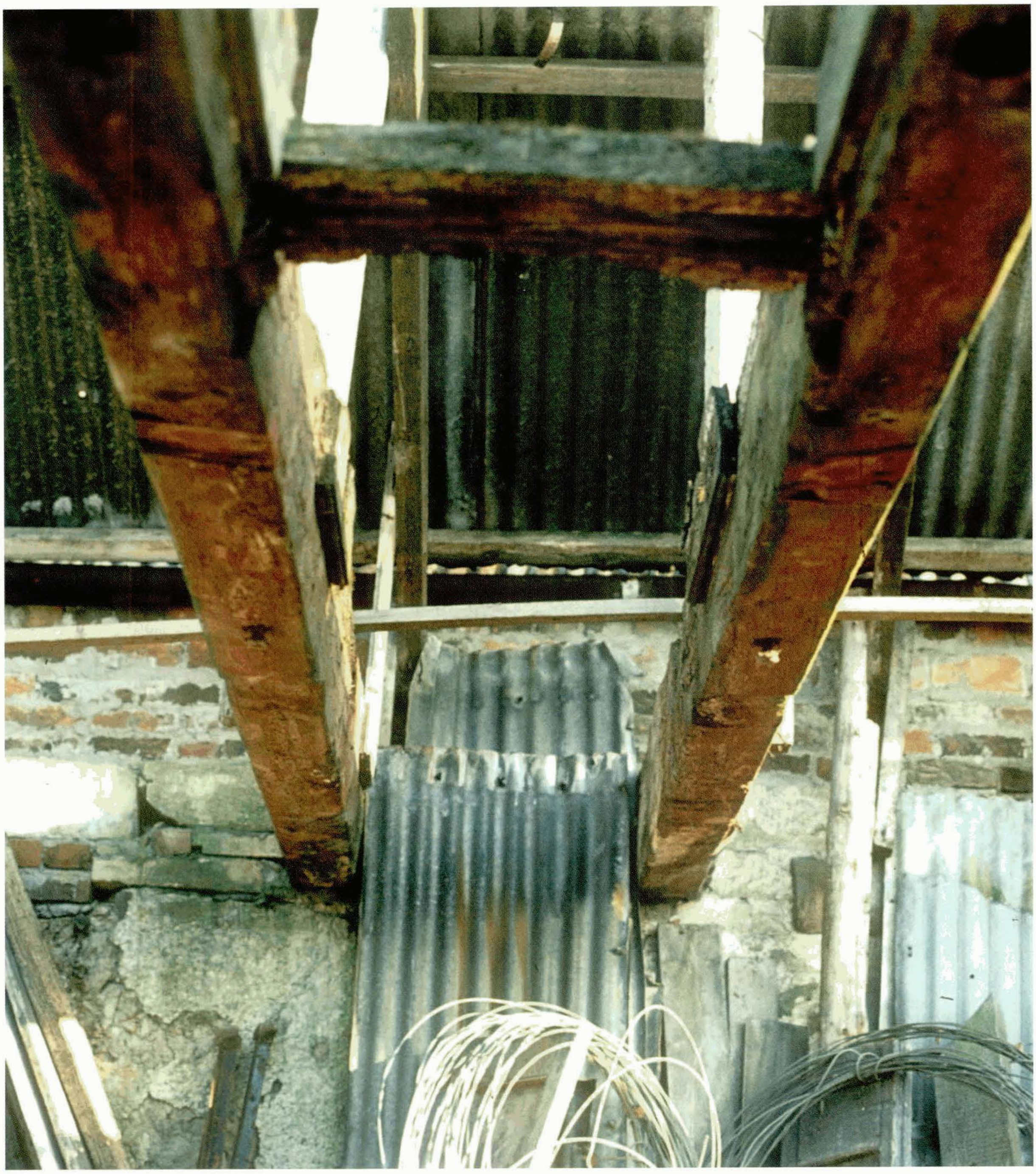
In situ repairs should only be undertaken when the conservator is convinced that all joints are sound and free from corrosion.

If damage is minor or restricted to a small area it may be worthwhile consulting and contracting a coachbuilding firm to carry out the works. They may well have the expertise needed to repair sheet metal, whether punctured or deformed.

In every case the nature of the repair should be carefully considered in terms of the historic fabric, the stresses that the adjoining fabric may be subjected to and the final appearance of the work. All changes to the original fabric should be discreetly identifiable and, if possible, dated.

ii) Factory Repairs

The measured drawings of the cladding, building or structure should be utilised to give each individual component an identification number. This will allow its reinstatement in exactly the correct position. A tag used must allow for the fact that the component may be shot-blasted, acid-pickled, or have paint removed prior to being re-galvanized. All such processes would remove or obliterate identification numbers painted on, or lightly scratched into, the surface of the component. Identification discs attached to the component by wire, possibly to fixing holes, may be the answer, but it is essential to consult with the conservator regarding the materials to be used both for disc and its attachment. This is necessary to avoid unwanted chemical actions between the processes used on the component and the materials of the disc. It is also essential to establish whether there is any chance of the disc becoming



Illus 18 Flatfield, Carse of Gowrie. Salvaged sheets stored for future use. © Ingval Maxwell

welded to the surface of the component, or damaging its protective system, during or after application.

Before any work is commenced it is essential to fully understand the principles behind the design and to compensate for the removal of components for conservation: suitable support must be given to those elements remaining in situ.

Similarly, if the dismantling process is to extend to the entire structure it is advisable to dismantle in reverse order to the original construction process.

6.2.2 Replacement Components

Replacement should be, as far as possible, on a strict like-for-like basis. It should not involve replacement of wrought iron or carburized iron with mild steel or low carbon steel to achieve a 'quick fix' solution.

Every effort should be made to find suitable replacement metals: changes should only be accepted with the full backing of an expert in metal conservation.

7.0 CONCLUSIONS

Britain had a leading role as one of the early industrialised nations. Ferrous metal cladding played an important part in providing affordable workspaces, accommodation, administrative, educational, leisure, religious and sporting venues for a rapidly expanding population during the change from a rural to an industrial economy. Thus it is essential to conserve a proportion of these early structures for future generations.

Unfortunately, many of these interesting structures have been swept away, often by authorities or individuals who have failed to realise their historical significance.

One notable exception to this general trend is the Pump Rooms, Tenbury Wells, Worcestershire. This interesting building was in a poor state of repair, having lost some of its cladding. The refurbishment was carried out by Jacqueline Demaus RIBA, Leominster, Herefordshire, and ninety per cent of the surviving cladding sheets were regalvanized and reused in the refurbishment. The completed building received a Hot Dip Galvanizing Award in 2000.

But early ferrous metal-clad structures are now becoming rare, and there is still a huge gap in our knowledge as to how best to protect the survivors for future generations.

The author advises caution, careful recording, meticulous research, and consultation with skilled conservators.

Illus 21 Quothquhan, Shieldhill Hall © Crown copyright Historic Scotland

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WARD: 1997 *Moduclad IP100 Roof and Wall Panels* Ward Building Components Ltd, MALTON.

WARD: 1997 *Moduclad Profiles for Roofs and Walls* Ward Building Components Ltd, MALTON.

WARD: 1998 *Moduclad Steel Roof Decking* Ward Building Components Ltd, MALTON.

9. GLOSSARY

ALLOY STEELS - Those which owe their properties to the presence of an element or elements other than carbon.

BASIC PIG IRON - Pig Iron containing so little silicon and sulphur that it is suited for easy conversion to Steel by the basic Open Hearth or Converter process. It is usually restricted to Pig Iron containing not more than one per cent of silicon.

BESSEMER PIG IRON - Pig iron which contains so little phosphorus and sulphur that it can be used by itself for conversion to steel by the original Bessemer process.

BESSEMER PROCESS - Industrial process for the manufacture of steel from pig iron, the impurities from which are oxidised into slag by air blown through the molten iron.

BESSEMER STEEL - Steel made by the Bessemer process whatever the carbon content.

BLISTER STEEL - Steel of plastic origin made by carburizing high class Swedish or other wrought iron of similar purity which has been subjected to a process of cementation in contact with charcoal, which process, whilst introducing carbon into the iron also develops blisters on the surface of the cemented bar. The blistered bars are heated and forged or rolled into merchant shapes or sizes.

HOMO IRON - A name sometimes given to a low carbon steel, usually soft basic steel with a carbon content between 0.08 and 0.15 per cent.

HOT METAL or DIRECT METAL - Molten Cast-Iron from the blast furnace before it has been allowed to solidify.

MALLEABLE IRON - Wrought iron.

MERCHANT BAR - Wrought iron in the form of Merchant bars or rods made by shearing a puddled bar into short lengths, piling it, and rolling or forging it at a welding heat.

MIXER METAL - Molten cast iron which has been passed into or through a metal mixer.

MOTTLED CAST IRON - Pig and cast-iron, the structure of which is mottled, with white parts in which no graphite is seen and grey parts where graphite is seen.

OPEN HEARTH PROCESS - Molten pig iron and scrap are packed into the furnace's shallow, wide, saucer shaped hearth, under its low roof and the liquid metal is heated further by overhead gas-burners using preheated air.

OPEN HEARTH STEEL - Steel made by the open hearth process, whatever its carbon content.

PIG IRON - Cast iron which has been cast direct from the Blast or other Furnace into moulds of varying sizes and shapes, known as pig moulds, then allowed to solidify in the form of pigs or slabs. Iron which has been reduced from the ore, usually in a Blast Furnace, in direct contact with solid carbon, and containing a considerable percentage of carbon, usually about 3.0 to 4.5 per cent.

PLATE IRON or PLATE METAL - The name applied in the UK to refined cast iron.

PUDDLED BAR - Rough bars usually about 25mm thick and 100mm wide, made by the first rolling of a ball of puddled iron.

PUDDLED IRON - Wrought Iron made by the puddling process.

PUDDLED STEEL - Steel made by the puddling process and necessarily slag-bearing. Iron containing sufficient carbon to be capable of hardening greatly by sudden cooling. It is slag-bearing because it is made by welding together pasty particles of metal in a bath of slag, as in puddling, and not freed later on by melting it from the slag.

STEEL - Iron of fluid origin which is malleable at least in one range of temperature, and which in addition is either cast into an initial malleable mass, capable of hardening greatly by sudden cooling or is a combination of the two previous qualities. Iron, (either pure or associated with other elements) which has been cast from a molten state, whether it hardens or not on rapid cooling from above its critical range, after solidification is so usefully malleable that it can be rolled or forged within some range of temperature. Such metal is steel whatever the carbon content.

WROUGHT IRON - Iron which is produced at a temperature below its own melting point, either direct from iron ore or from Cast Iron, as a malleable mass, by the aggregation of pasty particles without subsequent fusion. It contains so little carbon that it does not usefully harden when rapidly cooled. It is soft and readily malleable within wide limits of temperature, and always contains intermingled slag.

Illus 23 Kilburn, Angus: Sheep dip construction incorporating angle iron gates on a steel post and curve profiled corrugated iron side sheets © Ingval Maxwell

10. USEFUL ADDRESSES

As at August 2004

BRITISH FOUNDRY ASSOCIATION
McLaren Building
35 Dale End
Birmingham B4 7LN
Telephone: 0121 200 2100
www.castmetalsfederation.com/bfa.asp
admin@cmfed.co.uk

CASTINGS TECHNOLOGY INTERNATIONAL
Alvechurch
Birmingham B48 7QB
Telephone: 0152 766414
www.castingsdev.com
info@castingstechnology.com

INSTITUTE of CORROSION
Corrosion House
Vimy Court
Leighton Buzzard
Bedfordshire LU7 1FG
Telephone: 01525 851771
www.icorr.demon.co.uk
admin@icorr.demon.co.uk

IRONBRIDGE GORGE MUSEUM
Ironbridge
Telford
Shropshire TF8 7AW
Telephone: 01952 433522
www.ironbridge.org.ik
info@ironbridge.org.uk

NATIONAL CORROSION SERVICE
(contact Dr Alan Turnbull)
Queen's Road
Teddington
Middlesex TW11 0LW
Telephone: 020 8977 3222
www.npl.co.uk/materials/ncs
email n NCS@npl.co.uk

PAINT RESEARCH ASSOCIATION
8 Waldegrave Road
Teddington
Middlesex TW11 8LD
Telephone: 020 8614 4800
www.pra.org.uk
information@pra.org.uk

ROOFING, CLADDING AND INSULATION
RCI
Unity Media
Becket House
Vestry Road
sevenoaks
Kent TN14 5EJ
Telephone: 01732 748032
www.unity-media.co.uk
ekimber@unity-media.com

THE WELDING INSTITUTE
TWI Ltd
Granta Park
Greater Abington
Cambridge CB1 6AL
Telephone: 01223 891162
www.twi.co.uk
twi@twi.co.uk

WORSHIPFUL COMPANY of IRONMONGERS
Ironmongers' Hall
Shaftesbury Place
Barbican
London EC2Y 8AA
Telephone: 020 7776 2304
www.ironhall.co.uk
clerk@ironhall.co.uk

11. APPENDICES

APPENDIX A

Published Case Studies

The shortage of suitable case studies on ferrous metal cladding in Scotland has prompted the author to draw the reader's attention to case studies published elsewhere.

The examples chosen have been selected to highlight some of the problems mentioned in the text.

Le Pont Alexandre III, Paris France

'Le Pont Alexandre III' is basically a cast iron structure erected in 1900 as part of the 'Exposition Universelle' held in Paris that year.

A preliminary scientific study was undertaken by the 'Laboratoire de Recherche des Monuments Historiques' in collaboration with the 'Architecte en Chef des Monuments Historiques'.

The focus of this study was the Cast Iron.

The study comprised an inventory and quantification of the types of degradation of the monument, a documentary search and a stratigraphic examination of the paint layers to determine both the original colour and the types of paint.

The materials used in the construction of the bridge were analysed, and the physical damage was observed and plotted.

The research results and observations then prompted the research team to investigate adhesives that could be used to repair damaged components and resin-moulding techniques to replace missing parts.

The system of corrosion-resistant paints is described in the painting recommendations (Texier 1997).

The Manitoba North Cannon Stabilization Project, Hudson Bay, Canada

The Hudson Bay Company built the Prince of Wales Fort at the mouth of the Churchill River, between 1731 and 1772. The completed fort had 42 cast iron cannon on its ramparts.

Reconstruction of the fort in the 1930s and 1950s resulted in the early eighteenth century cannon being rediscovered in the rubble. Corrosion was destroying the surfaces with a subsequent loss of historic data.

The environment is marine sub-arctic and the site is virtually inaccessible for ten months of the year.

The project to conserve the cannon was initiated in 1980 and to date seventeen of the forty-two cannon have been treated.

The paper (Busse, 1997) summarises the cleaning methods employed, the passivation and barrier coatings used, the reasons for their selection and why each was reconsidered. A final treatment has still to be selected.

Bank of Montreal, Toronto, Canada

In 1989 a conservator was employed to assess the condition of the galvanised sheet-iron clad timber cupola on the Bank of Montreal. The cupola had been erected in 1886.

The cladding was not a pressed metal type but was made up of pieces of hand-cut galvanised sheet-iron, formed to clad the timber structure, and then soldered together.

The conservator then worked with sheet metal workers to conserve the cladding. This involved some repair and some replacement but respected the integrity of the original cladding to the extent that faults in the original detailing were deliberately repeated (Maltby, 1998).

Sawmill, Tom's River, Double Trouble State Park, New Jersey, USA.

The sawmill comprised a timber framed structure clad with galvanised sheet metal which had in turn been covered with wooden clapboarding at a much later date.

The Park authorities wished to reinstate the original condition by removing the clapboarding and conserving the galvanised sheeting. The work was carried out using a commercial rust converter followed by a protective coating of paint. The paint was a necessary intervention since the original galvanising had disappeared from the outer surface of the metal.

The interior surface of the galvanised sheeting was still in excellent condition and bore hand written inscriptions in pencil recording noteworthy events. The preservation of these inscriptions was considered critical to the interpretation of the mill and was one of the reasons for not pickling and regalvanising the sheets. (Maltby, 1998).

The Rookery, Chicago, USA.

The Rookery was originally constructed by Burnham and Root between 1885 and 1888 using an exposed (internally) ferrous metal structure protected by the Bower-Barff System (see section 2.07.6.v). It was later altered by Frank Lloyd Wright between 1905 and 1907, and by William Drummond between 1927 and 1932.

The investigation of the architectural finishes of the principal internal spaces - that is, the light court, lobbies and library - was undertaken between 1989 and 1990 in preparation for the restoration of the building. Assessment was based on in-situ investigation and laboratory analysis supplemented by written and photographic documentary sources.

Paint sampling and surface finish investigations were confirmed to selected areas within the principal locations. Whenever possible, known elements dated to the works of the three main designers were examined and sampled for comparison. Over 150 samples of existing coatings were removed, examined and analysed in the laboratory.

Once these materials were characterised, identified and documented, a programme of field testing was conducted to determine the feasibility of retaining these original or subsequent finishes. Overpainted or lost finishes were studied to replicate their historic appearance. This was done with consideration as to cost-effectiveness, consideration of health risks, and the wish to conserve as much of the original surface as possible (Matero: 1994: 208-228).

Le Radar Würzburg Riese du Mémorial pour la Paix, Nançay, France.

The radio-astronomy station at Nançay, France has two Würzburg Reise-type radar dishes converted to radio -telescopes.

One of these, which has not been used since 1962, is to be restored to its original condition as a Memorial for Peace.

The paper (Forrères & Périssère, 1997) examines the history of the object and the possibility of producing a true restoration, where full documentation is available and management of the restored object is assured.

The Submarine 'Holland I', Gosport, Hampshire

During the summer of 1993, the management of the Royal Navy Submarine Museum, Gosport, Hampshire became seriously concerned about the deterioration that had occurred to 'Holland I' since its removal from the seabed in 1981. This deterioration was due to chloride residues present in many of the interfaces of the submarine's structure. The paper (Barker, Johnston & O'Shea: 1997) describes the subsequent action.

APPENDIX B

Profiled Metal Sheeting and Cladding Sources.

The following list is an extract from a RCI see 10.00 below survey of manufacturers suppliers and fixers published in January/February 1998. This was updated in 2003.

Manufacturers and Suppliers Addresses

The following list was updated in 2003 and was correct at the time. Business activity including mergers and takeovers, but RCI update their data regularly means that this is initially out of date.

Note: the inclusion of any named manufacturer, supplier or product does not imply endorsement by Historic Scotland. These are merely shown as examples of their kind and others may be available.

ALPHA BUILDINGS COMPONENTS Ltd
Garratts Lane, Cradley Lane, West Midlands
B64 5RE
Tel 0121 561 1144 Fax 0121 561 4747
www.alphabuilding.co.uk

ADVANCED CLADDING & INSULATION GROUP Ltd
Raynes House, 3 Stokes Street Manchester, M11 4QU
Tel 0800 015 9190
www.advancedcladding.com
sales@advancedcladding.com

ARC Group Ltd
Lauren House, South Lane, Ash near Aldershot
Surrey GU12 6NG
Fax 01252 658 354

ASPHALTIC ROOFING SUPPLIES Ltd
Harding Way, St Ives, Cambridgeshire, PE17 4YJ
Tel01480 466 777
www.sigplc.co.uk
arsmarketing@yahoo.com

BERRIDGE MANUFACTURING COMPANY
1720 Maury Street, Houston, Texas 77026, USA
www.berridge.com rmarks@berridge.com

BRITISH STEEL STRIP PRODUCTS
PO Box 10, Newport, Gwent. NP9 OXN
TEL 0163 346 4646 FAX 0163 346 4175

BROWN & GLEGG Ltd
Bankhead Crossway Edinburgh South,
Sighthill Industrial Estate, Edinburgh Midlothian
EH11 4EZ
Tel 0131 453 6611 Fax 0131 453 1848
info@brownglegg.co.uk www.brownglegg.co.uk

BUILDERS IRON & ZINCWORK Ltd
Millmarsh Lane, Brimsdown, Enfield. EN3 7QA
sales@bizenginering.com
Tel 0208 443 3300 Fax 0208 173 5216

CLADDING & DECKING UK Ltd
William Nadin Way,Swadlincote, DE11 OBB
www.clad-deck-corus.co.uk
Tel 0128 321 1700 Fax 0128 381 7100

METECNO UK Ltd
45 Newmains Avenue, Inchinnan Business Park,
Renfrew. PA4 9RR
Tel 0141 812 6866
www.metecno.co.uk info@metecno.co.uk

DECRA ROOF SYSTEMS (UK) Ltd
Unit 3 ,Faraday Centre, Faraday Road, Crawley
West Sussex RH10 9PX
Tel 0129 354 5058
www.decra.co.uk technical@decra.co.uk

ETERNIT BUILDING MATERIALS
Whaddon Road, Meldreth,Royston, Herts SG8 5RL
Tel 0176 326 4686
www.eternit.co.uk marketing@eternit.co.uk

EUROCLAD Ltd
Wentloog Corporate Park, Wentloog Road, Cardiff.
CF3 2ER
Tel 0292 079 0722 Fax 0292 079 3149

EUROPEAN PROFILES Ltd
Llandybie, Ammanford, Dyfed. SA18 3JG
www.europeanprofiles.co.uk
Tel 0126 985 0691 Fax 0126 985 1081
sales.technical@coruspanelsandprofiles.co.uk

ALUMASC EXTERIOR BUILDING PRODUCTS Ltd
White House Works, Bold Road, Sutton, St Helens,
Merseyside WA9 4JG
Tel 0174 4648 8700
info@exteriors.co.uk
www.alumasc-exteriors.co.uk

FORALL Ltd
Garratts Lane, Cradley Heath, West Midlands.
B64 5RE
Tel 0121 502 9200
mail@forall.co.uk www.forall.co.uk

GASELL PROFILES Ltd
Steadings Business Centre, Maisemore Court
Maisemore, Gloucestershire. GL2 8EY
Tel 01452 421234
www.gasell.co.uk technical@gasell.co.uk

GLENO INDUSTRIES Ltd
Grange Road, Houston Industrial Estate, Livingston. EH54 5DH
Tel 01506 433 2551 Fax 01506 434386
sale@coberworld.co.uk www.coberworld.co.uk

CORUS BUILDING SYSTEMS KALZIP DIVISION
Haydock Lane, Haydock, St Helens, Merseyside. WA11 9TY
Tel 01942 295 500
www.kalzip.co.uk kalzip-uk@corusgroup.com

KINGSPAN Ltd
Greenfield Business Park No 2, Holywell,Flintshire. CH8 7GT
Tel 01352 716100
www.kingspanpanels.com
info@kingspanpanels.com

LINDAB Ltd
Longman Court,Sketty Close, Brackmills, Northampton. NN4 7PW
Tel 01604 707630
www.lindab.com sale@lindab.co.uk

ERIK OLSSON & SoNER AB
Sliparegatan 5, Box 4003, S-300 04 Halmstad, Sweden.
Tel(46) 3510 0110
www.erikolssonosoner.se
info@erikolssonosoner.se

PRECISION METAL FORMING Ltd
Swindon Road, Cheltenham, Glos. GL51 9LS
www.pmf-corus.co.uk
Tel 01242 527511
Fax 01242 518929
technical@coruspanelsandprofiles.co.uk

RIMEX METALS (UK) Ltd
Aden Road, Ponders End, Enfield. EN3 7SU
Tel 020 8804 0633
www.rimexmetals.com sales@rimex.co.uk

RHEINZINK UK
Cedar House, Cedar Lane, Frimley, Camberley. GU16 7HZ
Tel 01276 686725
www.rheinzink.co.uk rheinink@wee-ha.com

HAIRONVILLE TAC Ltd
Abbotsfield Road, Abbotsfield Industrial Park, St Helens. WA9 4HU
Tel 01744 818181 Fax 01744 811505
www.haironvilletac.co.uk

RIGIDAL LIMITED
Unit 62 Blackpole Trading Estate, Worcester WR3 8ZJ
Tel 01905 750500
www.rigidal.co.uk sales@rigidal.co.uk

Illus 24 Brothershields, Midlothian: corrugated iron sheet smoke board in farm bothy © Ingval Maxwell