The Steel Construction Institute

NiDI

Steel Package Water and Waste Water Treatment Units

Steel in the Water Industry

The Steel Construction Institute

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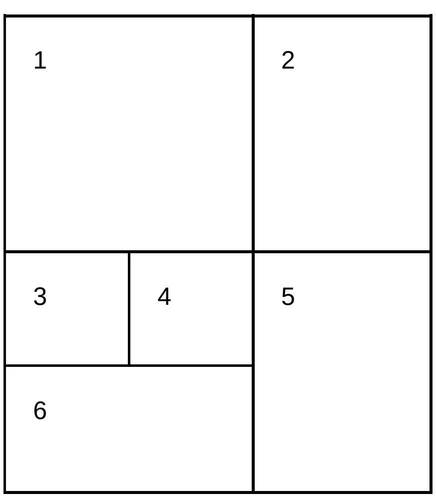

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Steel Package Water and Waste Water Treatment Units

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FOREWORD

The range and types of package treatment units within the water industry have been growing significantly over the last 10 years. This has been largely as a result of the 1991 EU directive requiring improved standards of waste water treatment.

The purpose of this publication is to promote the consideration and use of steel and stainless steel in package treatment units.

The publication provides useful general information for water company engineers and specifiers at the conceptual design stages of the procurement process. The technical information on durability, design, fabrication and installation will also be of use to civil engineering contractors and plant manufacturers.

This publication has been prepared by The Steel Construction Institute (SCI) under the guidance of a Working Group formed by USWIG (Users of Steel in the Water Industry Group). The Working Group included representatives from water companies, plant manufacturers, fabricators and the steel industry, as listed below:

ABC Stainless Limited
Anglian Water
Avesta Sheffield Ltd
Bechtel Water Technology Ltd (North West Water)
Biwater Treatment Ltd
Corus Colors
Entec Ltd
Huber Technology
J Fletcher (Engineers) Ltd
Nickel Development Institute
Northumbrian Water Ltd
Outokumpu Oy
Oy JA-RO AB
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Stainless Metric Stock (SMS) Ltd
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SUMMARY

This publication addresses the use of steel and stainless steel package units for water and waste water treatment. A package treatment unit is a module or series of linked modules that is constructed in a factory and subsequently transported to site for installation. Package units can be assembled rapidly on site with the minimum of site works.

A general assessment of the benefits of package construction is given. The suitability of carbon steel and stainless steel as materials for the container, processing plant and pipework is discussed in the context of their material properties and durability. Advice is given on good practice in design, fabrication, installation and maintenance. A reference list of the principal British and European standards relating to steel is given in an Appendix.

A series of case studies of recent projects is included to demonstrate the range of current applications of package units for different types of treatment process, both on a large and small scale.

Modules en acier pour le traitement des eaux et des eaux usées

Résumé

Cette publication est consacrée à l'utilisation de modules en acier et en acier inoxydable pour le traitement des eaux et des eaux usées. Une unite de traitement est constituée d'un module ou d'une série de modules reliés entre eux qui sont fabriqués dans une usine et sont ensuite transportés et installés sur site. Ces modules peuvent être installés rapidement avec un minimum de travail sur site.

Une analyse des avantages de ces modules est donnée. La bonne adéquation de lacier au carbone et de lacier inoxydable en tant que matériau servant pour réaliser l'enveloppe, l'unité de traitement et les canalisations est discutée dans le contexte des propriétés de ces matériaux et de leur durabilité. Des conseils de bonne pratique sont donné pour le dimensionnement, la fabrication, l'installation et la maintenance de ces installations. Une liste de références des principaux règlements britanniques et européens relatifs à lacier est donnée en annexe.

La publication comporte également une revue de projets récents afin de montrer le domaine d'application de ce type de module pour différents types de traitement des eaux.

Stahlbauteile für die Wasser- and Abwasserbehandlung

Zusammenfassung

Diese Publikation widmet sich der Anwendung von Bauteilen aus Stahl und Edelstahl für die Wasser- and Abwasserbehandlung. Ein Bauteil ist in diesem Zusammenhang ein in der Werkstatt gefertigtes Modul oder mehrere miteinander verbundene Module, das nachfogend zur Baustelle transportiert und dort montiert wird. Die Bauteile können auf der Baustelle mit einem Minimum an Arbeit zusammengesetzt werden.

Eine allgemeine Beurteilung der Vorteile dieser Modulbauweise wird vorgestellt. Die Eignung von Stahl and Edelstahl als Materialien für Behälter, die Anlage und Leitungen wird im Zusammenhang met deren Materialeigenschaften und Dauerhaftigkeit diskutiert. Praxisorientierte Ratschläge hinsichtlich Entwurf/Berechnung, Herstellung, Montage and Unterhaltung werden gegeben. Eine Referenzliste der wichtigsten britischen and europäischen Normen bezüglich Stahl ist im Anhang zu finden.

Eine Reihe von Fallstudien jüngster Projekte ist enthalten, um die Bandbreite aktueller Anwendungen solcher Module für unterschiedliche Behandlungsprozesse im großen and kleinen Maßstab zu demonstrieren.

Empaquetamientos de acero para agua y para tratamiento de agua

Resumen

Esta publicación se reftere al uso de empaquetamientos de acero y acero inoxidable para agua y tratamiento de aguas residuales. La unidad de paquetes de tratamiento es un módulo o serie de módulos conectados que se construye en fábrica y posteriormente se transporta al emplazamiento destinado para su instalación. Las unidades se pueden montar rápidamente con el mínimo de trabajos de acondicionamiento del emplazamiento.

Se da una estimación general de los beneficios de la construcción de empaquetamientos. En el contexto de la durabilidad y propiedades de los materiales se discute la adecuación de los aceros al carbono y de los inoxidables para los contenedores, plantas de proceso y tuberías. Se dan normas de buena práctica para el proyecto de fabricatión, instalación y mantenimiento. Finalmente en un apéndice se incluye una lista de las principales normas europeas y británicas relativas al acero.

Se describen una serie de estudios de casos proyectados recientemente para demostrar las posibilidades de aplicación a diferentes tipos de procesos tanto a gran como a pequeña escala.

Unità prefabbricate in acciaio per il trattamento delle acque e delle acque di rifiuto

Sommario

Questa pubblicazione tratta l'utilizzo di unità prefabbricate in acciaio al carbonio e acciaio inossidabile per il trattamento delle acque e delle acque di rifzuto. L'unità prefabbricata di trattamento è costituita da un modulo o da una serie di moduli costruito in fabbrica e trasportati nel luogo dell'installazione. Le unità prefabbricate possono essere assembrate rapidamente in loco con la minima lavorazione in cantiere.

Nella pubblicazione viene fornita una valutazione globale dei benefice associate a queste costruzioni prefabbricate. La convenienza dell'acciaio al carbonio e dell'acciaio inossidabile come materiale per l'involucro, per gli impianti di processo e per i sistemi di tubazioni è discussa con specifico riferimento alle proprietà del materiale e alla durabilità. Sono inoltre fornite informazioni di supporto relativamente alla buona pratica nella progettazione, nella fabbricazione,

nell’installazione e nella manutenzione. Nell’appendice viene presentato un elenco di riferimenti relativi alle principali normative britanniche ed europee sull’acciaio.

Viene inclusa una serie di casi pratici relativi a recenti progetti con la precisa finalità di dimostrare il campo di applicazione delle unità prefabbricate per i differenti processi di trattamento, sia su piccola sia su grande scala.

1 INTRODUCTION

Package plant is pre-engineered and pre-fabricated in standardised capacities or units which can be assembled or moved directly to the job site, or from one location to another, minimising hook-up on site. Smaller units can be transported as one assembled unit but larger capacities can be made up from a number of identical small units installed in parallel.

The range and types of package plant are increasing in response to growing demand. The mandatory EU Urban Waste Water Treatment Directive[1] that came into effect in 2000 means that smaller towns and villages in the UK will need to improve the standards of waste water treatment. The relatively short time in which these secondary treatment works need to be constructed place package systems at an advantage because of their quick fabrication, transportation and installation.

Steel is an efficient and versatile material for structural purposes because it has a high strength-to-weight ratio. The material is ductile with good fracture toughness for most practical applications. Product forms range from thin sheet material, rolled structural sections and plates, to heavy forgings and castings of intricate shape. Today, modern, durable protective coatings for structural steel are available that allow extended maintenance intervals and improved performance, when used appropriately. Alternatively, protective coatings can be dispensed with if stainless steel is specified.

A discussion of the various methods of water and waste water treatment and the selection and design of a particular piece of process equipment are outside the scope of this publication. However, a recent publication by CIRIA[2] presents a detailed review of current practice on the selection, operation and maintenance of small package waste water treatment plant.

When procuring treatment plant, the initial costs of material, fabrication, foundations and process equipment are important and immediate considerations. Other recurrent costs which need to be considered in overall economic discussions surrounding a proposed project include maintenance, running costs, possible future alterations and dismantling. Total plant cost is a complex issue because of the interaction of various elements (steel material, corrosion protection, fabrication, transportation, installation *etc*.). Usually, the best design of one aspect conflicts with others. It is not, therefore, simply a case of optimising each to achieve an optimum solution for the whole plant, but rather that the costing should be examined in an integrated, holistic manner. There is more potential for reducing costs of fabrication and installation than of the steel material itself.

This publication seeks to promote the use of steel and stainless steel package plant. The benefits of this form of construction are highlighted and the suitability of steel and stainless steel is discussed. Information on material properties, durability, design, construction and pipework is given. Steel, allied with modern design and fabrication techniques, often provides the shortest and most cost-effective route between specification and an operational plant. A series of case studies illustrates a range of recently installed package plant, giving summary information on site requirements, installation time and materials used in the package plant.

2 WHAT ARE PACKAGE TREATMENT UNITS?

2.1 Types of package treatment units

The term *package treatment unit* is applied to a wide spectrum of plant manufactured and assembled ahead of time, usually at a manufacturing facility remote from the site. A package unit is typically delivered to the site as a skid-mounted unit, pre-piped and pre-wired ready for connecting to the process tanks and mains services, thus saving on installation work and operational downtime.

In the early years of package units, plant size was usually limited to the maximum that could be transported by a truck. However, nowadays, large-capacity package plants can be fabricated in sections and then assembled on site, or multiple units installed in parallel.

The units can be enclosed beneath ergonomically designed covers that reduce odours, noise nuisance and visual impact, allowing installations to be located in close proximity to domestic dwellings.

There is a range of units offering different kinds of treatment process; they are often combined to offer a complete treatment plant.

Package treatment plant is now available for a wide range of potable as well as for waste water and industrial effluent treatment processes. Package plant is often the most cost-effective solution for treating waste water from small communities and recreational areas, from construction sites, military installations and other areas not served by municipal services. It is ideal for emergency supplies (*e.g.*, for treatment works failing their final effluent consent) and for planned temporary systems during refurbishment of filters or rotating biological contactors (RBC). Package units can also provide a first stage of treatment for effluent from industry, particularly the food and drink sector, in order to cut discharge costs.

Some treatment processes for which package units are available include:

- Activated sludge treatment.
- Filtration (including dissolved air flotation (DAF) and biological aerated filter (BAF™)) .
- Screening.
- Separation and settlement.
- UV treatment.
- Treatment by RBC with either integral or separate settling tanks.
- Iron and manganese removal.

BAF™ is a trade mark registered by Copa Limited.

Figure 2.1 shows the layout of a typical steel package waste water treatment plant, fabricated and installed in France, capable of treating waste water from between 100 and 500 persons. The plant has several compartments that can each contain a separate process. Some proprietary examples of package treatment units are given in Figures 2.2 to 2.5.

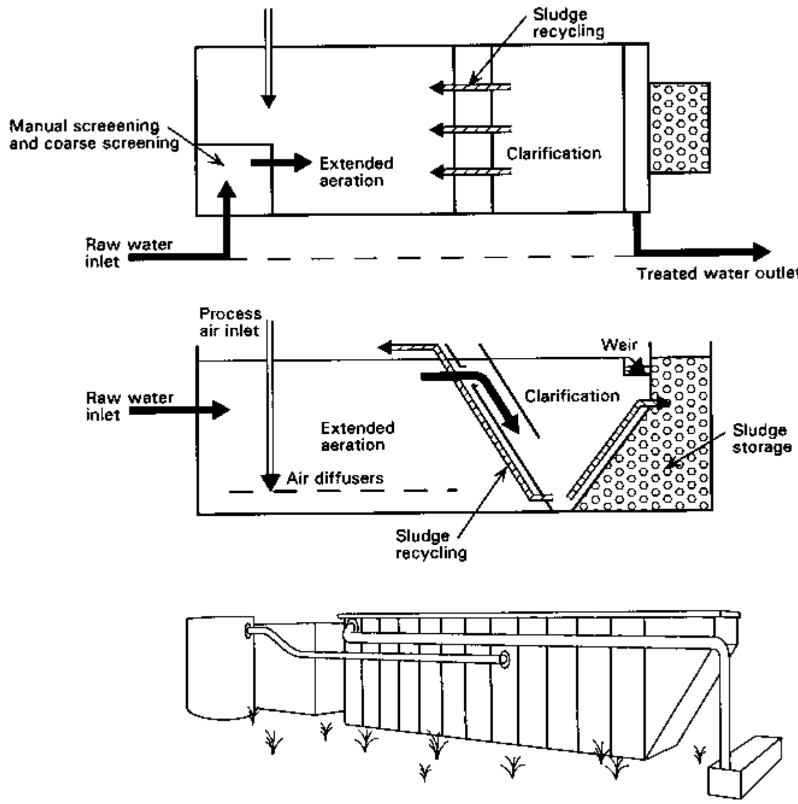
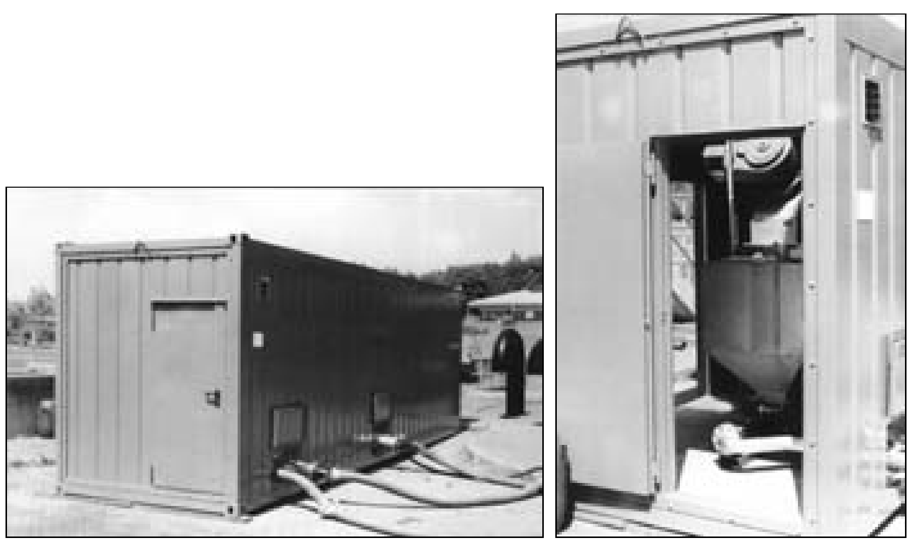
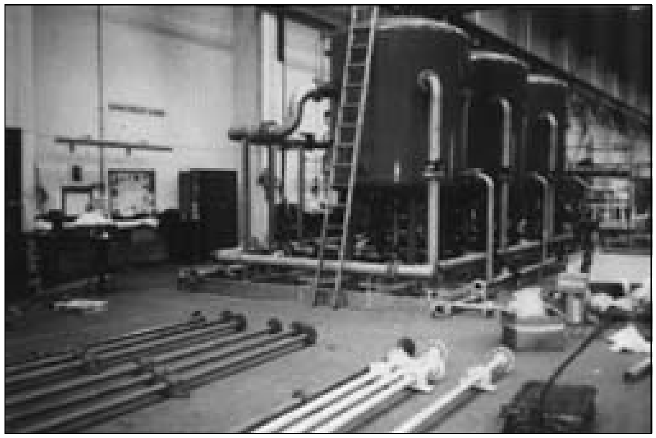


Figure 2.1 *A French “AP Minibloc” steel package wastewater treatment plant for a population of 100 to 500*



Courtesy of Huber Technology

Figure 2.2 *Containerised sludge thickener in a carbon steel container*



Courtesy of Biwater Treatment Ltd

Figure 2.3 *A package iron removal plant assembled in the factory on skids*

Courtesy of Copa Limited

Figure 2.4 *A Biological Aerated Filter (BAF™) unit on a trailer ready to be transported to site. The unit is fabricated in stainless steel and then painted for aesthetic purposes.*

Courtesy of Copa Limited

Figure 2.5 *A BAF™ unit on site and on-line*

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2.2 Advantages of package treatment units

The main advantages of package treatment units are:

Optimal location for the fabrication

Pre-assembly in factory conditions optimises the location of the work and maximises the efficiency and accuracy of the fabrication process. It allows suppliers and contractors to exploit special skills or specialised equipment. Expensive or specialised components can be kept secure until installation in their final position. Difficulties which might be experienced in fabricating on site are avoided.

Improved predictability through pre-assembly

Pre-assembly facilitates production under controlled conditions, often inside a factory or special works, with improved quality, minimisation of rework and reduced vulnerability to bad weather. Pre-installation inspection and testing can be done at the works, leading to early assurance of compliance with specification. Pre-commissioning should also produce a greater awareness of, and provision for, future maintenance requirements.

Improved predictability through standardization

Project teams benefit from previous experience and established solutions that have been tried and tested. It is easier to refine successful methods or products through feedback from practical use without having to check compatibility.

Standardisation improves the prospects for subsequent recycling or reuse of components. It simplifies obtaining extra or replacement components and products that fit the existing process unit for use in maintenance, repairs or extensions. Operators and maintenance staff are also more familiar with common maintenance issues and solutions.

Compact footprint

The compact footprint (the area of land taken up by the package plant) means that units can be employed for small communities or individual establishments. Package plant can be located above or below ground level and tends to be less visually obtrusive than conventional treatment plants constructed on site.

Rapid installation

The cost of the civil work required to prepare the site is significantly reduced. Minimising site activity reduces health and safety risks and lessens the impact on the environment. This is of particular benefit in works at an existing plant where there would be problems of noise, disruption of occupants and security, or where site processes risk local environmental damage. A reduced overall programme time can often be achieved by overlapping activities, *e.g.*, plant is assembled off site while a structure is built on site.

Predictable cost

Pre-assembly reduces the extent of unknown costs such as on site delays and re-work.

Flexible plant capacity

Two or more plants can be connected in parallel for larger applications. Where future requirements cannot be predicted accurately, they can also be used in modular construction allowing further modules to be added as necessary.

Demountable and reusable

The ease of transporting complete units by road makes them ideal for relieving overloaded works and for re-use elsewhere. Package units enable temporary or permanent removal, or replacement with minimum disruption. Expensive demolition costs can be avoided.

Suitable for temporary or emergency measures

Package units can be deployed for temporary or emergency measures until permanent works are constructed, for example, when a major maintenance programme reduces process availability in the permanent plant.

Predictable programme

Standardisation allows timescales for manufacture and assembly to be refined through iteration, such that jobs run to shorter and better-defined timetables. Pre-assembly provides programme control through more predictable factory-type manufacturing procedures and by completing sections of the project off site, in advance of the on site construction period. The project manager can therefore be more definite about the actual construction period and project delivery schedule.

Ease of operation and design for unattended operation

Package units contain pre-installed process control instruments which can be designed for unattended operation. It is often possible to limit operator input to periodic maintenance visits, which is an obvious advantage for treatment plants away from main population centres.

Aesthetics

The approval of package units by local authorities in both rural and urban areas will depend on several factors. Besides restricting the level of noise and odour coming from a package unit, the appearance of these units must also be approved. Steel package plants can be ergonomically designed and fabricated into any shape and painted any colour to suit their environment.

2.3 Package plant for waste water treatment units

Package plant for waste water treatment is typically based on aerobic oxidation of the waste water. Detailed design is undertaken by the manufacturers; prospective buyers need only specify the population to be served and the quality requirements for the effluent from the package plant. Traditional waste water treatment processes which do not require an electrical power supply (*e.g.*, biological filters) and modern processes which do require electrical power (*e.g.*, RBCs) are both available as package plant.

With the implementation of EU legislation in the UK, certain types of plant may need to comply with more stringent standards. For example, the EU Urban Waste Water Treatment Directive[1] was implemented in the UK as the Urban Waste

Water Treatment Regulations 1994[3]; the Regulations require that works discharging to sensitive receiving waters meet either a concentration limit or a minimum percentage reduction in nutrient concentration.

Article 4 of the Directive states that:

Member States shall ensure that urban waste water entering collecting systems shall before discharge be subject to secondary treatment or an equivalent treatment as follows:

- *At the latest by 31 December 2000 for all discharges from agglomerations of more than 15,000 population equivalent.*
- *At the latest by 31 December 2005 for all discharges from agglomerations of between 10,000 and 15,000 population equivalent.*
- *At the latest by 31 December 2005 for discharges to fresh-water and estuaries from agglomerations of between 2000 and 10,000 population equivalent.*

The significance of this progressive lowering of the population threshold at which the Urban Waste Water Treatment Directive comes into force is that further investment in smaller treatment works will be needed to satisfy the requirements. The relatively short time in which the water companies have to construct these secondary treatment works will place package systems at an advantage because of their quick fabrication, transportation and installation.

There are few British Standards that are directly applicable to steel package waste water treatment units. For the smaller units (serving populations up to 1000), the current British Standard for the design and construction of waste water treatment plant is BS 6297 *Code of practice for design and installation of small sewage treatment works and cesspools*[4].

A draft CEN document[5] dealing with the design, construction and testing of package plant serving populations of 50 or less has been written to harmonise existing standards in Germany, Norway and the UK. It covers plant dimensions, treatment capacity, watertightness, structural requirements, durability, testing, marking quality control and instructions for installation, operation and maintenance. When implemented, it will supersede BS 6297 for works serving populations of 50 or less.

Water Industry Specification WIS 4-25-01[6] contains relevant information relating to the design and construction of rectangular and cylindrical steel tanks in open and closed operations.

3 WHY USE STEEL FOR PACKAGE TREATMENT UNITS?

Suitable materials for package plant include glass fibre reinforced plastics (GRP), polyethylene, concrete, steel and stainless steel. Pipework is typically carbon steel, stainless steel or plastic.

Whereas GRP is fairly widely used for small-scale package plant units (serving population equivalents up to about 200-300), it tends to become less economical for larger units which place higher strength and stiffness demands on the construction material.

Steel and stainless steel are ideal materials for use in package plant and provide very cost-effective solutions compared to other materials. The main reasons for manufacturing package plant from steel are summarised below:

(1) Predictable quality

Steel is a factory-made product, with all the operations of manufacture tightly controlled; so the resulting material is of highly consistent quality. Its properties and strength are known long before it is incorporated into a product.

(2) High strength to weight ratio

Steel is an inherently high strength material, with strength characteristics higher than most other construction materials. It is a very efficient structural material, with a high strength to weight ratio, which means that less mass is required to achieve a given load capacity system, and which in turn can permit smaller structures with a smaller footprint. This also means less total mass, with all the inherent savings that this implies, including the possibility of smaller foundations. There is less weight to lift and transport, and less imposed loading on the foundations. However, 'minimum weight' designs can be uneconomic, since excessively 'refined' design usually introduces so much complication to detail that savings in material are often swallowed up by the extra cost of fabrication.

(3) Ease of fabrication

Structural steel lends itself to a variety of fabrication processes. It can readily be converted from the mill product (sheet, strip, plate and profiled sections) into the finished fabricated piece. These processes include cutting by shearing, flame cutting or sawing; hole making by punching or drilling; shaping by bending or rolling; and joining by welding or by mechanical means. Steel members can be fabricated to a high degree of accuracy with tolerances kept to a minimum.

(4) Suitability for shop fabrication

Structural steel is particularly suitable for shop fabrication and can be easily pre-fabricated under controlled conditions. This provides a real potential for time saving on the construction site, and it also means that site work can be reduced to simple handling and assembly operations. Also, depending on the circumstances, size of shop pieces need only be limited by economics of shipping, handling and erection. The fabrication shop is the ideal place to apply protective finishes.

However, unrealistic rules for quality and inspection of steel structures should not be imposed. Since it is relatively easy to inspect steel fabrications in the shop, it is also easy to over-inspect, without any real value being obtained for the extra money spent.

(5) Environmentally friendly

In environmental terms, steel is not 'used', it is only 'borrowed' for its current role and is returned at the end of its life for recycling. Steel is unique among major construction materials in that it always contains recycled content; it is completely recyclable at the end of its product life and may be recycled without loss of quality.

(6) Adaptable

Structural steel provides maximum adaptability for changes in the use of a unit, because structural alterations can usually be accommodated with relative ease. Where additional members are required, connections can be made to the existing frame with minimum disturbance and cost.

(7) Installation possible in adverse weather conditions

Often complete steel structures can be installed in conditions where no other material is appropriate, *e.g.*, in sub-zero temperatures where the casting of concrete would not be possible.

The additional advantages of using stainless steel for package plant include:

(8) No protective coatings or corrosion allowance are required

There is no dependence upon applied coatings (organic, polymeric, cementitious or metallic) for corrosion protection. Hence, no allowances for corrosion loss are required at the design stage, no constituents of the coatings are lost into the water and no coating maintenance is required. Any design constraints that arise from having to apply surface finishes are also removed.

(9) Good abrasion resistance

Stainless steel has excellent wear-resistant properties which are particularly important for mechanical systems. Wear resistance results in low maintenance costs and long life, even in installations subject to cyclic vibrations.

Note that although the raw material cost of stainless steel is higher, weight for weight, than carbon steel, the overall installed cost of plant using stainless steel may be less, particularly if whole life costs are considered.

4 STEEL MATERIAL

Carbon and stainless steels are efficient and versatile materials for structural purposes because of their high strength-to-weight ratio. Mechanical properties are expressed in terms of the results of tensile tests giving yield strength, ultimate strength and elongation to failure.

This Section gives a brief summary of the material properties and designation systems of carbon steel and stainless steel. A list of the principal Standards relating to the materials is given in Appendix A; individually numbered references are not given in the text.

4.1 Carbon steel

4.1.1 Designation

Structural steel material grades are currently designated using a four-character reference code that indicates the specified material yield strength (in N/mm^2). The most common grades are S275 and S355 (these correspond to grades formerly referred to as 43 and 50 respectively, to the now withdrawn BS 4360). Additional characters are sometimes added to indicate other properties, such as toughness.

4.1.2 Standards for sections, plate and strip material

Hot rolled sections and plate are usually specified to BS EN 10025; hollow sections are specified to BS EN 10210. In both Standards, grades S275 and S355 are available. Thin material is referred to as ‘strip’ or ‘sheet’ and is specified to one of a number of Standards, usually to BS EN 10111, BS EN 10130 or BS EN 10139; galvanised strip is specified to BS EN 10142.

4.1.3 Properties

Carbon steel generally behaves as a linear elastic material with a high and relatively constant value of elastic modulus up to yield (proof) strength. It has a high capacity for accepting plastic deformation beyond the yield strength, which is valuable for drawing and forming of different products, as well as for general ductility in structural applications.

Structural steel is often required to have toughness (against brittle fracture) when it is subject to tensile stresses at low temperatures. Adequate toughness is readily attainable with commonly available grades; where required, a designation, such as JO or J2, is added to the strength grade designation. The lowest temperature that the steelwork will experience depends on the location and exposure of the structure.

All steels to the above-mentioned Standards are weldable, although for thicker materials there are limitations on the weld procedures that can be used; preheat may be needed during welding.

4.2 Stainless steel

Just as there is a range of structural and engineering carbon steels meeting different requirements of strength, weldability and toughness, so there is a range of stainless steels with progressively higher levels of corrosion resistance and strength. To achieve the optimum economic benefit from using stainless steel, it is important to select a grade that is adequate for the application without being unnecessarily highly alloyed and costly. Austenitic stainless steels are the most widely used grades of stainless steel in water industry applications. Duplex stainless steels are occasionally specified in particularly aggressive environments.

4.2.1 Designation

Material grades for stainless steel are designated according to BS EN 10088 using a 1+4 digit reference code, such as 1.4301. However, stainless steels have been know for many years by a three digit code (sometimes plus an extra letter) in accordance with the (now partly superseded) British Standards and AISI system, for example, 304. It is currently common to refer to either or to both references.

4.2.2 Properties

The stress-strain behaviour of stainless steel differs from that of carbon steel in certain respects. Austenitic stainless steel does not follow the linear elastic behaviour typical of carbon steel and does not reach a clear yield point. Instead, stainless steel proof strength is defined for a particular offset permanent strain (conventionally the 0.2% strain). BS EN 10088 gives minimum specified 0.2% proof strengths of the common austenitic grades as around 220 N/mm^2 and for the duplex grade 1.4462 (2205) as 460 N/mm^2.

The difference in stress-strain behaviour has implications on the design strength and the deflection of stainless steel components. The issues are discussed in an SCI Design Guide[7] and updated in a new publication[8].

Austenitic stainless steels are characterised by good toughness and fatigue resistance and therefore have long life even in installations subject to cyclic loading. They are essentially non-magnetic, but may become slightly magnetic when cold-worked.

Compared with carbon steels, austenitic stainless steels have 30-50% greater thermal expansion and 30% lower thermal conductivity. These differences can be readily accommodated by appropriate welding practice and by allowance for more expansion in long or restrained pipe runs.

4.2.3 Corrosion resistance

Standard austenitic grades are capable of meeting most of the corrosion conditions encountered in water treatment and handling equipment. Grade 1.4301 (commonly known as 304) is a widely used grade with 17-18% chromium and 8-11% nickel alloy content. Grade 1.4401 (commonly known as 316) contains molybdenum which improves pitting and crevice corrosion resistance.

Duplex stainless steels are stronger, and have better resistance to certain forms of corrosion than standard austenitic grades.

5 DURABILITY

Selection of coated carbon steel or stainless steel for a particular application depends on an evaluation of all the technical and economic factors which will affect a project throughout its entire operating life.

5.1 Carbon steel

5.1.1 Introduction

Carbon steel corrodes in the presence of oxygen and water. However, modern, durable protective coatings for steel are available which provide corrosion protection and allow extended maintenance intervals. Methods of protection against the corrosion of carbon steels are described below. Appendix A lists Standards for preparing and applying coatings to protect steel against corrosion.

In all cases, the application of a coating system should be carried out in accordance with the coating system's manufacturer's recommendations. Each coat should be of a different colour, of uniform thickness and free from runs and imperfections. It is important that the coating system used should correspond to the substrate and be appropriate to the environment of exposure.

Though it may add considerably to the packing and transport costs, it is very important to handle the material with great care after a protective coating has been applied.

5.1.2 Surface preparation

The durability of modern high performance protective coatings depends to a great extent on the condition of the steel surface at the time of application. The surface preparation of steel is essentially concerned with the removal of rust and millscale to ensure it is free from contamination. Various methods are described in BS 7079-Al and the equivalent ISO 8501-1. Methods of surface preparation include blast cleaning, hand and power tool cleaning, wet (abrasive) blast cleaning and ultra high pressure water blasting.

5.1.3 Metallic coatings

There are basically two methods of applying metal coatings to structural steelwork; hot-dip galvanising and metal spraying. The corrosion protection provided by metallic coatings is mainly dependent not on the method of application but on its thickness.

Hot-dip galvanising. The most common method of applying a metal coating to structural steelwork is by galvanising. The process involves:

(a) cleaning the steel from all forms of rust, either by blast-cleaning or "pickling" in acid,

(b) dipping the steel into a bath of molten zinc during which the two react to form a series of zinc/iron alloys on the steel surface, and

(c) removing the steel from the bath during which a layer of pure zinc forms on top of the alloys.

The thickness of the galvanised coating is influenced by various factors, such as the steel surface, the steel composition, the size of the workpiece and the duration of dipping.

The specification of hot-dip galvanised coatings for structural steelwork is covered by BS EN ISO 1461.

Metal spray coatings. In this process, a metallic coating of either zinc, aluminum or a zinc-aluminium alloy is sprayed onto the structural steelwork. (Sprayed aluminum coatings are not generally used in the water treatment industry.) The metal, in powder form, is fed through a special spray-gun containing a heat source. Molten globules of the metal are blown by a compressed air jet onto the previously blast-cleaned steel surface. The coatings can be applied in the shop or at site and there is no limitation on the size of the workpiece as one would find with hot-dip galvanising.

The protection of structural steelwork against atmospheric corrosion by metal-sprayed aluminum or zinc coatings is covered in BS 2569. Other British Standards relating to metal spray coatings are BS EN 22063 and BS EN ISO 14713.

In addition to galvanising and metal spraying, a whole range of methods can now be used to modify the surface properties of carbon steel, for example, the local application of a cobalt alloy coating. This can be a more economical approach than making a whole component from a higher grade of steel. Cobalt alloy coatings have good resistance to erosion, cavitation and adhesive wear, combined with good corrosion resistance.

5.1.4 Paint coatings

Painting is the principal method of protecting structural steelwork from corrosion and is usually applied as a series of coats. The standard methods used for applying paints (brush, roller, air-spray) have a significant effect on the quality and durability of the coating. The principal conditions which affect the application of paint coatings are temperature and humidity; these can be more easily controlled under shop-conditions than on site.

Epoxy coatings are supplied as two separate components, usually referred to as the base and the curing agent. When these two components are mixed (immediately before use), a chemical reaction occurs. Both solvent-based and solvent-free epoxy coatings are available. Solvent-free epoxy coatings can be applied as very thick films, often in a single coat.

The new European Standard covering protective paint systems is BS EN ISO 1244 which partially replaces BS 5493. Black bituminous solution for cold application should comply with BS 6949 for general purposes, and BS 3416 where in contact with potable water. To avoid the possibility of the presence of carcinogenic polyaromatic hydrocarbons, all bituminous paints and coatings should be manufactured from petroleum or asphaltic bitumen and not from coal tar bitumen. Hot applied coatings should comply with BS 4147.

5.1.5 Vitreous enamel coatings

Vitreous enamel is created by a process of vitrifying inorganic material at high temperature; these coatings are therefore often referred to as 'glass coatings'. Because they are formed by baking in a furnace, the coatings can only be applied to prefabricated panels at the works. When such coating is used for tanks, *etc*., the components must be joined by bolting, since welding would destroy the coating in the vicinity of the weld. Vitreous enamel coatings are extremely durable but are susceptible to mechanical damage during handling, erection and throughout their service life. They are not widely used in package plant, but are a common method of protecting steel tanks in the water industry.

5.1.6 Water Industry Specifications

Water Industry Specification WIS 4-52-01[9] is a performance-based specification covering the broad range of polymeric coating types used within the industry. It includes a range of performance tests relating to the physical characteristics and performance of coatings, *e.g*., adhesion, penetration, wear, impact, and flexibility.

The Information and Guidance Note 4-52-02[10] prepared in parallel with the WIS gives guidance on the use of such coatings in the following areas:

- The design of metallic fittings, pipework and structures which are to be protected with polymeric anti-corrosion coatings.
- The selection of polymeric anti-corrosion coatings for the protection of metallic fittings, pipework and structures.
- The packaging and handling of products protected with polymeric anti-corrosion coatings.

The Water Industry Mechanical and Electrical Specification WIMES 4-01[11] is a specification for protective coatings for use in the water industry, closely based on BS 5493 now partially replaced. It deals with surface preparation, application of the coating system, materials and coating quality. Tables for a range of environments and substrates give recommendations for surface preparation and protective systems.

All materials in contact with water for public supply must take account of the water contact requirements of the Drinking Water Inspectorate (DWI), where appropriate.

5.2 Stainless steel

Stainless steel alloys contain a minimum of 10.5% chromium. Unlike carbon steel, stainless steel has a natural corrosion resistance; exposure to air or water results in the spontaneous formation of a thin, stable, chromium-rich oxide film. This film provides a high degree of protection that reforms rapidly if damaged by abrasion. Consequently, the material can be used and exposed without any applied coatings. In areas where there are extensive maintenance requirements with consequential risk to surface coatings, stainless steel would be the preferred material.

Standard austenitic stainless steels such as grade 1.4301 (304) and 1.4401 (316) are capable of meeting most of the corrosion conditions encountered in water treatment and handling equipment. The molybdenum containing alloys, for example grade 1.4401 (316), are more resistant to localised corrosion and are preferred for more aggressive conditions or simply for greater insurance against unusual conditions which may arise. A wide range of more highly alloyed, special stainless steels is available for applications where greater corrosion resistance is needed. For higher strength, a duplex stainless steel may be suitable.

Good system design and maintenance of good fabrication practices are essential to obtain the optimum performance from stainless steels, whatever the grade selected. The recent Water Industry Information and Guidance Note 4-25-02 *Applications for stainless steel in the water industry*[12] gives the following recommendations on the choice of grade of stainless steel to ensure durability:

- 304 types are suitable for use in most flowing water systems at ambient temperature, where chloride levels are less than 200 ppm. Oxidising treatment additions will reduce this limit. They are well suited to applications where abrasion and erosion resistance are required, as in screens and grids.
- The molybdenum-containing 316 types have a higher corrosion resistance and may be used for waters with chloride levels of up to around 1000 ppm.
- The presence of oxidising agents such as chlorine increase the possibility of crevice corrosion for a given level of chloride in waters. Trials in US plants with flowing raw waters with less than 23 ppm chloride indicate that the 304 types can be used for chlorine levels up to the highest level investigated, 2 ppm. The 316 types offer a greater margin of corrosion resistance.
- In areas of plant where moist chlorine vapours may collect and concentrate, good ventilation or, if not possible, a more corrosion resistant grade of stainless steel may be required. Regular washing with potable water also avoids chloride build-up caused by chlorine.
- For optimum corrosion performance in the as-welded condition, the low carbon ‘L’ grades should be specified.

Occasionally, stainless steel equipment is painted externally for aesthetic reasons or for protection against a local chloride or aggressive solution. It may also be painted as a precaution against bimetallic corrosion of the less noble material to which it is connected. Paint manufacturers should be consulted for advice on the correct surface treatment, primer and finishing coat combinations suited to a given environment.

5.3 Designing for durability

The prevention of corrosion should be a consideration during the design stage of a project. Good detailing often has very little cost implication but can have an important bearing on the corrosion performance of a component. The main points to be considered are:

Avoid the entrapment of moisture and dirt

Examples of good practice are:

- Avoiding the creation of cavities and crevices *etc*.

- Using welded joints rather than unsealed bolted joints.
- Avoiding lap joints (or sealing them properly if they are needed).
- Sealing the abutting surfaces between the two parts of a connection using high strength friction grip bolts.
- Providing drainage holes for water, where necessary.
- Sealing box sections.
- Providing free circulation of air around the structure.

Avoid contact with other materials

Bimetallic connections should be avoided wherever possible. If they are necessary, the contact surfaces should be insulated (see PD 6484 *Commentary on corrosion at bimetallic contacts and its alleviation*).

Ensure that the selected protective coatings can be applied efficiently

Examples of good practice include:

- Providing adequate access for thermal spraying, paint spraying *etc*.
- Providing access for subsequent maintenance.
- Simplifying the shape of the components to be coated – large flat surfaces are easier to protect than more complicated shapes.
- Ensuring that an adequate protective coating is applied to sharp edges and corners, for example by 'stripe coating' (an additional locally applied coat) or by the rounding of the corners or edges.
- Removing weld profile irregularities.
- Locating load bearing members in the least corrosive locations, where possible.

Minimise the risk of damage to coatings

Lifting lugs or brackets should be provided where possible to reduce damage during handling and erection.

6 DESIGN AND CONSTRUCTION

6.1 Good practice in design

The processes used in fabrication and erection should be considered during design to ensure that unnecessary cost is avoided, for example:

- Material is cheaper when ordered in bulk. Small quantities of different sizes should be avoided as far as possible.
- The number of pieces to be handled should be reduced to a minimum and excessive stiffening of members avoided.
- Allowance should be made for weld distortion and fabrication tolerances.
- Automatic fabrication techniques reduce costs.
- The cost of delivery, particularly overseas, can be reduced by careful design.
- Good quality control is essential but specifications should not be unnecessarily stringent, since this will increase costs.

The detailing of structural steelwork, *i.e.*, the way in which the various individual pieces are cut and joined together, has a direct influence on the ease or difficulty of construction, on the cost, and on the performance of the structure in service. The latter will have a direct influence on maintenance requirements which in turn affects costs. For example, every opportunity should be taken to locate welds in such positions so that the welder has good access to produce smooth, sound welds.

The cardinal rule is that, relatively, labour is expensive but material is cheap. At a detailed level, standardisation, particularly of connection and fixing details, can lead to significant economies, even if it implies some apparent wastage of steel.

Good design should aim to minimise material handling and preparation. For carbon steel, fabrication procedures and sequencing may be influenced by the corrosion protection required to the steelwork.

The designer should take into account the effects not only of the design upon maintenance painting, but also the influence of the initial coating system. For example, galvanised steelwork can only be safely over-coated when all soluble corrosion products are removed. Once removal of these products is achieved, a wide range of paints (*e.g.*, drying oil based, one or two pack chemical resistant) can be used. Etch primers are available which assist adhesion to the zinc surface.

Section 5.3 recommends some design details which promote durability.

There are loading restrictions on vehicles in terms of weight, width, height and length and this should be considered in the design of the package plant size.

For most manufacturers and users, the plant needs to comply with statutory requirements and Building Regulations, and be in accordance with the relevant British or European Standard. CE marking is required for new package plants supplied or placed into service after 1 January 1995, to comply with the general safety requirements for machinery and electrical equipment[13]. There are few

British Standards that are directly applicable to steel package units. The general building steelwork design code, BS 5950, can be used for the evaluation of the design strength. Guidance on design loads can be obtained from tank codes such as BS 2654. (See also Water Industry Specification WIS 4-25-01 *Specification for the use of steel tanks in the water industry*[6].)

6.2 Fabrication

Fabrication involves handling, storage, cutting, forming and welding.

BS 5950: Parts 2 and 7 cover the fabrication and erection of hot rolled and cold formed steel sections, respectively. The National Structural Steelwork Specification also contains useful information on fabrication and erection.

ENV 1090 is the recent European standard covering the fabrication and erection of structural steel (Part 1 deals with carbon steel and Part 6 with stainless steel). Appendix A of this document gives the full references.

6.3 Handling and storage

6.3.1 Carbon steel

Storage areas on site should be firm and level with wooden sleepers or other suitable material placed on the ground at regular intervals to act as bearers. Where possible, members should be stored so that water does not collect in webs and hollows.

Where structures can distort under their own weight when lifted, stiffened lifting points should be provided.

6.3.2 Stainless steel

Cleanliness is a very important aspect of all operations with stainless steel. Stainless steel should be inspected immediately after delivery for any surface damage.

Material is best stored under cover, both for security reasons and to prevent accumulation of dust and deposits, particularly in industrial or marine locations. Dry storage is preferred, especially if a wrapping that might absorb water and stain the surface, such as cardboard, has been used. Carbon steel racking for stainless steel requires protection, usually by wooden slats and runners. These should be inspected regularly to prevent scratching of stock by exposed fastenings.

Iron particles embedded in stainless steel surfaces during fabrication are a cause of ‘surface rusting’ on commissioning. When carbon steel lifting or handling equipment such as strapping, crane hooks, chains or rollers are being used, appropriate protective material should be placed between the stainless steel and carbon steel to prevent damage. Clean, heavy cardboard or light plywood are suitable materials for this purpose. Stainless steel slippers or wooden packers, for example, should be used on fork-lift trucks to prevent contamination.

Segregation of materials (carbon steels from stainless steels from non-ferrous metals) during storage, handling and fabrication is critical. Where necessary, a means of protecting the surface of stainless steel components during transportation, storage and erection should be given.

6.4 Cutting and forming

6.4.1 Carbon steel

In thin sections, such as sheet material, steel can be cut satisfactorily by guillotine shearing and although this may form a hardened edge it is usually of little or no consequence for these thin materials. Thicker material in structural sections up to about 15 mm thickness can also be cut by heavy-duty shears, useful for small part pieces such as gussets, brackets *etc*. Flame cutting is carried out using an oxyacetylene torch to burn the steel away in a narrow slit and this is widely used for cutting thicker sections in machine-controlled cutting equipment.

Steel can be bent, formed or drawn into different shapes. For example, the curved sections of tubular members and cylindrical parts of vessels are often rolled from flat plate to the required curvature.

6.4.2 Stainless steel

Thermal (*e.g.*, plasma and laser) and cold cutting techniques can be used on austenitic stainless steels; the steel can be guillotined, sheared and sawn on normal machine tools. When shearing and guillotining, the capacity of the equipment should be down-rated by 50-60% relative to carbon steels, because of the work hardening characteristics of the austenitic grades. The heat affected zone should be removed before further processing is undertaken.

Stainless steel can be cold formed, but, as with cutting and shearing, cold forming equipment for stainless steels needs to be of adequate rigidity and power to cope with the higher work hardening rates. Allowance must also be made in bending and rolling for the greater spring-back characteristics of stainless steels. Austenitic stainless steels retain their ductility after forming to a greater extent than carbon steels.

As with storage and handling, contamination from iron particles by pressure contact with rollers or tooling must be avoided. Local application of adhesive plastic films or tape can be used to prevent direct contact.

6.5 Welding

6.5.1 General issues

Welding offers a means of making continuous, load bearing, metallic joints between the components of a structure. A welded joint is made by fusing parent metal from both components being joined, usually with added weld metal. The properties of both the weld metal and the surrounding heat affected zone may differ from those of the parent metal.

Welding should be undertaken in accordance with a written and approved welding procedure, and the welder should be qualified for the welding procedures being used. British Standards BS EN 287 and BS EN 288 cover the approval procedures.

BS 5135, now partially replaced by BS EN 1011-1, specifies the general requirements for the arc welding of steels. Examination procedures and weld acceptance criteria are laid down in a number of British and European standards.

6.5.2 Stainless steel

Austenitic stainless steels are readily weldable by manual or automated techniques. All the normal arc welding processes for both shop and site welding can be used. A specification for the arc welding of stainless steels is given in BS EN 1011-3.

Use of a balanced welding technique is a factor in countering the risks of distortion from the combined effects of the low thermal conductivity and high thermal expansion coefficient of austenitic stainless steels.

Austenitic steels do not normally require preheating prior to welding nor post weld heat treatment.

Stainless steel can be welded to carbon steel using well-known technology and standard equipment. Normal considerations for preheating according to, for example, BS 5135, must be applied to the carbon steel side of the joint.

The optimum corrosion performance of stainless steel welded joints is achieved by removing crevice features and all weld heat tints by mechanical dressing or cleaning as necessary and then acid pickling and passivating the joint. For optimum corrosion performance, oxide films and any dechromed layers beneath them must be removed.

For mechanical cleaning, all abrasive media must be iron-free. Wire brushes must be made of a suitable grade of stainless steel wire to avoid contamination.

Further information on welding is given in Reference 12.

6.6 Installation

6.6.1 General

By its nature, site work tends to be more costly than shop work. The philosophy inherent in package units is to minimise time on site by prefabricating the unit so that it can be delivered on site in a virtually finished state, simply needing to be lifted into position and hooked up. Since the unit is completed within factory conditions, fabrication cannot be delayed or disrupted due to adverse weather conditions.

In all cases, package treatment units should be installed in accordance with the manufacturer’s instructions. The installation sequence should be clearly specified, particularly if there is the possibility that an incorrect installation sequence could lead to instability of the structure.

In all handling and slinging operations it is very important to try to minimize damage to a painted coating. Wherever possible, non-metallic slings should be used, as they will reduce the risk of damage to paintwork; they are also less likely to slip than chain or wire slings.

6.6.2 Stainless steel

Prefabricated assemblies should be protected from dust, mechanical damage and contamination. Iron contamination can be removed by applying a nitric acid based cleaning and passivating agent.

The plant should be washed down with potable grade water at the end of installation operations.

6.7 Maintenance and inspection

Timely maintenance is necessary to ensure the successful long-term operation of any package plant. Any repairs and modifications must be designed, specified and executed to the same standards as for original fabrication. It is essential that manufacturers of package plant provide adequate maintenance instructions.

Particular circumstances which can result in inadequate maintenance are joint ownership (where responsibility for maintenance is unclear) and change of ownership, where the owner is not aware of the maintenance requirements.

6.7.1 Carbon steel

Regular inspection of the plant and proper routine maintenance prevents major remedial work being necessary to the corrosion protection.

Maintenance needs should be determined by means of planned inspections made at regular intervals. Comparing the inspection results with reliable records of the first and subsequent inspection gives the basis for defining maintenance requirements.

The choice of a maintenance paint process depends on the existing coating and its condition, the standard of surface preparation that is possible, the working environment, the time available, safety requirements, access and economic considerations.

The decision whether maintenance is to be by patch painting or a complete recoat is influenced as much by access as by the state of the existing work. For example, if much scaffolding is required it may be more economical to repaint overall rather than carry out several touch-ups.

6.7.2 Stainless steel

Regular inspection and, if necessary, routine maintenance will ensure the long life of stainless steel plant. It is important that the build-up of dirt deposits and crevice conditions on both the inside and outside of components is avoided. At non-coastal sites, free exposure to rainwater is often enough to keep most stainless steel components clean, with periodic washing down of shadowed or dribble regions as necessary. In marine, salt spray environments and in enclosed chambers where there is chlorine present in the atmosphere, regular wash-down procedures should be followed.

It is unlikely that a problem of general corrosion (extensive and generally uniform loss of section) will be encountered with stainless steel. Accordingly, wall thickness checks using appropriate ultrasonic equipment will normally apply only to regions which are subject to abrasive wear.

The main objective of inspection will be to check for any localised corrosion at critical locations. These may include, on external structures:

- Dirt and deposit traps sheltered from rainwater washing and regions exposed to evaporating liquids from leaks and dribbles.
- Any sites of brown staining. On newly commissioned plant this is often a result of undetected iron contamination which only becomes apparent early in the life of the plant. Once the iron contamination is detected and removed, this staining does not recur. Recurrent brown staining is an indication of the presence of an unexpected corrosive agent and should be investigated.

7 PIPEWORK

Pipework is an essential element in any water or waste water treatment plant. Pipework may be required within any package unit, will be needed to connect the unit to other parts of the system and may even comprise the majority of a separate package unit within a treatment plant.

7.1 Stainless steel pipe

7.1.1 Stainless steel pipework systems

There is a range of material to choose from for pipework (as summarised in Section 7.2) but the material that complements best the high quality off site construction characteristics of package units is stainless steel.

The use of stainless steel pipe is already popular amongst specifiers and fabricators in the water industry owing to its high quality, flexibility of use and ease of installation. The total installed cost of stainless steel is generally less than that for carbon steel piping because of savings in assembly, connection and installation costs.

The selection of a piping system is dictated by its suitability for the operating conditions, ease of installation and cost considerations. Three systems of stainless steel process piping are commonly used, each having its own attributes and benefits:

Lightweight Metric

This system is characterised by having a uniform bore diameter through tube and fittings for any one specified pipe size, with wall thicknesses of 1 to 10 mm. It offers a lightweight pipe design solution where free flow of liquids and semi-solids is required at up to 16 bar pressure. Lightweight Metric pipework is easily demountable.

ANSI

This has traditionally been the standard system for process piping worldwide. It was developed from American carbon steel specifications for high pressure and high temperature requirements. It is suitable for pressures up to 100 bar.

ISO

This is the International Standard for process piping utilising ANSI outside diameter sizes but with more appropriate wall thicknesses, reflecting the strength and corrosion resistance of stainless steel. It is suitable for pressures up to 40 bar.

The above systems are all suitable for operating conditions up to 150°C. They are readily available in 304 and 316 types of stainless steel with inside diameters from 4 mm to 1200 mm.

7.1.2 Design, welding procedures and installation

Good pipeline design, fabrication and maintenance are essential to obtain the optimum performance of stainless steels, whatever the grade selected[14]. Wherever possible, pipelines should be designed to allow regular internal wetting in order to minimise the formation of salt and other deposits on drying out. In sludge lines, stagnant and low flow conditions should be avoided, to inhibit under-deposit corrosion (free flowing conditions assist in reducing deposit formation).

For thin-walled stainless steel pipework, the mounting methods have to incorporate appropriate cushioning to provide the acoustic damping required to avoid vibration under any pressure pulsing.

High quality welding procedures should be developed that are appropriate to the grade of stainless steel pipework being used. In choosing a weld procedure the following considerations should be taken into account:

- Circumferential welds should achieve a smooth profile.
- Welds in areas exposed to sludge (the outside of aeration piping and the inside of digester and sludge piping) should avoid all deposit traps, ridges and crevices as far as possible.
- Weld preparation and access for welding should be such as to achieve optimum geometry of the weld, ease final finishing and avoid harmful heat tint formation.
- Use of inert gas backup on the inside of the piping during welding to minimise oxidation and heat tint.
- The use of matching composition or higher molybdenum content weld consumables.

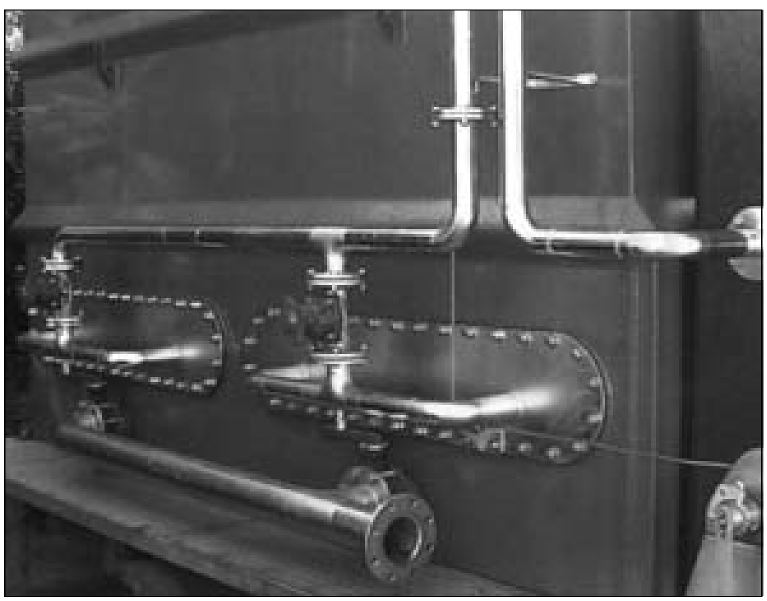
After welding, pickling is needed to remove heat tint scale, embedded iron or other pit-initiating defects from the weld and metal surfaces. Pickling is carried out in acid vats or by the application of pastes and mild acid solutions to the potentially contaminated areas, followed by thorough neutralising washes to remove any excess acid and paste residues from the metal surface.

After hydrostatic pressure testing has been carried out, pipelines should be drained completely. Where, for any reason, unavoidable deposits can occur along the pipeline, ports should be provided to allow access for cleaning. When a plant is shut down for a prolonged period of time, the pipework should be kept wet by circulating water for a minimum period every couple of days. Alternatively, the pipework should be flushed with clean water, drained completely and blown to dry out.

Figures 7.1 and 7.2 show stainless steel pipework in package plant.

Courtesy of Biwater Treatment Ltd

Figure 7.1 *Skid mounted stainless steel pipework assembly for a package plant*



Courtesy of Copa Limited

Figure 7.2 *Stainless steel pipework in a BAF™ package plant*

BAF™ is a trade mark registered by Copa Limited.

7.1.3 A summary of recommendations for good practice

The following list summarises a number of recommendations for good practice in design, construction and operation of stainless steel pipework.

Design

- avoid stagnant and low flow conditions,
- avoid geometries which might allow chlorine to be trapped and concentrate in the vapour space,
- piping exposed to sludge should be joined by smooth, contoured and crevice-free circumferential butt welds,
- avoid gaskets with leachable chlorides,
- specify stainless steel type 316 where chlorides exceed 200 ppm or where residual chlorine exceeds 2 ppm.

Construction

- pickle to remove embedded iron and heat tint scale,

Operation

- remove deposits and keep piping clean,
- aerate and agitate sludge to reduce its tendency to adhere to the surface of the piping,
- thoroughly clean off the sludge from the outside diameter of the piping when the aeration basin is taken out of service,
- avoid over-chlorination.

7.1.4 Comparison with other pipe materials

Although the raw material cost of stainless steel is higher, weight for weight, than some alternative materials, the overall installed cost of plant which utilises stainless steel pipes may be less. Savings are achieved in the following ways:

- Corrosion-resistant coatings are unnecessary; so there are no costs associated with applying them or maintaining their integrity during or after fabrication.
- Fixings and components can be smaller and lighter because of the higher strength of stainless pipe.
- Pipework systems are easier (and cheaper) to transport and install because they are lighter.
- The high resistance to erosion means that smaller bore, thinner-wall pipes can be used.
- With thin wall tubing, it may be possible to form tee joints by trepanning a hole and then pulling a lip on it. The adjoining member can then be attached by means of a simple circumferential weld onto the material ‘pulled’ from the tube wall.

The Water Industry Information and Guidance Note Applications for stainless steel in the water industry[12] gives a comparison between the initial costs of 6 m runs of stainless steel, carbon steel and ductile iron pipework. Cost and weight savings that arise from using stainless steel result from the elimination of corrosion allowance and coatings and the simplification of joining and assembly made possible by using stainless steel. Additional advantages (not taken into account in this cost comparison) are that spooled pipework assemblies in stainless steel allow compact layouts. This, together with the reduced weight for lifting, helps to achieve a small site footprint.

7.2 Plastic, carbon steel and ductile iron pipe

Plastic pipe

Plastic piping, chiefly polyethylene and ABS, is used widely in the water industry. It is lightweight and has good durability. Plastic piping is generally regarded as being competitive with steel pipework for lower pressures, say less than 10 bar, for temperatures up to about 80°C and for sizes up to about 100 mm nominal bore.

GRP pipe

GRP piping is occasionally used in the water industry, tending to be competitive with steel for the larger nominal bores ranging from approximately 150 mm to 600 mm.

Carbon steel pipe

Epoxy-coated carbon steel pipe is only rarely used in package treatment units. It is generally not as suitable as stainless steel or plastic pipe in respect of durability.

Where it must be used in order to connect to existing coated carbon steel pipe that is adjacent in an existing process treatment line, care should be taken to ensure compatibility of bolted flanges and gaskets with the previous specification used.

Ductile iron pipe

Ductile iron pipework is not commonly used in package units as it generally comes in larger diameters and is more suitable for heavier duty applications.

8 CASE STUDIES

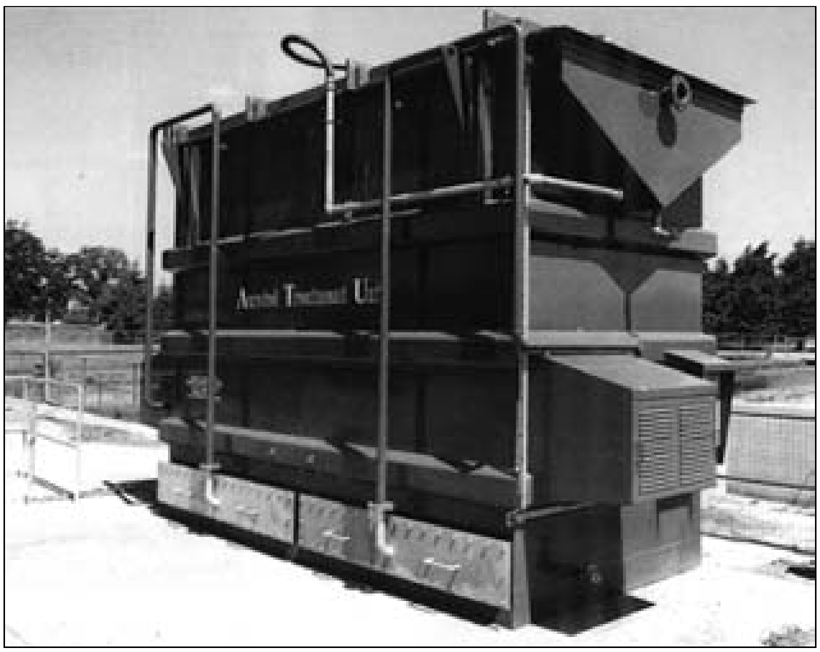
This Section gives 17 brief case studies which demonstrate a variety of package water and waste water treatment plant. The table below summarises the plant featured in the case studies.

Case study number	Description of package plant	Population equivalent
1	Aerobic biological waste water treatment	-
2	Treatment of borehole, river or dam water	-
3	Waste water treatment plant for a holiday park	422
4	Treatment plant for effluent from food processing	-
5	Waste water treatment plant for research centre in Antarctica	124
6	Below ground waste water treatment	500
7	Temporary waste water treatment during filter refurbishment	750
8	Waste water treatment to increase works capacity	750
9	Temporary waste water treatment	300
10	Waste water treatment to increase works capacity	400
11	Total preliminary treatment	-
12	Sewage sludge dewatering	-
13	UV disinfection of process water	-
14	UV disinfection of waste water	1200
15	Water softening plant	-
16	Iron removal plant	-
17	Water treatment plant	-

Case study 1: Aerobic biological waste water treatment

Location:	*Monkmoor Sewage Treatment Works, Shrewsbury*
Year:	*1993*
Client:	*Severn Trent Water*
Manufacturer:	*Haith Industrial Limited*

REQUIREMENTS	*Aerobic biological waste water treatment*
Treatment process:	*Aerobic Biological Treatment*
Capacity:	*4 litres/sec 16.8 kg/day*
Population equivalent:	*Not specified*
Design life:	*15 years minimum for the external shell*
Site conditions	*Above ground*



SOLUTION		*Aerated Treatment Unit*
Materials:	Piping:	*Carbon steel, 4 mm to 6 mm thick*
	Container:	*Carbon steel grade S275*
Footprint area:		*4 m × 2 m*
Installation time:		*1 day*

Case study 2: Treatment of borehole, river or dam water

Location:	*Nigeria*
Year:	*1998*
Client:	*Private*
Manufacturer:	*Naston Limited*

REQUIREMENTS	*Mobile water treatment*
Treatment process:	*Treatment of borehole, river or dam water source to drinking water standards*
Capacity:	*90 m^3/hour*
Population equivalent:	*N/A*
Design life:	*At least 15 years*
Site conditions	*Mobile, above ground*

SOLUTION		*Compak modular water treatment plant*
Materials:	Pressure vessel and supporting structure:	*Epoxy coated carbon steel, typically 5 mm thick*
	Pipework and fittings:	*Plastic (ABS)*
Footprint area:		*6 m $\times$ 2.5 m (service + clarification + filtration module)*
Installation time:		*A few hours*

Case study 3: Waste water treatment plant for a holiday park

Location:	*Inverberg Holiday Park, Loch Lomond*
Year:	*1999*
Client:	*Luss Estates*
Manufacturer:	*Hodge Separators Limited*

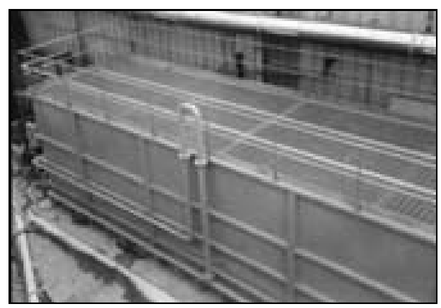
REQUIREMENTS	*Waste water treatment plant for a holiday park*
Treatment process:	*Submerged biological aerated filter, primary and final settlement*
Capacity:	*68 m^3/day*
Population equivalent:	*422*
Design life:	*At least 20 years*
Site conditions:	*Above ground*

SOLUTION		*CTX bioreactor*
Materials:	Process plant:	*Carbon steel, 6 mm plate with external reinforcement*
	Piping:	*Carbon steel*
	Container:	*Carbon steel, 6 mm plate with external reinforcement*
Footprint area:		*35 m^2*
Installation time:		*4 days*

Case study 4: Treatment plant for effluent from food processing

Location:	*Naas, Republic of Ireland*
Year:	*1999*
Client:	*QK Meats*
Manufacturer:	*Hodge Separators Limited*

REQUIREMENTS	*Treatment plant for effluent derived from food processing*
Treatment process:	*Submerged biological aerated filtration*
Capacity:	*1000 mg/l BOD @ 700 m^3/day*
Population equivalent:	*N/A*
Design life:	*At least 20 years*
Site conditions:	*Above ground*



SOLUTION		*CTX bioreactor*
Materials:	Process plant:	*Carbon steel, 6 mm plate with external reinforcement*
	Piping:	*Carbon steel*
	Container:	*Carbon steel, 6 mm plate with external reinforcement*
Footprint area:		*42 m^2*
Installation time:		*4 days (excluding civil works)*

Case study 5: Waste water treatment plant for research centre in Antarctica

Location:	*Rothera Base, Antarctica*
Year:	*1999*
Client:	*British Antarctic Survey*
Manufacturer:	*Hodge Separators Limited*

REQUIREMENTS	*Waste water treatment plant for research centre*
Treatment process:	*Submerged biological aerated filtration and sludge treatment. Plant supplied with 50 mm cavity insulation and heat tank.*
Capacity:	*25 m^3/day*
Population equivalent:	*124*
Design life:	*At least 20 years*
Site conditions:	*Due to extreme weather conditions, plant sheltered in building*

SOLUTION		*CTX bioreactor*
Materials:	Process plant:	*Carbon steel, 6 mm plate with external reinforcement*
	Piping:	*Carbon steel*
	Container:	*Carbon steel, 6 mm plate with external reinforcement*
Footprint area:		*14.5 m^2 (main plant),* *3.65 m^2 (sludge treatment tank)*
Installation time:		*5 days*

Case study 6: Below ground waste water treatment

Location:	*Widecombe, Devon*
Year:	*1998*
Client:	*South West Water*
Manufacturer:	*Copa Limited*

REQUIREMENTS	*Below ground waste water treatment*
Treatment process:	*Submerged biological aerated filter*
Capacity:	*21 kg/day*
Population equivalent:	*500*
Design life:	*30 years*
Site conditions:	*Below ground*

SOLUTION		*Copa Limited BAF™ CB500*
Materials:	Process plant:	*Stainless steel, grade 1.4301 (304)*
	Piping:	*Plastic (ABS)*
	Kiosk:	*GRP*
Footprint area:		*16m² (including kiosk)*
Installation time:		*3 weeks*

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Case study 7: Temporary waste water treatment plant during filter refurbishment

Location:	*RAF Lyneham*
Year:	*1998*
Client:	*Wessex Water*
Manufacturer:	*Copa Limited*

REQUIREMENTS	*Temporary treatment during filter refurbishment*
Treatment process:	*Biological aerated filter (mobile treatment units)*
Capacity:	*31.5 kg/day*
Population equivalent:	*750*
Design life:	*30 years*
Site conditions:	*Above ground*

SOLUTION		*Copa Limited BAF™ CB750 (temporary, mobile treatment units, designed for ease of re-location)*
Materials:	Process plant:	*Stainless steel, grade 1.4301 (304)*
	Piping:	*Plastic (ABS)*
	Kiosk:	*GRP*
Footprint area:		*21.4 m²* *(8 tonnes in weight, transport by low loader)*
Installation time:		*4 days*

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Case study 8: Waste water treatment to increase works capacity

Location:	*HMP & YOI Guys March, Dorset*
Year:	*1998*
Client:	*HM Prison Service*
Manufacturer:	*Copa Limited*

REQUIREMENTS	*BAF™ installation to increase works capacity*	
Treatment process:	*Submerged biological aerated filter, primary and final settlement*	
Capacity:	*31.5 kg/day*	*20:30:20 BOD:SS:NH_3*
Population equivalent:	*750*	
Design life:	*30 years*	
Site conditions:	*Above ground*	

SOLUTION		*Copa Limited BAF™ CB750*
Materials:	Process plant:	*Stainless steel, grade 1.4301 (304)*
	Piping:	*Plastic (ABS)*
	Kiosk:	*GRP*
Footprint area:		*21.4 m^2*
Installation time:		*2 weeks to install complete works (including pumps, flow meters, settlement tanks etc.)*

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Case study 9: Temporary waste water treatment

Location:	*Burton Sewage Treatment Works*
Year:	*1999*
Client:	*Wessex Water*
Manufacturer:	*Copa Limited*

REQUIREMENTS	*Temporary waste water treatment*	
Treatment process:	*Submerged biological aerated filter, primary and final settlement*	
Capacity:	*12.6 kg/day*	*20:30:20 BOD:SS:NH_3*
Population equivalent:	*300*	
Design life:	*30 years*	
Site conditions:	*Above ground*	

SOLUTION		*Copa Limited BAF™ CB300 (temporary, mobile treatment units, designed for ease of re-location)*
Materials:	Process plant:	*Stainless steel, grade 1.4301 (304)*
	Piping:	*Plastic (ABS)*
	Kiosk:	*GRP*
Footprint area:		*13 m^2* *(4.5 tonnes in weight)*
Installation time:		*2 days*

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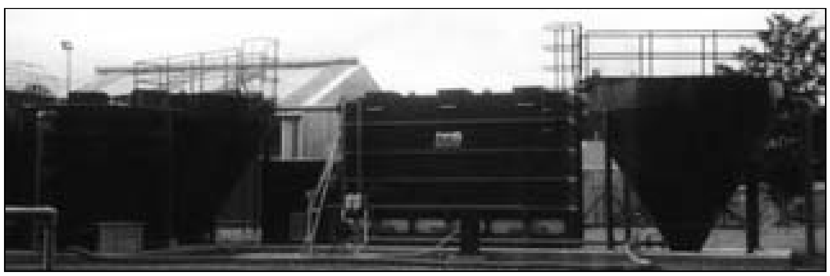
Case study 10: Waste water treatment to increase works capacity

Location:	*Almondbank WTP, Perthshire*
Year:	*1999*
Client:	*North of Scotland Water Authority*
Manufacturer:	*Copa Limited*

REQUIREMENTS	*BAF™ installation to increase works capacity to cope with a new housing development*
Treatment process:	*Submerged biological aerated filter, primary and final settlement*
Capacity:	*16.8 kg/day 20:30:20 BOD:SS:NH_3*
Population equivalent:	*400*
Design life:	*30 years*
Site conditions:	*Above ground*



SOLUTION		*Copa Limited BAF™ B400N*
Materials:	Process plant:	*Stainless steel, grade 1.4301 (304)*
	Piping:	*Plastic (ABS)*
	Kiosk:	*GRP*
Footprint area:		*17 m^2*
Installation time:		*3 weeks to install complete works (including pumps, flow meters, settlement tanks etc.)*

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Case study 11 : Total preliminary treatment

Location:	*Dunblane Sewage Treatment Works*
Year:	*1994*
Client:	*East of Scotland Water (Central Regional Council)*
Manufacturer:	*Huber Technology*

REQUIREMENTS	*Total preliminary treatment*
Treatment process:	*Screening (> 6 mm) separation, washing, compaction and discharge* *Grit (> 0.2 mm) separation, washing and discharge* *Grease removal and discharge*
Capacity:	*160 l/s per stream*
Population equivalent:	*N/A*
Design life:	*20 years*
Site conditions:	*Installed into a prepared chamber on an existing site*

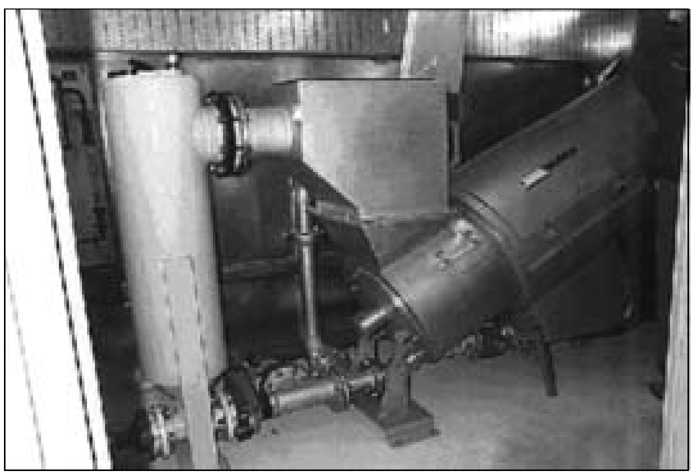
SOLUTION		*2 No Ro5 Packaged inlet works*
Materials:	Process plant:	*Stainless steel, grade 1.4541*[1)]
	Piping:	*Stainless steel, grades 1.4301 and 1.4541* *Plastic (ABS)*
	Container:	*Stainless steel, grade 1.4541*
	Frost protection:	*Stainless steel, grades 1.4301 and 1.4541*
Footprint area:		*15.5×2.0 m^2*
Installation time:		*10 days per unit*

1) Grade 1.4541 (commonly known as 321) is a titanium stabilised version of grade 1.4301 (304) which can be specified to provide good corrosion performance in the as-welded condition.

Case study 12: Sewage sludge dewatering

Location:	*Stornoway, Benbecula, Kirkwall, Granton on Spey, Aviemore Sewage Treatment Works*
Year:	*1999*
Client:	*North of Scotland Water (Central Regional Council)*
Manufacturer:	*Huber Technology*

REQUIREMENTS	*Sewage sludge dewatering*
Treatment process:	*Dewatering primary/imported sewage sludge from 2-3% dissolved solids up to 30-40% dissolved solids using pressurised filtration within a cylindrical dewatering chamber.*
Capacity:	*3-5 m^3/h @ 3-5% d.s. per unit*
Population equivalent:	*N/A*
Design life:	*20 years*
Site conditions	*Installed onto a prepared plinth on existing sites*



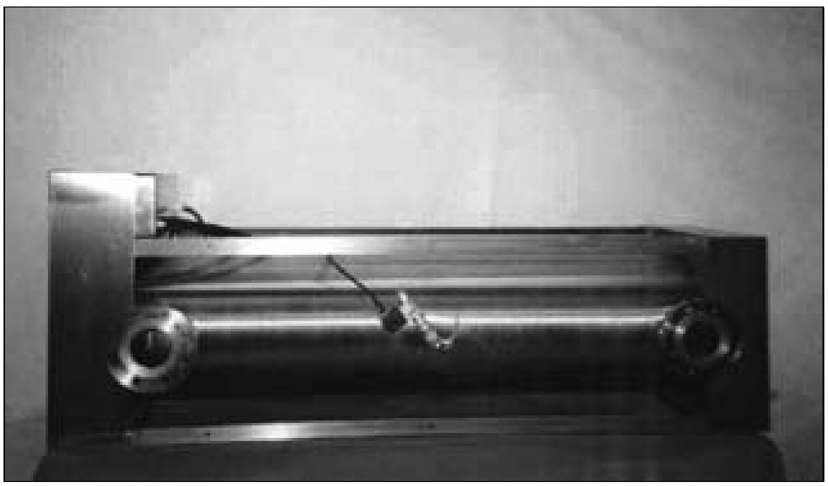
SOLUTION		*Containerised RoS3.1 sludge dewaterer, complete with all auxiliary equipment, on each site*
Materials:	Process plant:	*Stainless steel, grade 1.4541*[1)]
	Piping:	*Stainless steel, grades 1.4301 and 1.4541* *Plastic (ABS)*
	Container:	*Painted carbon steel, insulated with mineral wool*
	Internal cladding:	*Galvanised steel sheet, 1 mm thick*
Footprint area:		*6.5 m × 2.4 m*
Installation time:		*1 day (per unit)*

1) Grade 1.4541 (commonly known as 321) is a titanium stabilised version of grade 1.4301 (304) which can be specified to provide good corrosion performance in the as-welded condition.

Case study 13: UV disinfection of process water

Location:	*Attleborough, Norfolk*
Year:	*1998*
Client:	*Banham Poultry Ltd*
Manufacturer:	*Wedeco UV Systems plc*

REQUIREMENTS	*Disinfection of process water to permit safe re-use for grey water applications*
Treatment process:	*UV disinfection of process water*
Capacity:	*1000 m^3/day*
Population equivalent:	*N/A*
Design life:	*20 years*
Site conditions:	*Industrial pump room*

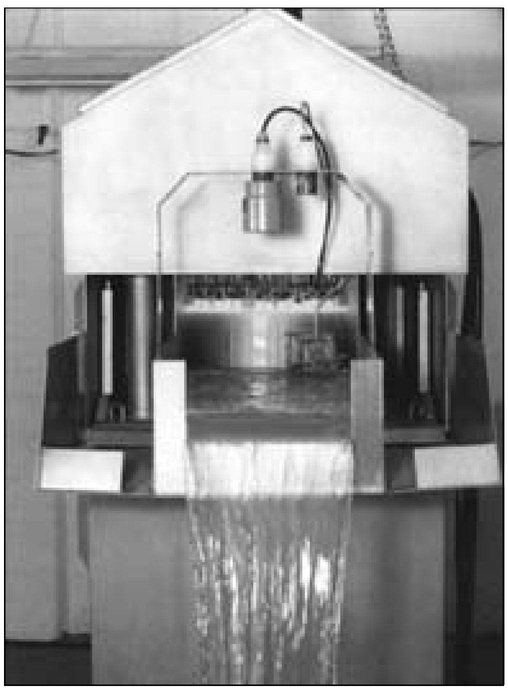


SOLUTION		*EL20 Effluent unit*
Materials:	Process plant:	*Stainless steel, grade 1.4404 (316L)*
	Piping:	*Stainless steel, grade 1.4404 (316L)*
	Container:	*Stainless steel, grade 1.4404 (316L)*
Footprint area:		*2.0 m × 1.0m*
Installation time:		*2 days*

Case study 14: UV disinfection of waste water

Location:	*Pen-y-Bout Waste water treatment works, Wales*
Year:	*1999*
Client:	*Hyder Consulting*
Manufacturer:	*Wedeco UV Systems plc*

REQUIREMENTS	*Plant installed for evaluation and field testing against Environmental Agency requirements*
Treatment process:	*UV disinfection of waste water*
Capacity:	*90 m^3/hour*
Population equivalent:	*1200*
Design life:	*25 years*
Site conditions:	*Above or below ground*



SOLUTION		*EFF36 Effluent module*
Materials:	Process plant:	*Stainless steel, grade 1.4404 (316L)*
	Piping:	*Stainless steel, grade 1.4404 (316L)*
	Container:	*Stainless steel, grade 1.4404 (316L)*
Footprint area:		*1.0 m × 1.0 m (plus 2.0 m × 1.0 m for electrics)*
Installation time:		*2 days*

Case study 15: Water softening plant

Location:	*Woodmansterne*
Year:	*1998*
Client:	*Sutton & East Surrey Water*
Manufacturer:	*Biwater Treatment Limited*

Requirements	*Modernization and increasing capacity of existing water softening plant*
Treatment process:	*Water softening*
Capacity:	*50 million litres per day*
Population equivalent:	*N/A*
Design life:	*20 years*
Site conditions:	*Existing site, above ground*

Stainless steel pellet reactor (1 of 3)

Installation of pellet reactor through roof

SOLUTION		
Materials:	Process plant (pellet reactors):	*Stainless steel, grade 1.4401 (316)*
	Piping:	*Stainless steel, grade 1.4401 (316) and epoxy-coated carbon steel*
Footprint area:		*100 m × 100 m*
Installation time:		*1 month (installation of 3 pellet reactors and associated pipework)*

Case study 16: Iron removal plant

Location:	*Benhall*
Year:	*1995*
Client:	*Essex & Suffolk Water*
Manufacturer:	*Biwater Treatment Limited*

REQUIREMENTS	*Modernization and increasing capacity of existing iron removal plant*
Treatment process:	*Iron removal*
Capacity:	*4.5 million litres per day*
Population equivalent:	*N/A*
Design life:	*20 years*
Site conditions:	*Existing site, above ground*

Installation of filter vessels

Completed works layout

Solution		
Materials:	Process plant (filter vessel):	*Carbon steel with non-toxic bitumen lining*
	Piping:	*Stainless steel, grade 1.4401 (316)*
	Container:	*Carbon steel, epoxy-coated*
Footprint area:		*15 m × 30 m*
Installation time:		*2 weeks (installation of filter vessels and associated pipework)*

Case study 17: Water treatment plant

Location:	*Winston*
Year:	*1994*
Client:	*Anglian Water*
Manufacturer:	*Biwater Treatment Limited*

REQUIREMENTS	*New water treatment plant*
Treatment process:	*Water treatment*
Capacity:	*5.2 million litres per day*
Population equivalent:	*N/A*
Design life:	*20 years*
Site conditions:	*Greenfield site, above ground*

Installation of steel filter containers

Solution		
Materials:	Process plant (filter containers):	*Carbon steel with non-toxic bitumen coating*
	Piping:	*Stainless steel, grade 1.4401 (316)*
Footprint area:		*100 m × 100 m*
Installation time:		*1 month (installation of 4 filter containers and associated pipework)*

9 REFERENCES

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   Council directive concerning urban waste water treatment (91/271/EEC)
   Official Journal of the European Communities, No L135/40, 1991

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   The selection of package waste water treatment plants
   CIRIA, PR72, 2000

3. The Urban Waste Water Treatment (England and Wales) Regulations 1994 (SI 1994/2841)
   The Stationery Office, London, 1994

4. BRITISH STANDARDS INSTITUTION
   BS 6297: Code of practice for the design and installation of small sewage treatment works and cesspools
   BSI, 1983

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   prEN 12566 Small waste water treatment systems up to 50 PT
   Part 3: Packaged and/or site assembled domestic waste water treatment plants DC Draft for public comment 98/106709, 1997.

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   Water Industry Specification No. 4-25-01
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   Second Edition (SCI-P123)
   The Steel Construction Institute, 1993

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   Structural design of stainless steel (SCI-P291)
   To be published

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    Water Industry Information and Guidance Note No. 4-52-02
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    Protective coatings for use in the water industry
    The Pump Centre, AEA Technology plc, 1996

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The Steel Construction Institute, 1999
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BSI, 1997

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Guidelines for the use of stainless steel in municipal waste water treatment plants
Nickel Development Institute, NiDI Technical Series No. 10 076, 1995

10 SOURCES OF INFORMATION

For technical queries:

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Web: http://www.uvsystems.co.uk

APPENDIX A: British and European Steel Standards

The following is a list of British Standards relating to various aspects of the use of steel in construction. The list is not exhaustive and is subject to alteration as new or amended standards are introduced; BSI should be contacted directly for further information.

STRUCTURAL STEEL DESIGN

BS 2654 : 1989 : Specification for manufacture of vertical steel welded non-refrigerated storage tanks with butt welded shells for the petroleum industry

BS 5500 : 1997 : Specification for unfired fusion welded pressure vessels

BS 5950 : Structural use of steelwork in building
Part 1 : 1990 : Code of practice for design in simple and continuous construction - Hot rolled sections
Part 5 : 1998 : Code of practice for design of cold formed thin guage sections
Part 6 : 1995 : Code of practice for design of light gauge profiled steel sheeting

DD ENV 1993 : Eurocode 3 : Design of steel structures
DD ENV 1993-1-1 : 1992 : General rules and rules for buildings (together with UK NAD)

STEEL FABRICATION AND ERECTION

BS 5950 : Structural use of steelwork in building
Part 2 : 1992 : Specification for materials, fabrication and erection - Hot rolled sections
Part 7 : 1992 : Specification for materials and workmanship - Cold formed sections

ENV 1090 : Execution of steel structures
DD ENV 1090-1 : 1998 : General rules and rules for buildings (together with UK NAD)
ENV 1090-2 : 1998 : Supplementary rules for cold formed thin gauge components and sheeting
ENV 1090-6 : 2000 : Supplementary rules for stainless steels

National Structural Steelwork Specification (3rd Edition)
British Constructional Steelwork Association/Steel Construction Institute, 1994

STRUCTURAL STEEL

BS EN 10025 : 1993 : Hot-rolled products of non-alloy structural steels - Technical delivery conditions

BS EN 10028 : Specification for flat products made of steels for pressure purposes

BS EN 10095 : 1999 : Heat resisting steels and nickel alloys
(Supersedes BS 1449-2 : 1983)

BS EN 10111 : 1998 : Continuously hot-rolled low carbon steel sheet and strip for cold forming - Technical delivery conditions
(Supersedes BS 1449-1.2 : 1991)

BS EN 10130 : 1999 : Cold-rolled low-carbon steel flat products for cold forming - Technical delivery conditions
(Supersedes BS EN 10130 : 1991)

BS EN 10139 : 1998 : Cold rolled uncoated mild steel narrow strip for cold forming - Technical delivery conditions
(Supersedes BS 1449-1.9 : 1991)

BS EN 10142 : 2000 : Continuously hot-dip zinc coated low carbon steel sheet and strip for cold forming - Technical delivery conditions

BS EN 10147 : 2000 : Continuously hot-dip zinc coated structural steel sheet and strip - Technical delivery conditions

BS EN 10210-1 : 1994 : Hot finished structural hollow sections of non-alloy and fine grain structural steels - Technical delivery requirements

BS EN 10238 : 1997 : Automatically blast cleaned and automatically primed structural steel products

STAINLESS STEELS

BS EN 10088 : 1995 : Stainless steels

BS EN ISO 3506 : 1998: Mechanical properties of corrosion resistant stainless steel fasteners

WELDING MATERIALS AND PROCESSES

General

BS EN 729: 1995: Quality requirements for welding. Fusion welding of metallic materials

Process and consumables

BS 5135 : 1984 : Specification for arc welding of carbon and carbon manganese steels

BS EN 1011 : Welding - Recommendations for welding of metallic materials

BS EN 1011-1 : 1998 : General guidance for arc welding

BS EN 1011-3: 2000: Arc welding of stainless steel

Testing and examination

BS 709 : 1983 : Methods of destructive testing fusion welded joints and weld metal in steel

BS EN 287-1: 1992: Approval testing of welders for fusion welding

BS EN 288 : Specification and approval of welding procedures for metallic materials

CORROSION PREVENTION

BS 2569 : Specification for sprayed coatings
Part 2 : 1965 (1997) : Protection of iron and steel against corrosion and oxidation at elevated temperatures

BS 3416: 1991: Bitumen based coatings for cold application, suitable for use in contact with potable water

BS 4147 : 1980 (1987) : Specification for bitumen based hot-applied coating materials for protecting iron and steel, including suitable primers where required

BS 5493 : 1977 : Code of practice for protective coating of iron and steel structures against corrosion

BS 6949: 1991: Bitumen based coatings for cold application excluding use in contact with potable water

BS 7079: Preparation of steel substrates before application of paints and related products
Group B : Methods for the assessment of surface cleanliness
BS 7079: B9 : 1998 : Field method for the conductometric determination of water soluble salts

BS 7079: Preparation of steel substrates before application of paints and related products
Group C : Surface roughness characteristics of blast-cleaned steel substrates
(*Renumbered in BS EN ISO 8503 series*)

BS EN ISO 12944 : 1998 : Paints and varnishes - Corrosion protection of steel structures by protective paint systems
(*Partially supersedes BS 5493 : 1997*)

BS EN 22063 : 1994 : Metallic and other inorganic coatings - Thermal spraying - Zinc, aluminium and their alloys

BS EN ISO 1461: 1999 : Hot dip galvanized coatings on fabricated iron and steel articles - Specification and test methods

BS EN ISO 14713 : 1999 : Protection against corrosion of iron and steel in structures - Zinc and aluminium coatings - Guidelines
(*Supersedes BS 4479-6 : 1996 and partially supersedes BS 5493 : 1977 which is declared obsolescent*)

ISO 8501 : Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness
Part 1 : 1988 : Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings preparation grades after removal of previous coatings

BS EN ISO 8503 : Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast cleaned steel substrates
Part 1 : 1995 : Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast cleaned surfaces

ISO 11126-9 : 1999 : Preparation of steel substrates before application of paints and related products - Specification for non-metallic blast-cleaning abrasives - Part 9 : Staurolite

PD 6484 : 1979 (1990) : Commentary on corrosion at bimetallic contacts and its alleviation

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