| Trade of Metal Fabrication | |
| --- | --- |
| Module 3: | Plate Fabrication |
| Unit 2: | Stainless Steel Fabrication (Introduction) |
| | Phase 2 |

# Table of Contents

# List of Figures



# List of Tables

# Document Release History

| Date | Version | Comments |
|---|---|---|
| 12/12/06 | First draft | |
| 13/12/13 | SOLAS transfer | |
| | | |
| | | |

# Module 3 – Plate Fabrication

## Unit 2 – Stainless Steel Fabrication (Introduction)

**Duration – 6 Hours**

**Learning Outcome:**

By the end of this unit each apprentice will be able to:

- Identify the difficult grades and types of stainless steel
- Identify and describe examples of use of stainless steel in industry
- Describe the difficulties encountered when fabricating stainless steel
- Read and interpret fabrication drawing
- Mark out, plasma cut, drill form and weld exercise

**Key Learning Points:**

| | |
|---|---|
| Rk | Properties of stainless steel, e.g. corrosion resistance. |
| Rk | Advantages and disadvantages of using stainless steel. |
| Rk | Uses of stainless e.g. pharmaceutical industry, food/catering industry. |
| Rk | Modern high technology machines and techniques enable stainless be cut, machined, fabricated, formed and welded as readily as traditional steels. |
| Rk D | Read and interpret fabrication drawing. |
| Rk Sk | Mark out, plasma cutting, forming (springback), drilling, tacking and welding. *(Also see Module 3 Unit 1).* |
| Rk | Safety procedures when plasma cutting – drilling/forming – welding. *(Also see Module 3 Unit 1 and Module 2 Unit 3).* |
| P | Communication, quality of work, initiative. |

**Training Resources:**

- Fabrication workshop equipment
- Apprentice toolkit personal protective equipment (P.P.E.)
- Plasma cutter
- T.I.G. welding plant
- Drilling equipment
- Materials

**Key Learning Points Code:**

M = Maths D= Drawing RK = Related Knowledge Sc = Science

P = Personal Skills Sk = Skill H = Hazards

# Technical Drawing and Design

## Introduction

Technical drawing is a major method of communicating and exchanging design ideas in industry. Before looking at more aspects of technical drawing we will look at designing in general, but it must be remembered that this book is about technical drawing. The purpose here is to show how technical drawing fits into the overall design process. A number of design processes can be seen in various books. Although other design processes may appear different to those described here, if you look at others carefully, you will see a general pattern in them all.

Figure 1 describes a design process in a circular flow chart form. Why is it circular? This is because unless a completed design is suitable for the purpose for which it has been designed and made, the designer will have to go back to the beginning and start all over again.

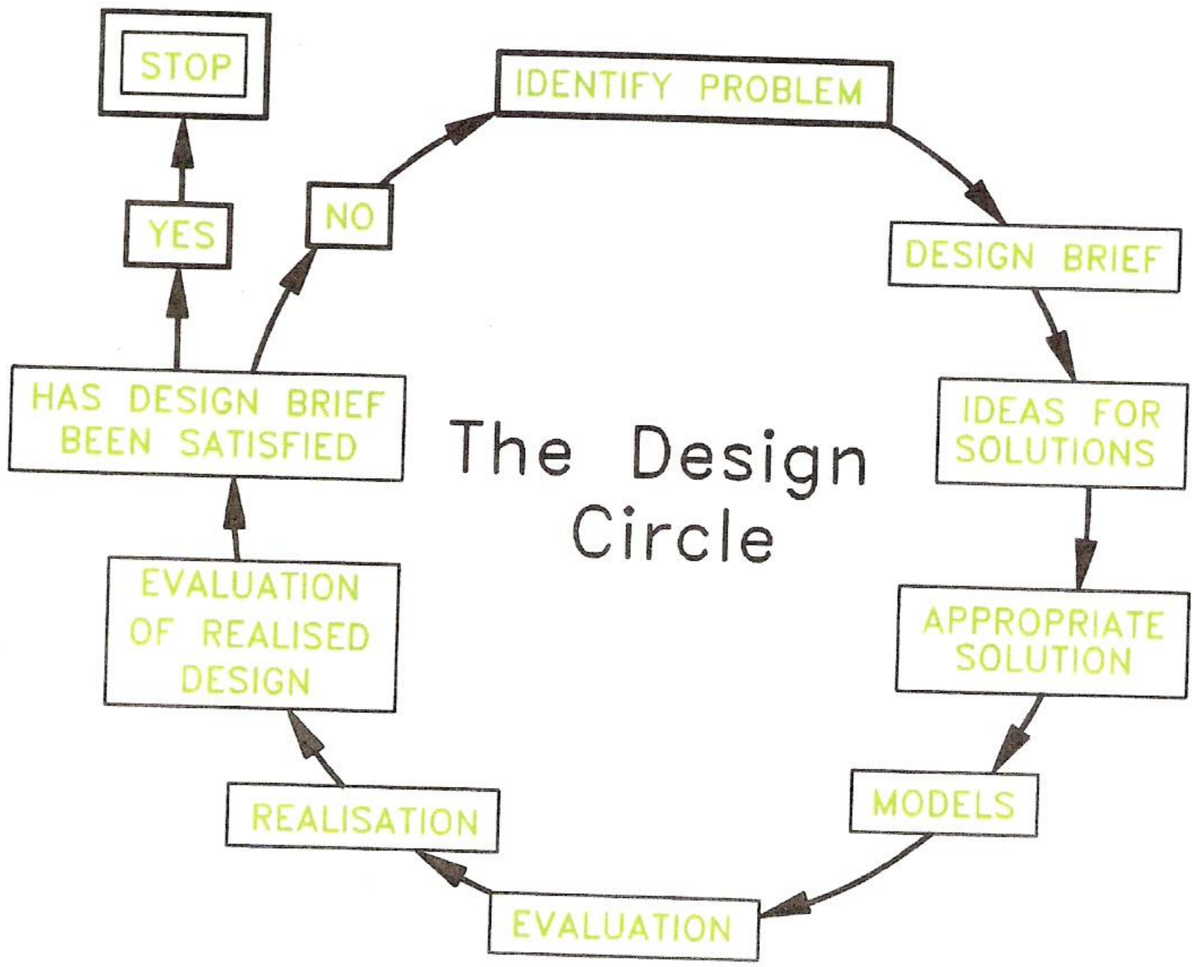


**Figure 1 - A Flow Chart Describing a Design Process**

In the given flow chart:

- **Identify problem**: what is it that the design is supposed to do? Why is the design being thought out and made? When starting to design anything, it is a good idea to state the problem which the design is supposed to be solving in a few brief notes.

- **Design brief**: having noted what the problem is, state in a few brief sentences what it is that is to be designed. Everything that is to be designed should start with such a design brief. The brief gives the terms of reference for the design. When the design has been completed, one should be able to check back to the design brief to see if the brief has been satisfied.

- **Ideas for solutions**: this is where technical drawing becomes an important part of designing. At this stage, any ideas about how the design brief can be tackled should be written down and also drawn - technical drawings are the best method of showing design ideas in a graphical form.

- **Appropriate solution**: again, technical drawing is an important part at this stage. The best of the solutions is chosen and accurate technical drawings of this chosen solution are made.

- **Models**: it may be necessary at this stage to make a model from the drawings of the chosen solution. These may be full size or scale.

- **Evaluation**: check whether the drawings are correct; check the model for suitability for solving the design brief. If the model is a working device, it may be given a whole range of tests to check whether its working parts are satisfactory.

- **Realisation**: make the design.

- **Evaluation of realised design**: does the completed design answer the design brief? Does the design solve the problem for which it has been made? If it is a device which moves or has moving parts, a range of tests may also be needed as part of the evaluation.

- **Has the design brief been satisfied**: if the answer is NO, then start again. If the answer is YES, the design process will stop. At this stage the design may go forward for manufacture in quantity. If it is a one-off design, the design process stops.

***Note***: in manufacturing industries, once a design has gone into manufacture, improvements of its design may well be needed from time to time. If faults show up in the design when it has been put to use, further work may be needed in order to solve the problems shown up by the faults.

# Welding Stainless Steel

## Introduction

The term stainless steel covers a group of corrosion and heat-resisting steels containing larger percentages of chromium and nickel than in the high tensile steels.

## Types of Stainless Steel

There are many different compositions, but all the stainless steels fall into three main groups as follows:

### Martensitic Steel

This group contains from 11.5 to 14 per cent chromium and from 0.2 to 0.4 per cent carbon. Such steels are difficult to weld because they can form the very hard martensitic structure regardless of the cooling rate. They are known as air-hardening steels. They can be welded by preheating to around 350°C and using a 25 per cent chromium and 20 per cent nickel flux coated electrode. A post-heat of 750°C usually ensures acceptable ductility.

### Ferritic Stainless Steel

This group contains between 16 and 30 per cent chromium, with a maximum of 0.1 per cent carbon. These materials can be welded with a preheat of 150°C and the use of the 25 per cent chromium and 20 per cent nickel core wire electrode. Sometimes combination welds are made, with the final layers being completed with electrodes of even higher chromium content (up to 30 per cent), in order to give the surface an extremely high resistance to corrosion. A post heat at 730°C should be performed immediately after welding to prevent brittleness.

### Austenitic Stainless Steel

This third group contains chromium and nickel in amounts that give a predominantly austenitic structure. The composition of austenitic stainless steels can be varied to suit the application, with chromium content from 7 to 30 per cent and a range of nickel content from 6 to 36 per cent, with carbon content below 0.25 per cent.

One of the most important steels in this group contains approximately 18 per cent chromium and 8 per cent nickel, with carbon content less than 0.12 per cent. This steel is readily welded by many processes if small amounts of titanium or niobium are added in the manufacturing process.

For special use at high temperatures, steels with 25 per cent chromium and 20 per cent nickel can be used.

# Austenitic Stainless Steel

## Properties

Typical composition:

18% chromium, 8% nickel, 0.15%carbon.

Remainder: Fe (S. & P. kept below 0.045%), Ti or Nb.

Effect of elements on properties:

The nickel is added to give toughness and may be increased to 11.5% to prevent work hardening (for rivets and fastenings). The chromium is added to give corrosion resistance. In addition titanium or niobium is often added to prevent inter-granular corrosion (weld decay) in the following proportions: Ti – 5 x C content, Nb = 10 x C content.

| | |
|---|---|
| Approximate melting temperature | 1420°C to 1395°C |
| Hardness | 170 Hv (water quench from 1000°C) |
| Tensile strength | Approx. 620 N/mm² |
| Yield point | Approx. 280 N/mm² |
| Mass | 7.92 g/cm³ at +20°C |
| Coefficient of linear expansion | 0.00002 per °C. |

## Identification

This iron-based alloy has a characteristic silver lustre imparted to it by the amount of chromium and nickel. It is the chromium which combines with oxygen and rapidly forms a very thin oxide which is continuous and stable and impervious to further attack by the atmosphere. The thickness of this oxide film increases with the degree of polish to give a mirror finish. These steels give a dull red spark when touched on a grinding wheel.

## Corrosion

The corrosion resistance is excellent in most environments but solutions of nitric, hydrofluoric and sulphuric acid will attack 18/8 stainless steel. These acid solutions are used to remove the oxide scale which result from strongly heating the material in air. The term used for this treatment is pickling.

*Weld decay (inter crystalline corrosion)*

Although 18/8 stainless steel has excellent corrosion resistance, if it is to be situated in a corrosive environment (such as slightly acidic water or corrosive liquid) it requires to be stabilised if welding is used to make the joints. This means that, even with carbon content below 0.1%, slow cooling of the metal to room temperature after welding will cause the carbon to combine with the chromium to form chromium carbide within the temperature range 500-900°C. This chromium carbide is then precipitated or thrown out of solution along the grain boundaries. As the carbon has united with the chromium, the iron is now left with little or no chromium near the grain boundaries, and so the iron in these regions is attacked by the acid. Titanium (plate) or niobium (electrode) is added during manufacture because carbon combines easily with these elements rather than with chromium and therefore leaves the iron combined and protected by the chromium. Figure 2 shows diagrammatically the relative area of weld decay in the temperature range.

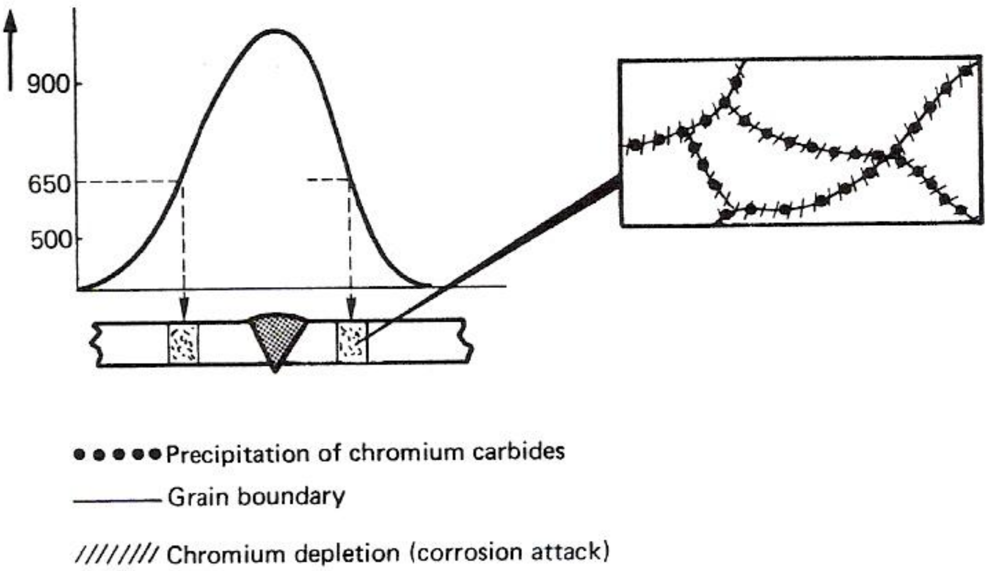


**Figure 2 - Weld Decay**

Two other types of corrosion to which the 18/8 type of steels are susceptible are: pitting corrosion due to chlorine ions, and stress corrosion due to residual stresses in conjunction with a corrosive medium. Molybdenum is added during steelmaking to reduce these two types of corrosion.

# Stainless Steel

## What is Stainless Steel?

Stainless steel is the generic name for a number of different steels used primarily for their resistance to corrosion. The key element they all share is a certain minimum percentage (by mass) of chromium: 12%. Although other elements, particularly nickel and molybdenum, are added to improve corrosion resistance, chromium is always the deciding factor.

## What Causes Corrosion?

Corrosion is a natural phenomenon as nature seeks to combine other elements which man has produced in a pure form for his own use. Iron occurs naturally as iron ore. Pure iron is therefore unstable and wants to "rust"; that is to combine with oxygen in the presence of water. For most of the Iron Age, which began about 1000 BC, cast and wrought iron were used; iron with a high carbon content and various unrefined impurities. The production of steel did not begin until the 19th century. At present the majority of steel produced in the world is carbon steel, which can be defined as an alloy of a small content of carbon combined with well-refined iron. Despite its various additions stainless steel still behaves as steel, it is not like the nickel alloys that are really alloys of a number of different metals, iron ore only being one. Even highly alloyed stainless steel grades, such as 316, have a minimum of 62% iron.

Carbon steels without any protection will form a coating of rust that will in a sense protect the rest of the steel. So constantly removing the rust exposes a new fresh layer of steel to be attacked. This is called general corrosion. Various coatings will impede the rusting process, in particular painting, coating with zinc (galvanised steel), and epoxy resins. Another lateral way of reducing corrosion is to put corrosion inhibitors into the solutions that would otherwise cause iron to corrode.

## The Unique Advantage of Stainless Steel

For a wide range of applications, stainless steel competes with carbon steels supplied with protective coatings, as well as other metals such as aluminium, brass and bronze. The success of stainless steel is based on the fact that it has one big advantage. The chromium in the stainless steel has a great affinity for oxygen, and will form on the surface of the steel at a molecular level a film of chromium oxide. This thin layer is described as passive, tenacious and self-renewing. Passive means that it does not react or influence other materials; tenacious means that it clings to the layer of steel and is not transferred elsewhere; self-renewing means that if damaged or forcibly removed more chromium from the steel will be exposed to the air and form more chromium oxide. This means that over a period of years a stainless steel knife can literally be worn away by daily use and by being re-sharpened on a sharpening stone and will still remain stainless. Manhole and access covers in the water treatment and chemical industry are widely made out of both galvanised steel and stainless steel. In normal use galvanised steel can last many years without corrosion occurring and in these cases there would be little advantage apart from aesthetic reasons to switch to stainless steel. Where stainless comes into its own is where the galvanised coating is constantly being worn away, for example by chains being dragged over it, or constantly being walked over, or where very corrosive chemicals are being randomly splashed onto it.

This leads to the fact that fabrication in stainless steel will always be more expensive than using ordinary steel, not just because of the higher cost of stainless steel, but also because it is more difficult to machine. However it is the better life cycle costs of stainless steel that makes it attractive, both in terms of much longer service life, less maintenance costs, and high scrap value on decommissioning.

## Product Characteristics

Stainless steel can be selected for use compared to other materials for a number of reasons, not just its corrosion resistance. These include:

- Aesthetic qualities: it can be polished to a satin or mirror finish;
- "Dry corrosion" occurs to steel at higher temperatures where it oxidises or scales up. Stainless steel is far more resistant to this than ordinary carbon steel and grades such as 310 (25% chromium 20% nickel) were specifically developed for use at high temperatures;
- Non-contamination of the liquids stainless comes into contact with, because there is no coating to break down and dissolve;
- Weight savings; as thinner sections and more innovative design structures can be used, with cost savings on foundations and platform weights;
- Many anti-corrosion coatings are fire hazards or the materials themselves have a low melting point.

## Applications

The most everyday use of stainless steel is obviously in cutlery. Very cheap cutlery is made out of grades 409 and 430, with the finest quality cutlery using specially produced 410 and 420 for the knives and grade 304 (18/8 stainless, 18% chromium 8% nickel) for the spoons and forks. The different grades are used as 410/420 can be hardened and tempered so that the knife blades will take a sharp edge, whereas the more ductile 18/8 stainless is easier to work and therefore more suitable for objects that have to undergo numerous shaping, buffing and grinding processes.

Very large amounts of stainless steel are used in food production and storage. The most commonly used grades are 304 and 316. Typical uses would be dairy, milk storage and ham curing, frozen and salted fish storage. Whereas 304 is used for normal temperatures and acid concentrations, 316 is used for harsher environments. For example 304 is used in cheese production, but where salted ham is being prepared 316 is used. For low concentrations of phosphoric acid (one of the constituents of cola) 304 is used, but at higher temperatures and concentrations 316 is used. Food slicers are made out of 420 and 440. Very often in food production stainless is used not because the food itself is corrosive but the use of stainless allows for faster and more efficient cleaning. For example in ice cream production 316 is specified so that strong anti-bacteriological cleaning and rinsing systems can be used. One of the great advantage of stainless steel is that imparts no taste to the food that is comes into contact with.

The pumping and containment of oils, gases and acids has created a large market for stainless tanks, pipes, pumps and valves. The storage of dilute nitric acid was one of the first major success stories for 18/8 stainless steel as it could be used for thinner sections and was more robust than other materials. Special grades of stainless have been developed to have greater corrosion resistance. These are used in desalination plants, sewage plants, offshore oilrigs, harbour support and ships propellers.

## Architecture

Architecture is a growing market. Many modern building uses stainless for cladding. When reinforced concrete first started to be used it was considered that the carbon steel used would not rust, as cement, obviously derived from limestone, is alkaline. However, constantly using grit salt on bridges can change the pH to acidic thereby rusting the steel, which expands and cracks the concrete. Stainless steel reinforcing bar, although initially expensive, is proving to have good life cycle costing. The low maintenance cost and anti-vandal characteristics of stainless provides a growing market in public transport, ticket machines and street furniture.

The nuclear power industry uses large quantities of stainless, often specified with a low cobalt content, for both power and radiation containment. Special louvered ventilation shafts are made, which are used in case of emergencies to seal off plants for years if necessary. Steam and gas turbines use stainless because of its corrosion resisting and heat resisting qualities.

Especially clean melted stainless is used for medical implants and artificial hips. A great deal of medical equipment - such as orthopaedic beds, cabinets and examination machines - is made as standard from stainless because of its hygienic and easy-clean qualities. Pharmaceutical companies use stainless for pill funnels and hoppers and for piping creams and solutions.

Automobile industries are making increasing use of stainless steel, primarily for exhaust systems (grade 409) and catalytic converters, but also for structural purposes.

## Self Assessment

Questions on Background Notes – Module 3.Unit 2

**1.** In your own words, give some basic information on Stainless Steel.

**2.** List some of the Properties of Stainless Steel.

**3.** List two advantages of using Stainless Steel.

# Answers to Questions 1-3. Module3.Unit 2

**1.**

**Stainless Steel:**

The term stainless steel covers a group of corrosion and heat resisting steels containing larger percentages of chromium and nickel than in the high tensile steels.

There are many different compositions, but all the stainless steels fall into three main groups:

**Martensitic Steel:**

This group contains from 11.5 to 14 per cent chromium and from 0.2 to 0.4 per cent carbon. Such steels are difficult to weld because they can form the very hard martensitic structure regardless of the cooling rate. They are known as air-hardening steels. They can be welded by preheating to around 350°c and using a 25 per cent chromium and 20 per cent nickel flux coated electrode. A post-heat of 750°c usually ensures acceptable ductility.

**Ferritic Stainless Steel:**

This group contains between 16 and 30 per cent chromium, with a maximum of 0.1 per cent carbon**.** These materials can be welded with a preheat of 150°c and the use of the 25 per cent chromium and 20 per cent nickel core wire electrode. Sometimes combination welds are made, with the final layers being completed with electrodes of even higher chromium content (up to 30 per cent), in order to give the surface an extremely high resistance to corrosion. A post heat at 730°c should be preformed immediately after welding to prevent brittleness.

**1. Continued:**

**Austenitic Stainless Steel:**

This third group contains chromium and nickel in amounts that give a predominantly austenitic structure. The composition of austenitic stainless steels can be varied to suit the application, with chromium content from 7 to 30 per cent and a range of nickel content from 6 to 36 per cent, with carbon content below 0.25 per cent.

One of the most important steels in this group contains approximately 18 per cent chromium and 8 per cent nickel, with carbon content less than 0.12 per cent. This steel is readily welded by processes if small amounts of titanium or niobium are added in the manufacturing process.

For special use at high temperatures, steels with 25 per cent chromium and 20 per cent nickel can be used.

**2.**

**Properties:**

Typical composition: 18% chromium, 8% nickel, 0.15% carbon.
Remainder: Fe (S. & P. kept below 0.045%), Ti or Nb.

Effect of elements on properties:

The nickel is added to give toughness and may be increased to 11.5% to prevent work hardening (for rivets and fastenings). The chromium is added to give resistance. Titanium or niobium is often added to prevent inter-granular corrosion (weld decay) in the following proportions:

Ti – 5 x C content, Nb = 10 x C content.

| | |
|---|---|
| Approximate melting temperature | 1420°c to 1395°c |
| Hardness | 170 Hv (water quench from 1000°c) |
| Tensile strength | approx. 620 N/mm² |
| Yield point | approx. 280 N/mm² |

**3.**

**Advantages of Stainless Steel:**

Does not react or influence other materials.

Used extensively in the food/catering divisions.

Used widely in the medical world. E.g. Plates and screws to repair bones.

**Aesthetic Qualities:**
It can be polished to a satin or mirror finish.

**Dry Corrosion:**
Stainless steel is far more resistant to this than ordinary carbon steel. Grades such as 310 (25% chromium 20% nickel) were specifically developed for use at high temperatures.

**Non-contamination:**
Because there is no coating to break down and dissolve there is no contamination of liquids that stainless steel comes in contact with.

**Weight:**
As thinner sections and more innovative design structures can be used, giving cost savings on foundations and platform weights.

# Index