Government of **Western Australia**
**School Curriculum and Standards Authority**

WACE
Western Australian Certificate of Education

**Western Australian Certificate of Education**
**Examination, 2012**

# Engineering Studies
## Stage 3

## DOCUMENT BOOKLET

 Ref: 12-045

**Document 1**

**Extract from the National Code of Practice for the Installation of Electric Drives in Vehicles**

## 2 TECHNICAL AND SAFETY REQUIREMENTS - ELECTRICAL

### 2.1 Electrical Definitions

ELV: Extra Low Voltage. Any voltage that never exceeds 60V DC or 25V AC. (Typically powering electrical items such as lights, horn, fans, etc.).
HAZV: Hazardous Voltage. Any voltage that may be greater than 60V DC or 25V AC at any time.

### 2.2 Battery Type

There is a significant difference in safety requirements for different types of batteries. For the purposes of this document, batteries are divided into two principal types:
Class A: The batteries do not contain (spillable) liquid and do not discharge gases into the atmosphere during normal operation.
Class B: The batteries contain (spillable) liquid and/or discharge gas during normal operation.

As a broad classification, lead-acid flooded batteries are Class B, while Nickel Metal Hydride (NiMH) and Lithium batteries are Class A.

### 2.3 Battery Restraint

The batteries that power the vehicle must be fixed in position so that they will not easily break free in a crash and thus create a hazard to the driver, passengers or other road users. The battery restraint system must adequately withstand at least the following crash accelerations:
Front impact – 20 g (i.e. 20 times the battery weight);
Side impact – 15 g;
Rear impact – 10 g; and
Vertical (rollover) impact – 10 g.

An impact sensing (G force) switch should be fitted to the vehicle so that the traction circuit is opened in the event of an impact.

### 2.4 Containment of Batteries

All batteries that must be vented (i.e. Class B batteries) must be fully sealed from the passenger compartment, so that the transmission of gases or flames is prevented. The sealed compartment should be made from corrosion resistant materials, or if this not practical, lined with corrosive resistant materials. Fully sealed (i.e. Class A batteries) need not comply with this section.

### 2.7 Marking of Hazardous Voltage Components

Electric vehicles usually employ higher voltages than normal internal combustion vehicles and consideration needs to be shown to the safety of the end-user of the vehicle, service personnel, and emergency responders in the event of an accident. All wiring in the vehicle connected to a HAZV battery pack (either positive or negative), or containing HAZV relative to the chassis of the vehicle, must be coloured orange even when installed within orange conduit.

### 2.10 Hazardous Voltage Disconnect

The power on procedure must be applied via a key switch. It must not be possible to remove this key in any position that energises the drive train or makes active driving possible. Disconnection of the traction pack from the rest of the traction circuit must be by a contactor operated by the ignition switch.

## 3 TECHNICAL AND SAFETY REQUIREMENTS - MECHANICAL

### 3.1 Changes to Vehicle Mass and Load Carrying Capacity

Following an electric vehicle conversion there is a strong likelihood that certain mechanical components of the vehicle will become overloaded because of the increase in mass caused by the addition of the traction batteries and motors.
In assessing the total mass and mass distribution allow at least 68 kg per passenger, plus 13.6 kg of luggage for each passenger, for a total minimum allowance of 81.6 kg per passenger.

### 3.2 Brakes and Steering

Because mass distribution is an important factor in maintaining good handling and braking characteristics of a vehicle, it must be considered carefully in the design of a conversion or Internal Combustion Vehicle Locating the battery pack entirely behind the rear axle should be avoided as it may lighten steering and/or cause the vehicle to yaw in a dangerous manner, particularly if the vehicle has a relatively large rear overhang. Vehicles with front wheel drive may also lose drive traction.

**Document 2**

**The NMB-MAT Stepper Motor**

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**Document 3**

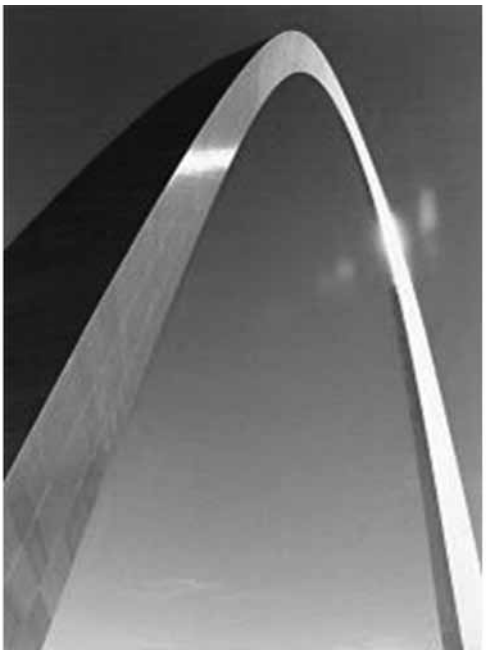
**Stainless Steel**

In metallurgy, stainless steel, also known as inox steel or inox from French ‘inoxydable’, is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass.

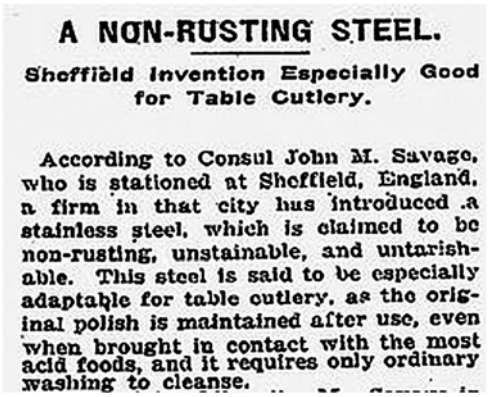
Stainless steel does not corrode, rust or stain with water as ordinary steel does, but despite the name it is not fully stain-proof. It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment the alloy must endure. Stainless steel is used where both the properties of steel and resistance to corrosion are required.

Stainless steel differs from carbon steel in the amount of chromium present. Unprotected carbon steel rusts readily when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide. Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure.

Passivation only occurs if the proportion of chromium is high enough.



**The 630-foot (192 m) high, stainless-clad (type 304) Gateway Arch defines St. Louis’s skyline**



A NON-RUSTING STEEL.

Sheffield Invention Especially Good for Table Cutlery.

According to Consul John M. Savage, who is stationed at Sheffield, England, a firm in that city has introduced a stainless steel, which is claimed to be non-rusting, unstainable, and untarnishable. This steel is said to be especially adaptable for table cutlery, as the original polish is maintained after use, even when brought in contact with the most acid foods, and it requires only ordinary washing to cleanse.

**An announcement, that appeared in a January 1915 issue of the New York Times, of the development of stainless steel**

**History**

A few corrosion-resistant iron artefacts survive from antiquity. A famous example is the Iron Pillar of Delhi, erected by order of Kumara Gupta I around AD 400. Unlike stainless steel, however, these artifacts owe their durability not to chromium but to their high phosphorus content, which, together with favorable local weather conditions, promotes the formation of a solid protective passivation layer of iron oxides and phosphates, rather than the non-protective cracked rust layer that develops on most ironwork.

**Document 3** (continued)

The corrosion resistance of iron-chromium alloys was first recognised in 1821 by French metallurgist Pierre Berthier, who noted their resistance against attack by some acids and suggested their use in cutlery. Metallurgists of the 19th century were unable to produce the combination of low carbon and high-chromium found in most modern stainless steels, and the high-chromium alloys they could produce were too brittle to be practical.

In the late 1890s Hans Goldschmidt of Germany developed an aluminothermic (thermite) process for producing carbon-free chromium. Between 1904 and 1911 several researchers, particularly Leon Guillet of France, prepared alloys that would today be considered stainless steel.

Friedrich Krupp Germaniawerft built the 305-tonne sailing yacht *Germania* featuring a chrome-nickel steel hull in Germany in 1908. In 1911, Philip Monnartz reported on the relationship between chromium content and corrosion resistance. On October 17, 1912, Krupp engineers Benno Strauss and Eduard Maurer patented austenitic stainless steel as ThyssenKrupp Nirosta.

Similar developments were taking place contemporaneously in the United States, where Christian Dantsizen and Frederick Becket were industrialising ferritic stainless steel. In 1912, Elwood Haynes applied for a US patent on a martensitic stainless steel alloy, which was not granted until 1919.

Also in 1912, Harry Brearley of the Brown-Firth research laboratory in Sheffield, England, while seeking a corrosion-resistant alloy for gun barrels, discovered and subsequently industrialised a martensitic stainless steel alloy. The discovery was announced two years later in a January 1915 newspaper article in the *New York Times*. The metal was later marketed under the 'Staybrite' brand by Firth Vickers in England and was used for the new entrance canopy for the Savoy Hotel in London in 1929.

Brearley applied for a US patent during 1915, only to find that Haynes had already registered a patent. Brearley and Haynes pooled their funding and with a group of investors formed the American Stainless Steel Corporation, with headquarters in Pittsburgh, Pennsylvania. In the beginning stainless steel was sold in the US under different brand names like 'Allegheny metal' and 'Nirosta steel'. In 1929 before the Great Depression hit, over 25 000 tonnes of stainless steel were manufactured and sold in the US.

**Properties**

High oxidation-resistance in air at ambient temperature is normally achieved with additions of a minimum of 13% (by weight) chromium, and up to 26% is used for harsh environments. The chromium forms a passivation layer of chromium(III) oxide ($Cr_2O_3$) when exposed to oxygen. The layer is too thin to be visible, and the metal remains lustrous. The layer is impervious to water and air, protecting the metal beneath. Also, this layer quickly reforms when the surface is scratched. This phenomenon is called *passivation* and is seen in other metals, such as aluminium and titanium. Corrosion resistance can be adversely affected if the component is used in a non-oxygenated environment, a typical example being underwater keel bolts buried in timber.

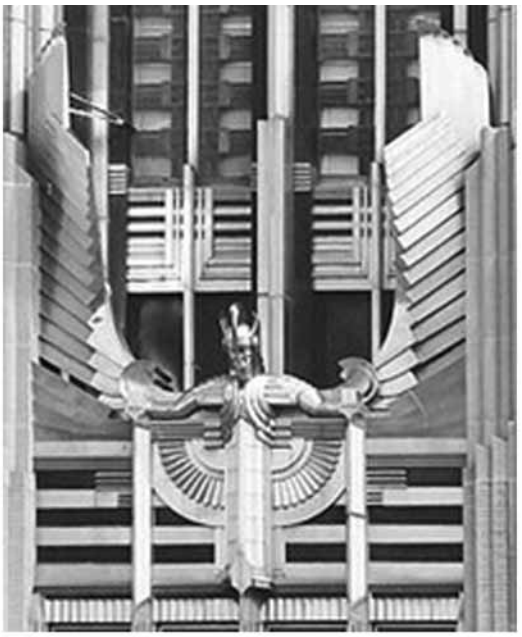
When stainless steel parts such as nuts and bolts are forced together, the oxide layer can be scraped off, causing the parts to weld together. When disassembled, the welded material may be torn and pitted, an effect known as *galling*. This destructive galling can be best avoided by the use of dissimilar materials for the parts forced together, for example bronze and stainless steel,

or even different types of stainless steels (martensitic against austenitic), when metal-to-metal wear is a concern. Nitronic alloys reduce the tendency to gall through selective alloying with manganese and nitrogen. In addition, threaded joints may be lubricated to prevent galling.

**Applications**

Stainless steel's resistance to corrosion and staining, low maintenance and familiar lustre make it an ideal material for many applications. There are over 150 grades of stainless steel, of which fifteen are most commonly used. The alloy is milled into coils, sheets, plates, bars, wire, and tubing to be used in cookware, cutlery, hardware, surgical instruments, major appliances, industrial equipment (for example, in sugar refineries) and as an automotive and aerospace structural alloy and construction material in large buildings. Storage tanks and tankers used to transport orange juice and other food are often made of stainless steel, because of its corrosion resistance and antibacterial properties. This also influences its use in commercial kitchens and food processing plants, as it can be steam-cleaned and sterilised and does not need paint or other surface finishes.

**The pinnacle of New York's Chrysler Building is clad with type 302 stainless steel**



**An art deco sculpture on the Niagara-Mohawk Power building in Syracuse, New York**

Stainless steel is used for jewellery and watches, with 316L being the type commonly used for such applications. It can be re-finished by any jeweller and will not oxidise or turn black.

Some firearms incorporate stainless steel components as an alternative to blued or parkerised steel. Some handgun models, such as the Smith & Wesson Model 60 and the Colt M1911 pistol, can be made entirely from stainless steel. This gives a high-lustre finish similar in appearance to nickel plating. Unlike plating, the finish is not subject to flaking, peeling, wear-off from rubbing (as when repeatedly removed from a holster), or rust when scratched.

Some automotive manufacturers use stainless steel as decorative highlights in their vehicles.

**Document 3** (continued)

**Architectural**

Stainless steel is used for buildings for both practical and aesthetic reasons. Stainless steel was in vogue during the art deco period. The most famous example of this is the upper portion of the Chrysler Building (pictured). Some diners and fast-food restaurants use large ornamental panels and stainless fixtures and furniture. Because of the durability of the material, many of these buildings retain their original appearance.

The forging of stainless steel has given rise to a fresh approach to architectural blacksmithing in recent years.

Type 316 stainless is used on the exterior of both the Petronas Twin Towers and the Jin Mao Building, two of the world's tallest skyscrapers.

The Parliament House of Australia in Canberra has a stainless steel flagpole weighing over 200 tonnes.

The aeration building in the Edmonton Composting Facility, the size of 14 hockey rinks, is the largest stainless steel building in North America.

**Bridges**

- Minorca Road Bridge (Spain) is the first stainless steel road bridge.
- Sant Fruitos Pedestrian Bridge (Catalonia, Spain), arch pedestrian bridge.
- Padre Arrupe Bridge (Bilbao, Spain) links the Guggenheim museum to the University of Deusto.

**Monuments and sculptures**

- The Unisphere, constructed as the theme symbol of the 1964-5 World's Fair in New York City, is the world's largest globe-shaped structure.
- The Gateway Arch (pictured) is clad entirely in stainless steel: 804 tonnes of 6.4 mm plate, #3 finish, type 304 stainless steel.
- The United States Air Force Memorial has an austenitic stainless steel structural skin.
- The Atomium in Brussels, Belgium was renovated with stainless steel cladding in a renovation completed in 2006; previously the spheres and tubes of the structure were clad in aluminium.
- The Cloud Gate sculpture by Anish Kapoor, in Chicago, USA.
- The Sibelius monument in Helsinki, Finland, is made entirely of stainless steel tubes.

**Other**

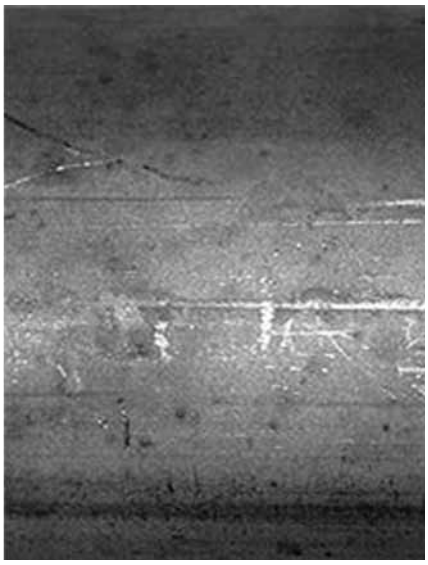
- The DeLorean DMC-12 automobile used stainless steel body panels over a glass-reinforced plastic monocoque.
- Passenger rail cars have commonly been manufactured using corrugated stainless steel panels (for additional structural strength). One notable example was the early Pioneer Zephyr.

**Recycling and reuse**

Stainless steel is 100% recyclable. An average stainless steel object is composed of about 60% recycled material of which approximately 40% originates from end-of-life products and about 60% comes from manufacturing processes. According to the International Resource Panel's *Metal Stocks in Society* report, the per capita stock of stainless steel in use in society is 80–180 kg in more developed countries and 15 kg in less-developed countries.

There is a secondary market that recycles usable scrap for many stainless steel markets. The product is mostly coil, sheet and blanks. This material is purchased at a less-than-prime price and sold to commercial quality stampers and sheet metal houses. The material may have scratches, pits and dents but is made to the current specifications.

**Stainless steel finishes**



**316L stainless steel, with an unpolished, mill finish.**

Standard mill finishes can be applied to flat rolled stainless steel directly by the rollers and by mechanical abrasives. Steel is first rolled to size and thickness and then annealed to change the properties of the final material. Any oxidation that forms on the surface (mill scale) is removed by pickling, and a passivation layer is created on the surface. A final finish can then be applied to achieve the desired aesthetic appearance.

- No. 0: Hot rolled, annealed, thicker plates
- No. 1: Hot rolled, annealed and passivated
- No. 2D: Cold rolled, annealed, pickled and passivated
- No. 2B: Same as above with additional pass-through highly polished rollers
- No. 2BA: Bright annealed (BA or 2R) same as above, then bright annealed under oxygen-free atmospheric condition
- No. 3: Coarse abrasive finish applied mechanically
- No. 4: Brushed finish
- No. 5: Satin finish
- No. 6: Matte finish
- No. 7: Reflective finish
- No. 8: Mirror finish
- No. 9: Bead blast finish
- No. 10: Heat coloured finish-wide range of electropolished and heat coloured surfaces

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## ACKNOWLEDGEMENTS

**Document 1** Extract from: Australian Motor Vehicle Certification Board. (2011). *National code of practice for the light vehicle construction and modification.* Retrieved July, 2012, from www.infrastructure.gov.au/roads/vehicle_regulation/bulletin/pdf/NCOP14_Guidelines_Electric_Drive_01Jan2011.pdf.

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