2. The amplifier controller measures the difference between current control.
3. The reactor rectifier controls the current from the ship's electrical system to the external anodes (charged +ve).
4. Anodes are usually of non-consumable, relatively noble metals.

Note: Although initial cost is high, these systems have a longer life, reduce hull maintenance and weigh less than sacrificial anode systems.

5.18 The use of paints as protection against corrosion

Paints are often the main and sometimes the only form of readily available protection. Paint consists of pigment dispersed in a liquid called the 'vehicle'. *Corrosion-inhibiting paints* for application to steel have the following vehicle types:

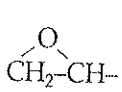
(a) Bitumen or pitch, either dissolved in solvent naphtha or heat-blended.

(b) Oils, consisting mainly of vegetable drying oils, e.g. linseed oil and tung oil. Drying oils are highly unsaturated and polymerise to resin under the influence of oxygen from the air.

(c) Alkyl resins which have improved drying time and film-forming properties. They are cross-linked polymers of maleic anhydride.

(d) Chemical-resistant paints.

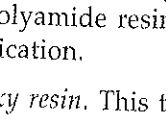
(i) *Epoxy resins*. These contain more than one epoxide group:



Chemicals produced from petroleum and natural gas are a source of epoxy resins. These paints often consist of a 'two pack' formulation, a solution of epoxy resin with a solution of a cold curing agent such as an amine or polyamide resin. They are mixed before application.

(ii) *Coal tar/epoxy resin*. This type combines the chemical resistance of epoxy resin with the impermeability of coal tar.

(iii) *Polyurethane resins*. A reaction between isocyanates and hydroxyl containing compounds produces the 'urethane' linkage:



These paints are tough, hard, glossy, abrasion resistant and chemical and weather resistant. Polyurethanes are not used under water on steel ships but only on superstructures.

(iv) *Vinyl resins*. These are obtained by the polymerisation of organic compounds containing the vinyl group $H_2C{=}CH{-}$. As vinyl resin paints have poor adhesion to bare steel surfaces, they are generally applied over a pre-treatment powder. Vinyl paints are among the most effective for the underwater protection of steel and are used widely in shipbuilding.

(v) *Zinc-rich paints*. These contain metallic zinc as a pigment in sufficient quantity to ensure electrical conductivity through the dry paint film to the steel. They are said to be capable of protecting the steel cathodically. Protection could be due mainly to the corrosion resistance of zinc. The pigment content should be greater than 90%, the vehicle usually being an epoxy resin.

(e) Anti-fouling paints. These consist of pigments which give body and colour to the paint together with materials that are poisonous to marine vegetable and animal growth. To prolong the life of the paint, the poisonous compounds must dissolve slowly in seawater, e.g. copper-based paints. The *James Craig* is a three-masted iron barque, built in 1874 and abandoned at Recherche Bay in Tasmania in the early 1930s. The restoration process now being carried out at Wharf 7, Darling Harbour in Sydney has used the following modern paints:

(i) An underwater anticorrosive paint, Inertuf HS Vinyl, which has vinyl tar as the vehicle.

(ii) An anti-fouling maintenance and repair paint, Red Interviron, which contains copper oxide.

(iii) A topsides and internal bulwarks paint, which includes Interzinc 72 containing pure zinc powder (>90% Zn). Polyurethane resins have also been used on the superstructure.

(iv) The final coat, as on Sydney's Harbour Bridge, contains micaceous iron oxide.