
Recommendations for

Corrosion and scale prevention in engine cooling water systems

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The following BSI references relate to the work on this standard:

Committee references C/37 and C/37/6 Draft for comment 71/50360

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Foreword

BS 3926, Recommendations for the use and maintenance of engine coolant solutions, was drawn up with vehicle engines specifically in mind. This British Standard covers all types of engines using closed cooling systems and deals with scale prevention as well as corrosion prevention. In addition to the integral cooling systems of internal combustion engines there are also external systems used in connection with large engine installations and with the test beds of engine manufacturers. These external systems may be closed, of the heat exchanger type, or open with the water running to waste or recirculated via a lagoon or an evaporative cooler. The treatment of water for use in open cooling systems may form the subject of a British Standard at some future date.

Recommendations for

Corrosion and scale prevention in engine cooling water systems

1. Scope

This British Standard covers the inhibitive treatment of water used in closed engine cooling water systems and includes recommendations for the cleaning of such systems and for the protection of drained systems.

Recommended field methods for the analysis of cooling water are described in Appendix A.

NOTE 1. The protection of cooling systems from damage resulting from freezing of the coolant is discussed in BS 3926. Formulations for corrosion-inhibited antifreeze solutions are specified in BS 3150, BS 3151 and BS 3152 (see also 3.4.3).

NOTE 2. The titles of the British Standards referred to in these recommendations are listed on the inside back cover.

2. Approach to the problem

2.1 Objects of cooling water treatment. The objects of cooling water treatment are:

- to increase engine reliability by maintaining a clean, efficient cooling system;
- to reduce corrosion of metallic components to a negligible or acceptably low value.

In achieving the above objects, cooling water treatment should not impair engine performance by causing frothing, or by the deposition of any materials that will impair heat transfer or adversely affect any non-metallic components in the engine.

2.2 Scale and corrosion development

2.2.1 Scale. Scale is usually formed in an engine cooling system by thermal breakdown of bicarbonate hardness in water, but it may also be due to deposition of other impurities such as calcium sulphate. Scale is deposited directly on to heat-transfer surfaces but this is not a serious problem with closed cooling systems unless there is either a high proportion of makeup water to replace losses due to evaporation or leakage, or contamination by sea water. Under these conditions scale can also be produced from sludge formed by interaction between the calcium or magnesium salts present and some corrosion inhibitors.

2.2.2 Corrosion. Corrosion results from the interaction of a metal with its environment and leads to the metal being either dissolved or converted to an insoluble product e.g. an oxide. The use of distilled or deionized water will not eliminate this tendency. The process differs for different metals but there are always two main features:

- (1) metal goes into solution at certain areas of the surface — these are anodic areas;
- (2) a complementary reaction must occur at other areas — these are cathodic areas.

The latter reaction usually involves oxygen and to this extent the presence of dissolved oxygen (from the air) is undesirable. However, with some of the more resistant metals and alloys, e.g. stainless steel, the presence of dissolved oxygen is necessary to maintain their corrosive resistance.

Corrosion can manifest itself in several ways of which the following are the most important.

a. General wastage. General wastage occurs by reaction of the metal with the aqueous coolant to give a uniform depth of penetration over the whole surface. The effect of localized anodic and cathodic areas is not pronounced and the uniform attack may be rapid or slow depending on the conditions. Although the depth of penetration may not be great, the total amount of corrosion product may be considerable; some of this will remain on the metal surface but much will be dispersed, as suspended matter, into the coolant.

b. Pitting. Pitting is produced when there are small and persistent anodic areas, often due to the failure of a protective process to cover all the surface. The metal dissolves at these places, leaving pits. The total amount of corrosion and corrosion deposits formed may be far less than in general wastage and the appearance of the coolant may not reveal that any corrosion is occurring, yet the rate of penetration of a pit through a metal wall may be catastrophic.

c. Crevice corrosion. The conditions in a crevice (a feature that should be avoided where possible in the engine design), or under loosely adherent scale, or at the bottom of a pit, may be different from those in the main bulk of the system and rapid corrosion may occur at these places.

d. Bi-metallic (galvanic) corrosion. If two different metals are in electrical contact their behaviour may be such as to make one metal anodic with increased tendency to corrosion, and the other cathodic and therefore protected. Proper selection of metals in contact will minimize trouble from this cause. In some circumstances undesirable bi-metallic contacts, although not present initially, may arise in service, for example, copper may dissolve from one part of the system and be deposited on aluminium elsewhere.

e. Impingement attack or erosion. This term is used to describe metal loss due to excessive water velocity. The attack may be further accelerated if the water contains abrasive particles.

f. Cavitation damage. Component vibration (e.g. in a wet cylinder liner) or local changes in water velocity and pressure may lead to the formation of bubbles or cavities in the coolant. These bubbles then rapidly collapse and the constant repetition of this at a metal surface produces intense pitting by a combination of mechanical and corrosive action.

g. Stress-corrosion and corrosion fatigue. Stress-corrosion occurs under the combined action of applied or internal mechanical stress and a corrosive environment. Certain alloys are particularly subject to it, for example, stainless steel in the presence of chloride and brass in the presence of ammonia. When the stresses are of a fluctuating nature, a similar type of failure known as corrosion-fatigue may occur.

h. Special cases of corrosion

(i) *Graphitization.* Cast iron is subject to a form of general wastage in which metal dissolves and the residue of corrosion products and graphite produces a surface of unaltered shape but which is soft and without mechanical strength.

(ii) *Dezincification.* Some brasses are subject to a form of attack in which the zinc is removed and porous copper remains.

2.3 Features of protective action

2.3.1 Scale prevention. Deposition of calcium and magnesium compounds from hard water on heat-transfer surfaces and other parts of cooling systems may be avoided either by the use of water that does not contain significant amounts of hardness salts (soft water) or by treatment of the water in one of two ways as follows.

(1) Hardness salts may be removed in an external treatment plant, which may be either a distillation plant or a water softener.

Softening may be used with fresh-water feed. The plant may be either of the ion-exchange or of the precipitation type, the choice depending on the hardness and other characteristics of the water.

A water treatment plant will rarely be installed solely to meet the requirements of filling and topping-up closed cooling systems. Frequently, however, distilled or other treated water will be available for other services and it may then be used for engine jacket requirements.

If local supplies of water are considered unsuitable and if soft water cannot be supplied from existing plant, supplies of suitable water may usually be purchased in bulk quantities at a reasonable price.

(2) As an alternative to removing the hardness salts from the water used for filling and topping-up the cooling system, additives are available for preventing scale. The choice is restricted to those that:

- a.* do not form a sludge but retain the calcium and magnesium permanently in solution;
- b.* are stable and retain their properties almost indefinitely under the conditions of use, especially with regard to temperature;
- c.* are compatible with any other additives (e.g. corrosion inhibitors) used in the system;
- d.* do not themselves promote corrosion or introduce any other problem, such as foaming of the finally treated cooling water;
- e.* do not adversely affect the thermal efficiency of the cooling system in any way.

2.3.2 Corrosion control. Corrosion in closed engine systems may be reduced to acceptable levels by the addition of suitable chemicals known as corrosion inhibitors. Frequently a combination of two or more inhibitors may be necessary. However, not all inhibitors are suitable for every type of cooling system and furthermore, all inhibitors are subject to certain limitations even in the systems for which they are most suitable. To be effective, any inhibitor should initially be present above a certain minimum concentration that will be dependent on the nature of the inhibitor and the type and operating conditions of the system. It is necessary to maintain the inhibitor concentration during service particularly as corrosion may be aggravated when insufficient inhibitor is present.

Field methods for checking the inhibitor concentrations are described in Appendix A.

The effectiveness of an inhibitor in reducing or preventing corrosion depends on a number of other factors and the more important of these are listed below.

(1) *The nature of the metal to be protected.* Many inhibitors are specific in their action, e.g. an inhibitor of the corrosion of copper would not necessarily be effective for ferrous metals.