

# MINERAL OIL HYDRAULIC SYSTEMS

## THE MEASUREMENT AND CONTROL OF WATER CONTAMINATION

BY

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### Introduction

For very obvious reasons, some considerable attention is given to the subject of solid particulate contamination of the working fluids of hydraulic systems. Although certain systems are designed to operate using special water-based fluids, the majority of systems employ conventional mineral oil fluids in which the presence of water can be just as detrimental to the operation of hydraulic components as solid particulate matter. Far less information is available on this particular aspect of contamination with the result that the average maintainer is not well informed about the procedures and techniques that are available for the measurement and control of water contamination. In many respects the problem presents less difficulty than does the presence of solid particulate, and quite simple methods can be employed to minimize its effects.

In a mineral oil hydraulic fluid, water may be present even though the fluid appears to be clear and bright; this is because there are always small amounts of water dissolved in the oil. When a hydraulic system is contaminated with either fresh water or sea water beyond its saturation level at a certain temperature, the fluid will become cloudy. This cloudiness is caused by the fine dispersion of water droplets in the oil. As the temperature increases so will the solubility of the water present in the oil. Water present in this dissolved state is unlikely to have any serious adverse effect upon the working surfaces of the components with which it is in intimate contact. However, as the system cools some of this water will come out of solution. If the system is allowed to cool for any appreciable length of time, e.g. a system that is subject to long periods of non-operation or is perhaps shut-down over a weekend, many of the water droplets will combine and tend to settle in pockets around the system, and under these conditions corrosion and breakdown of the lubrication film is likely to occur. FIG. 1 is a typical solubility curve for a standard mineral oil hydraulic fluid.

### The General Problem

Water may be present in the working fluid in the following forms:

- (a) In solution.
- (b) In suspension.
- (c) In separated state.

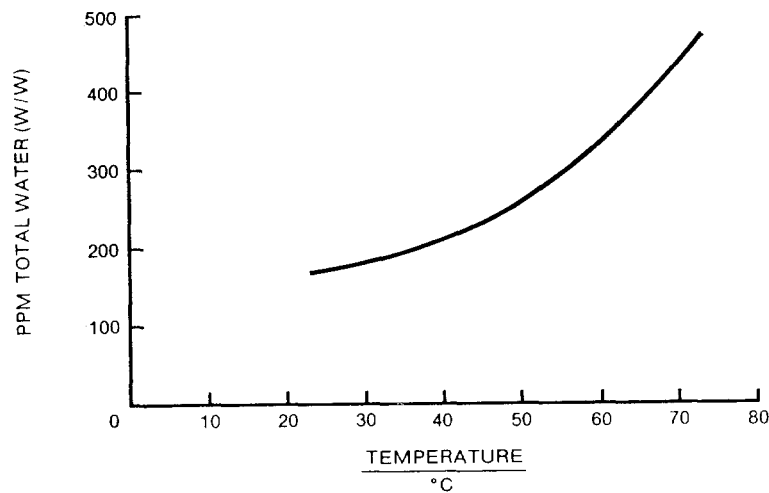


FIG. 1—TYPICAL SOLUBILITY CURVE FOR WATER IN HYDRAULIC OIL.

A conventional hydraulic mineral oil with a viscosity of 30 centistokes at 40°C may well contain 50–100 ppm of water in solution upon delivery in a sealed drum. In a normal system this quantity of water is unlikely to create a problem. However, because most hydraulic systems rely upon ventilation through the breather fitted in the top cover of the reservoir, a considerable amount of atmospheric movement into and out of the reservoir will take place during system operation, this being particularly the case with accumulator systems. Because the air that is interchanged will contain water vapour, condensation and increase of the moisture content level of the system fluid will occur. Hydraulic systems are very often provided with water coolers and although the reliability of these equipments is high, there is always the possibility of leakage or seal failure; some simple coolers take the form of water cooling coils submerged in the reservoir. Erosion can sometimes occur leading to pinhole leakages and a gradual increase of water contamination. Hydraulic equipments fitted in ships are also subject to considerable exposure to sea water, particularly where used for the operation of deck machinery, and therefore a further source of contamination exists via exposed seals, joints, rams, etc. Certain ship systems, e.g. stabilizers, bow thrusters, controllable-pitch propellers, etc., operate below the ship's waterline and therefore present special problems.

Most hydraulic systems operate at around 50°C and at this temperature the saturation level for a standard mineral oil is between 250–300 ppm. Provided the equipment is operated frequently, experience indicates that corrosion and lubrication problems, due to the presence of water at this level, are unlikely to cause operational difficulties or lead to early component failure, and that, for most operational systems, water contamination up to a level of 500 ppm can be tolerated without ill effect. Above this level however, the water is likely to separate around the system in sufficient quantities to form slugs or small pockets, and this is likely to affect the operation of control valves causing them to stick and eventually to seize. Rolling bearings are also components that will be likely to suffer early failure under water-contaminated fluid conditions.

### Water Removal and Control

Use can be made of the property of water to separate from oil after a period of inactivity and it is good practice to drain separated water from the bottoms of reservoirs and other low points around the system periodically. It is also

good design practice to fit a combined air filter/drier to the breathing arrangements fitted to the system header tanks; the drier element usually contains a water absorbent chemical and can fairly simply be regenerated by heating.

Various methods are available for the removal of water from hydraulic fluids. Some examples are:

- (a) Coalescer filters which remove water from fluids by the coalescence or uniting of the finely emulsified water droplets as they travel through the media layers to form fairly regular-sized droplets, usually on the outer surface of the media.
- (b) Stripper columns which allow dry air to be passed upwards through a vertical column packed with metal separators, down through which the oil flows under conditions of high vacuum. Water present is therefore removed by evaporation.
- (c) Centrifugal separators which have probably been in use for the removal of water from mineral oils longer than most other methods; they rely upon the high-speed rotation of the fluid within a series of conical drums to remove water or any solid matter present which has a specific gravity higher than the oil.

Although all of the above-mentioned techniques are very effective for the removal of gross water contamination, none of them are particularly satisfactory when applied to mineral oils used in hydraulic systems. In order to achieve satisfactory flow rates through coalescers and centrifuges it is necessary to reduce the viscosity of the oil by raising its temperature. This tends to be self-defeating because much of the water is then driven into solution with the oil. Experiments carried out with coalescer filters, for example, have shown that at 30°C gross water contamination could be reduced to about 0.2 per cent. (0.02 per cent. being dissolved water), and raising the temperature to 70°C only reduced the contamination to 0.1 per cent. (0.05 per cent. being

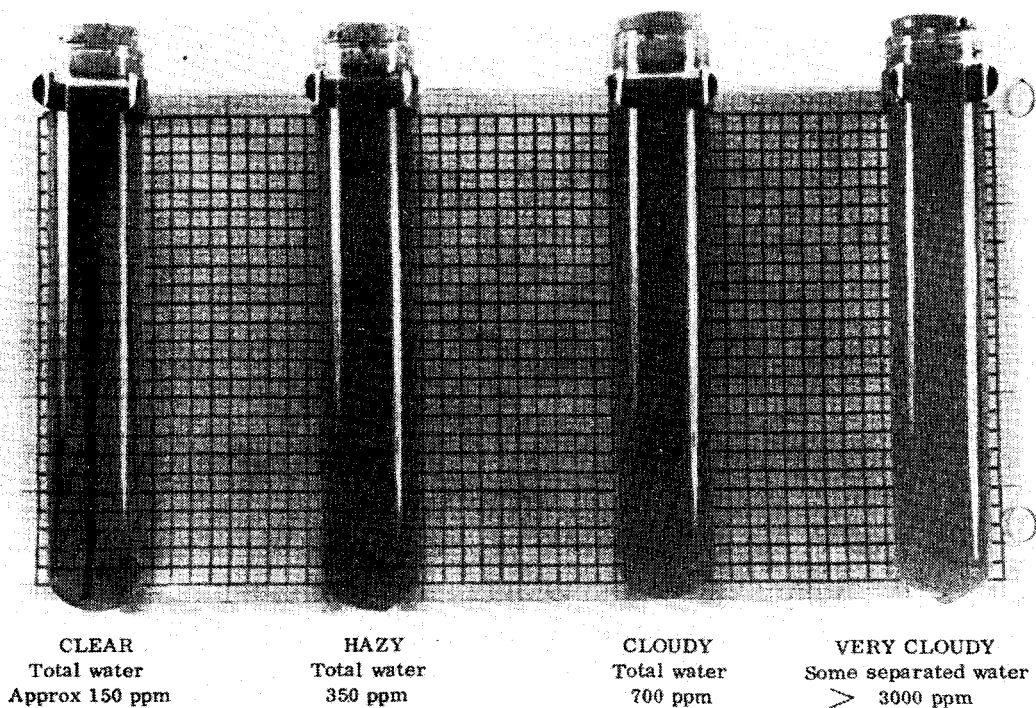


FIG. 2—THE EFFECT OF WATER UPON THE CLOUDINESS OF MINERAL OIL

dissolved water). A further problem encountered when processing sea-water contaminated fluids using the vacuum separator column is that of the residual salt crystals which remain in the fluid after the water is evaporated.

Experience within the Royal Navy has shown that:

- (a) Provided the level of water present in mineral oil hydraulic systems is kept below 500 ppm then equipment life and operation is unlikely to suffer.
- (b) In most well-designed systems this level can be maintained by good husbandry, i.e. monitoring the level of water present, draining off from low points periodically, topping up with clean dry fluid, etc.
- (c) Catastrophic failure can be prevented if early warning can be given of incipient water leakage into the system.

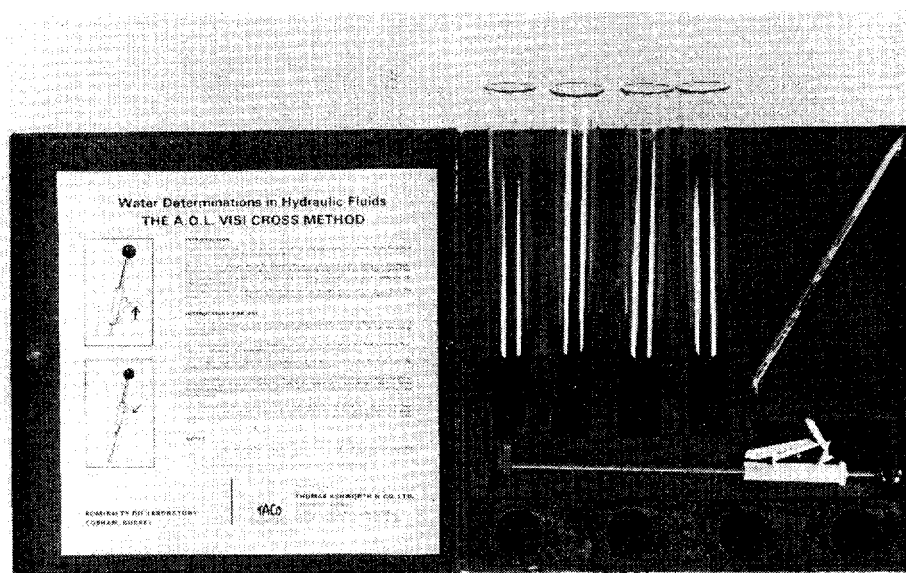


FIG. 3—THE VISI-CROSS MOISTURE TEST KIT

### Measurement of Water Contamination

Karl Fischer and Dean and Stark are standard laboratory procedures for the determination of water in oil. However, their use to the maintainer is limited by the time taken to transmit samples. A procedure known as the 'crackle' test has been employed for many years; this simple test requires a sample of fluid to be heated in a test tube, the observation of an audible crackle during heating being an indication of the presence of water. Experiments have shown however that this test is far too discriminating for hydraulic fluids and can set unrealistically low levels of contamination; often quite audible crackles are obtained from fluids with contamination levels of 100 ppm or less. There is therefore a tendency to reject fluid which is quite satisfactory for most hydraulic purposes.

It has been necessary therefore to develop a simple field technique that can be used to monitor realistic values of water contamination. Use has been made of the cloudy appearance of oil when contaminated with water to devise a simple test method. FIG. 2 illustrates the effect of various quantities of water upon the clarity of a typical hydraulic oil. Based upon this principle, a simple device known as the Admiralty Oil Laboratory Visi-Cross Moisture

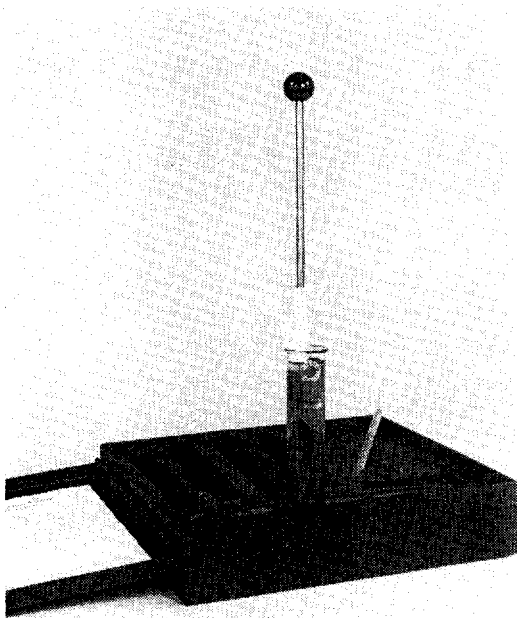


FIG. 4(a)—OIL CONTAMINATED WITH LESS THAN 100 PPM WATER

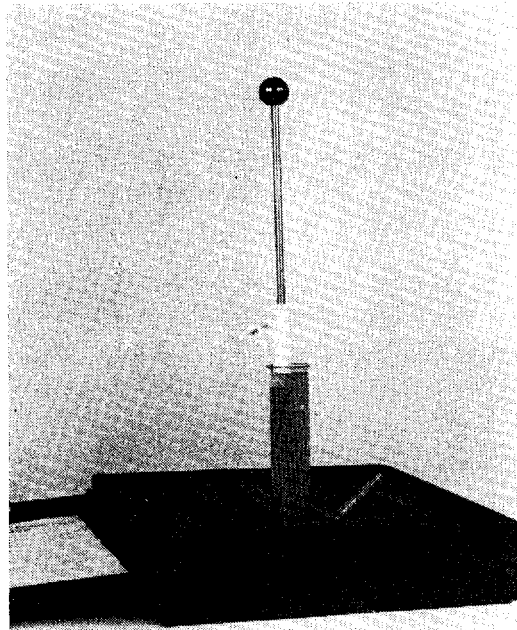


FIG. 4(c)—OIL CONTAMINATED WITH WATER APPROACHING 500 PPM

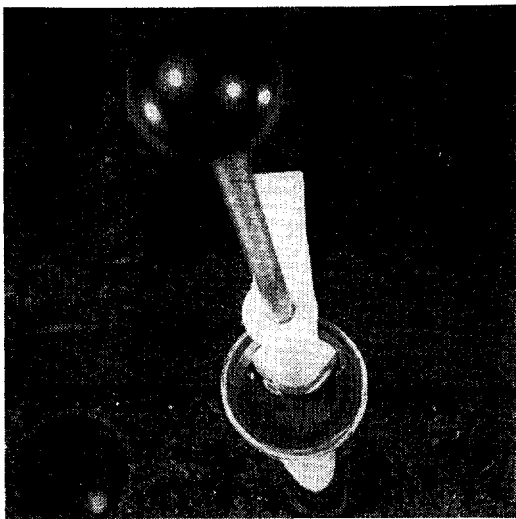


FIG. 4(b)—VERTICAL VIEW OF VISI-CROSS (<100 PPM)

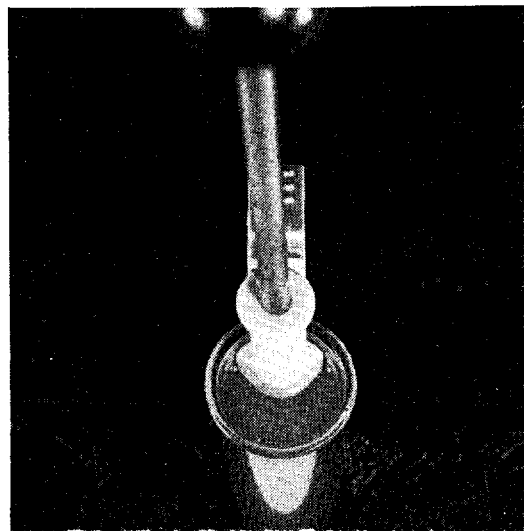


FIG. 4(d)—VERTICAL VIEW OF VISI-CROSS (APPROACHING 500 PPM)

Tester has been developed. The instrument consists of a sliding rod which can be clamped to the top of a test tube containing a sample of contaminated oil. A small cross device is fitted to the bottom of the sliding rod which can be lowered into the fluid until the cross is obscured by the turbidity of the fluid. Calibrations on the sliding rod relate the depth of the rod to the amount of water contamination present. FIG. 3 shows the complete kit and FIG. 4 (a)-(d) illustrates its use.

The test is extremely simple to carry out, requiring only that the fluid be allowed to cool to room temperature before the assessment is made. The instrument can be used with most standard mineral oil hydraulic fluids.

**Conclusions**

The operator is equipped with a ready means for monitoring the presence of water in his hydraulic system, and can take simple remedial action to contain the level of contamination within acceptable limits. In the event of excessive contamination, he is forewarned and can take measures to avoid catastrophic failure. The use of the Visi-Cross Moisture Tester in conjunction with the simple maintenance procedures outlined should contribute in no small measure to increased component life and improved system reliability.

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