HYDRAULIC HYGIENE IN ORDNANCE ENGINEERING

BY

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According to the post-sales researches of two world-famous firms marketing modern hydraulic power transmission systems on the one hand and high duty thrust and journal bearings on the other, dirt has been responsible for 85% or more of their customers' troubles. It is, therefore, well-worth knowing something about this common enemy and how best to avoid him in design, production and operation. As a result of recent researches, much more is now known about the problem, and the aim of this article is to describe the essentials of it in broad terms.

Before starting, it is interesting to note that, in the forced lubrication systems of the best regulated marine engines and gearing, the presence of dirt particles of .007 in. is considered by the Michell Bearing Co. to be not unusual. In modern automobile engines fitted with the latest and best design of filter, the corresponding figure is .001 in. In precision hydraulic systems the corresponding figure is about .0015 in. for the fine oil motors fitted in precision fire-control systems such as S.T.A.A.G. and the Close Range Blind Fire Director, &c.

Dirt liable to find its way into lubrication and hydraulic systems comes from the following seven main sources:—

(*a*) Core-sand ;

(*b*) Scale off pipes, tanks and welded parts ;

(*c*) Workshop dirt ;

(*d*) Atmospheric dust ;

(*e*) Sludge or foreign matter in the oil as supplied by the oil company or oil vendor ;

(*f*) Metallic products of wear ;

(*g*) Scale and dirt from cleaning tools, wire brushes, &c.

Precautions

It has been found that the attack on the enemy, to be successful, must be four-pronged as follows:—

(*a*) Prevention of entry ;

(*b*) Provision of adequate permanent filters, separators and strainers in the system ;

(*c*) Provision in the design for the insertion of temporary ultra-fine (low capacity) filters for initial cleaning runs ;

(*d*) Deliberately designing the system to tolerate particles of a certain maximum size. (In other words, assuming that complete prevention or trapping is virtually impossible.)

Three attacks without the fourth will spell trouble, and these four prongs will be taken in turn.

A.—Prevention of Entry

(a) Core-sand

Topical arguments as to whether to paint, or not to paint crank cases are considered by precision hydraulic engineers to be laughable. They know that the following expensive processes are *all* essential: fettling, shot-blasting, metal dressing, bakelite impregnation, and baking, in that order. Nothing less will prevent minute particles of core-sand from "sweating" out of the pores of the metal under the prolonged influence of hot oil.

(b) Scale off pipes, tanks and welded parts

Precision hydraulic engineers now know that acid pickling or other chemical processes are virtually useless for cleaning steel pipes and tanks. Nothing less than severe mechanical abrasion by wicked-looking power-driven tools will remove pipe or weld scale, and the pipe-work must be designed to pass these tools.

This process must, of course, be combined with wire-brushing and, finally, the use of dry, filtered medium pressure air blast. It is interesting to note that it has been found necessary to repeat this elaborate pipe-cleaning process each time after the pipes have been bent or subjected to heat. After treatment, all pipes *must* be immediately plugged or sealed, and must remain so until final assembly.

(c) Workshop Dirt

Operatives must have clean hands and clean white overalls. The assembly workshop must be built to hospital standards of cleanliness and lighting. This means that the operatives must be provided by the management with the means of washing their hands, wiping their feet, and obtaining clean overalls; and no files, scrapers, &c., must be allowed in the shop where final assembly takes place. Work benches must be designed for easy cleaning and must be kept clean and tidy.

A recent example of complete lack of hygiene in assembly was a servo-unit drawn from store which failed immediately after being shipped and balanced. When the unit was opened it was found that among other foreign matter the pilot valve ports still contained a considerably quantity of the lapping paste used to bed the valve in.

(d) Atmospheric Dust

Double doors and air-cleaning systems must be provided. If the air inside the assembly shop be maintained at a slightly higher pressure than outside, so much the better.

(e) Sludge, foreign matter or water in the oil as supplied

All oil received from the suppliers must be treated with the utmost suspicion, until proved by rigorous tests of samples to be clean. It is regretted to have to say that even all oil received from the Naval Store Department must be regarded as guilty until it has been proved innocent.

A quick and simple method of testing oil received on board for foreign matter is to pour it through filter paper or ordinary white blotting paper; the amount of filtrate left gives a direct indication of the cleanliness of the oil.

If the oil has been standing, then the sample should be drawn from the bottom of the storage tank or drum, and in this case holding the oil to the light will often show at once whether it is fit for use. If the oil is agitated after being manhandled on board, or prior to striking down,

the foreign matter will be dispersed and a sample of not less than one-quarter per cent. of the total should be drawn and filtered.

All oil for servo systems should be supplied in sealed containers. Nevertheless it should be tested for water by the " Crackle Test " as should oil recovered. All oil recovered and any not supplied in sealed containers *must* be passed through a " Stream-line " filter* prior to the " Crackle Test ". The " Stream-line " filter will remove any significant foreign matter together with small quantities of water. Large quantities of water in the oil are liable to saturate the filter and render it useless.

To carry out the " Crackle test ", a sample of the oil is heated in a test tube over a spirit flame or taper. If water is present there will be an unmistakable " crackle ". For those not familiar with the test, it is a good plan to carry it out first with dry oil and then after adding a drop of water. The cackle test is entirely reliable and it should be noted that it is equally effective when testing diesel and furnace fuels for water. (See also *Journal of Naval Engineering*, Vol. 5, No. 2, July, 1951, page 107.)

(*f*) *Metallic products of Wear*

If the above precautions are followed, and if the design of the swash-plate hydraulic pumps and engines is correct, there will be virtually no products of wear after the first ten hours of running at full load. Careful researches have established that this is the length of the " running-in " period, after which the wear/time curve becomes almost flat. It follows that all pumps and engines should complete their running-in period and then be thoroughly cleansed before incorporation in the hydraulic system.

B.—Provision of Permanent Filters, Separators and Strainers in the System

Notwithstanding the elaborate precautions taken to prevent entry of the enemy, long and bitter experience shows that it must, nevertheless, be assumed that his fifth columns will have slipped in, although probably in an attenuated form. Even the most modern filters which will pass the necessary large quantity of oil, must be expected to pass dirt particles up to about .001 in. in diameter. This points to the next precaution.

C.—Provision in the Design for the Insertion of Fine/Low Capacity Filters for Initial Cleaning Runs

Once a hydraulic system can be rendered completely dirt-free, it will give no trouble even under the most arduous conditions for many years. It follows that the condition of freedom from dirt is well worth striving for.

Again, the experts have found that " cleaning runs " are essential. Provision should, therefore, be made in the design of the pipe system for the insertion of one or more ultra-fine (low capacity) filters. Cleaning runs must then be carried out at the highest expected oil temperature and at the maximum capacity permitted by the temporary filters. Even in the best regulated families, some fine dirt will be found in the temporary filters after the running-in period. Running-in filters must, of course, be again inserted and freely used whenever the hydraulic system is opened up, i.e. whenever any of its joints have been broken.

D.—Design of the System to tolerate Particles of a certain size

It might be thought that precautions A, B and C would have been enough,

* It is claimed by the makers that these filters remove all particles down to 4×10^{-6} in. The smaller type used in the Service for filtering servo oils handles 0.75 gallons in twenty-four hours.

but they are not. The oil system must be designed to tolerate particles up to a certain size.

This opens up a vast subject. One of the factors is what is called the " embedability " of the white-metal used. Recent researches in the Automobile Industry have shown that there is a definite limit to the permissible hardness of bearing metal, and to the thinness of the white-metal shells or inserts. Below these limits, the dirt particles will not be able to embed themselves, and thereby become comparatively innocuous. If they do not become fully embedded, the portions projecting out of the white-metal form an excellent lap*, guaranteed to wear away the hardest journal.

If white-metal is not used, then the maximum size of the dirt particles must never exceed the thinnest portion of the oil film under the worst conditions, probably .001 in. Ultra-precision control valves must be made to dither, otherwise the phenomenon of " hydraulic lock " (caused by minute particles of dirt wedging themselves into an even finer clearance in the control valve) will supervene. In many other ways the design must recognize the existence of the enemy's saboteurs, even though the first, second and third lines of defence have been made secure in the production shops.

Conclusion

The Director of Naval Ordnance is endeavouring to specify a standard of cleaning during manufacture and of cleanliness during assembly. Work continues in aid of satisfactory standards of filtration for cleaning runs and operational use. Understandably, manufacturers will not take kindly to this requirement because of the capital expenditure involved, but in no other way can hydraulics, the proven best form of power transmission for ordnance and many other applications, be made satisfactory or reliable.

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* A " lap " was originally the tool which a lapidary used (and still uses) to facet a gemstone. It consists of a disc like a gramophone turn-table made of copper or lead impregnated with carborundum.