SOCIETY OF AUTOMOTIVE ENGINEERS, Inc.
485 LEXINGTON AVENUE
NEW YORK 17, N.Y.

AERONAUTICAL INFORMATION REPORT

AIR 81

Issued 10-1-60
Revised

HYDRAULIC FLUID CHARACTERISTICS

INTRODUCTION

This report was prepared to indicate the various characteristics of a fluid which influence and control its useability for aero-space vehicle hydraulic purposes. Further, it discusses the effect of the fluid characteristics in the design of aero-space vehicle hydraulic systems and components.

1. SCOPE: This report discusses the characteristics of hydraulic fluids and evaluates their importance, not only from the standpoint of fluid formulation, but also in their effect on aero-space hydraulic system design and the materials used in the components of the system. In some cases numerical parameter limits are suggested, but, in general, the effect of a parameter is the basic consideration.

Not only must the characteristics of the fluid be considered in the design of a hydraulic system in which it is to be used, but also the characteristics of the system will affect the extent of the importance of the various characteristics of the fluid. In each individual system, as it employs a fluid, the characteristics of the fluid must be assessed with their immediate import and weighed in considering their effects on the system design requirements based upon the variables of system environment, function and basic design.

The fluid characteristics must be considered not only in the system design, but also in connection with the ground handling and servicing characteristics of the vehicle.

It can be said that the only characteristic of a hydraulic fluid that is absolute, is that it be a liquid throughout the range of use conditions. All the other parametric values form the basis for consideration in hydraulic system design.

2. HYDRAULIC FLUID CHARACTERISTICS:

2.1 General: To some extent it is possible to categorize hydraulic fluid characteristics and parameters and they will be listed in this manner, where practicable. The sequence of listing has no bearing on the relative importance of these parameters, moreover strength in one characteristic can often compensate for weakness in another.

2.2 Viscosity: Viscosity, describing as it does the resistance of a fluid to the motion of its particles, is one of the most important basis of measurement of the useability of a fluid both as a maximum and as a minimum. The importance of maximum and minimum viscosities rises from greatly varying effects which will be discussed in detail. Viscosity/Temperature curves should be provided in the fluid descriptive data. It is also desirable that pressure/viscosity curves at various temperature be furnished.

 Printed in U. S. A.

2.2.1 Maximum Viscosity: There appear to be two basic levels of maximum viscosity that are of importance in determining the useability of a fluid and the design criteria to be employed when it is used. In general, it can be stated that the maximum viscosity describes the minimum useable temperature of a fluid. These two maximum viscosity levels can be stated as, first, Maximum Starting Viscosity, and second, Maximum Operating Viscosity. The generally accepted Maximum Starting Viscosity level is 2500 centistokes. At this viscosity, full rate system operating cannot be achieved without excessive design penalties which are currently unthinkable in an air vehicle, due largely to the resultant excessive weight. It can be stated that any fluid which can be pumped can be started in operation and, therefore, the true Maximum Viscosity level is several times this value. Pump, system friction, engine or aerodynamic heating rapidly increases the fluid temperature once a system has been started and thus decreases the viscosity rapidly to the Maximum Operating Viscosity level, which is the viscosity at which full system operation can be expected. This viscosity level is one of the basic system design criteria and it is somewhere in the order of 500 centistokes. A higher placing of this level increases the system design problems, whereas a lower placement of the level decreases them and results in a weight saving.

2.2.2 Minimum Viscosity: One of the fluid characteristics that combine to establish the upper economical thermal limit of a specific fluid is its viscosity/temperature effect. A level of two (2) centistokes is generally accepted as a desired minimum for efficient pump operation. However, viscosities as low as 0.5 centistokes or less can be pumped, but with some types of pumps the efficiency will be reduced. It must also be noted that extremely low viscosity is often coupled with greatly reduced lubricity, with resultant effects on component life. Low viscosity also results in increased internal and external leakage in slide, servo and similar valves and actuator packing, which must be assessed as an effect resulting in reduced system efficiency, design penalties and criteria.

2.2.3 Pour Point: Normally this characteristic is of no importance to the hydraulic system or component designer. It does, however, indicate an absolute low thermal limit below which fluidity does not exist.

2.2.4 Low Temperature Stability: This is not generally considered to be a characteristic of a fluid that is a design consideration, but it generally describes a quality of the fluid to resist separation, decomposition and other forms of degradation during storage at extreme low temperature. Unless the results of low temperature reverse themselves when the temperature is increased a fluid is either unuseable or will require special storage and handling. This irreversibility would also affect the useability of the fluid in an aerospace vehicle as it would result in undesirable ground handling requirements for the vehicle.

2.2.5 Storage Stability: This characteristic is of considerable importance in the field of logistics. A fluid which requires special storage procedure and storage degradation checks is undesirable.

2.3 Lubricity: There are two basic and recognized tests for lubricity in a hydraulic fluid and it is felt that both should be retained as desirable indices. The shell-four-ball wear test is of considerable value as a preliminary screening indication of useability of a fluid and should be run at increments of approximately 100F from the lowest use temperature of the fluid to the highest use temperature and reported in the fluid descriptive data. The piston pump wear test is a much more reliable indication of the hydraulic system useability of a fluid. Since this test requires a much longer running time than the shell test, it is not necessary that it be run at numerous temperature increments, but only at the maximum use temperature of the fluid. For specification purposes, it is desirable that the pumping lubricity test be run on a pump which is representative of the general type of pumps expected to be used with the fluid. Good indication of lubricity from wear characteristics in one pump will not mean similar indication in pumps of different manufacturers. Lubricity is not only necessary from the standpoint of pumps, but also for slide, servo and similar valves and for its effect on packing life. However, in general, a fluid which has good indicated lubricity in a piston pump will also have the necessary lubricity for such valves.

In the development of new fluids, poor indicated pump lubricity does not necessarily indicate an unuseable fluid, but may rather indicate need for further pump development of the use of a different type of pump.

2.3.1 Load Carrying Capacity: A low load carrying capacity in a fluid will, in general, be evinced by a poor lubricity and will result in an undesirable fluid. The pumping test required for lubricity should be sufficient evidence of this capability, particularly in the effect on the pump bearings.

2.4 Combustion Indices:

2.4.1 Flash Point: This factor is of relatively small importance in hydraulic system design. Fluids can normally be used at temperatures greatly in excess of their flash point. It is desirable that the flash point be stated as it is an index of volatility and vapor pressure. For system design, it should also be considered from the standpoint of possible build-up of combustible fumes.

2.4.2 Autogenous Ignition Temperature and Fire Point: These basic indices of combustion probability should be stated as a function of pressure and are of considerable importance in establishing a top useable temperature limit of a fluid as an index of the temperature level at which special design precautions are necessary for the safe use of a fluid.

2.5 Vapor Pressure: In cases where a fluid is intended to be used at elevated temperatures, specification of the vapor pressure is a necessary design criteria. For non-specification fluids, it is also a necessary design base and must be stated in the fluid descriptive data. Vapor pressure is also to some extent used as an index of the upper thermal limit of a fluid. A low vapor pressure may be mandatory for upper altitude and space flight. These conditions will encourage evaporation especially with high temperatures.

2.6 Bulk Modulus: This characteristic should be stated as a family of curves at pressure ranges as a factor of bulk modulus versus temperature to the highest use temperature of a fluid. It is of great importance in dynamic considerations of hydraulic system design. While it is not susceptible to any great variation in the formulation of a fluid from any given base stock, it should be given great importance in the selection of desirable base stocks.

2.6.1 Gas Solution: The precentage of soluble gas versus pressure and temperature of a fluid should be stated in the fluid descriptive data and is a necessary factor in hydraulic system design.

2.7 Density: Density of hydraulic fluids is basically important as a basis for weight calculation in the design of a system and, therefore, it is desired that it be low. Since low density is in some cases coupled with a low bulk modulus, it must in such cases be sacrificed. Where a fluid specification is being prepared to cover fluids of a known class of base material, the permissible range of density versus temperature can be specified. In any case, the density-temperature relationship of a fluid should be stated in the fluid descriptive data.

2.8 Rubber Swell: Since this test is run on specially compounded rubbers which do not necessarily bear any relationship to the elastomeric base stocks, which will be used in a system, they can only be accepted as an indication of the effect of the fluid on the compound of the test. There is no statement in any current fluid specification as to the nature of the rubber used for the test, therefore, from the system design standpoint, any data so derived is valueless. The effect of rubber swell, shrinkage or degradation of a specific rubber compound in a given fluid is of considerable value in the design and installation of seals of that rubber-like fluid combination. Moreover, the free rubber swell or shrinkage in a given fluid cannot be taken as a numerical index of the confined rubber swell or shrinkage that will be found in an installation, but merely as a guide for design precautions and trends. The fluid descriptive data should state the free swell limits found with elastomers of probable use with the fluid as a guide to designers.

2.9 Shear Stability: The ability of the dements of a fluid formulation to withstand the shearing action of pumping and valve operation is of considerable importance in determining endurance life of a fluid. Shear breakdown is generally indicated by a lowering of viscosity and may also be accompanied by a loss of lubricity. In some fluids shear stability affects only polymeric additives to the fluid, but in others, where the base fluid is of a relatively long chain nature, it may be important to the base stock.

2.10 Thermal Characteristics:

2.10.1 Thermal Stability: The thermal stability factor of a fluid should be stated in the fluid descriptive data as a function of breakdown rate versus temperature. The nature of the products of thermal breakdown must also be stated and their effect on hydraulic system operation considered. Means of elimination of undesirable products of breakdown must be provided in cases where a fluid is to be used at temperatures where thermal breakdown is consequential or the duration of fluid used limited.

2.10.2 Degradation Products: The nature of the products resulting from thermal breakdown and other fluid degradation causes should be stated in the fluid descriptive data. They must not be of a type which will result in excessive gumming of valves and other components, or tend to corrode or otherwise destroy the materials of component manufacture. Where gaseous products are released means must be provided for their elimination from the system.

2.10.3 Thermal Expansion: The coefficient of thermal expansion of a fluid should be stated in the fluid descriptive data. In case this coefficient varies measurably as a function of temperature, it should be so stated. It is of considerable importance in system design, particularly when the temperature range to be covered by the hydraulic system is large.

2.10.4 Specific Heat: The specific heat of a fluid should be stated in the fluid descriptive data as a function of temperature and is of importance in thermodynamic considerations in the use and system and component design using that fluid.

2.10.5 Thermal Conductivity: The thermal conductivity of a fluid should be stated in the fluid descriptive data as a function of temperature and is of importance in thermodynamic considerations in the use and system and component design using that fluid.

2.10.6 Neutralization Number: Change in neutralization number following exposure to anticipated conditions of system operation can be taken as an indication of fluid deterioration where correlation has been established with changes causing loss in service performance. A mere statement of the absolute value of the change has no significance per se. The nature of the products responsible for the change and their effect on system and fluid performance should also be stated, and are more indicative of the true effect.

2.11 Electrical Conductivity: The electrical conductivity of a fluid should be stated in the fluid descriptive data as a function of temperature and while not of general importance in system or component design does constitute a desired index for certain specific purposes.

2.12 Water Effects:

2.12.1 Hydrolytic Stability: A high degree of hydrolytic stability is a very desirable feature in a hydraulic fluid and should be stated in the fluid descriptive data as a function of water percentage. The nature of the products of hydrolytic breakdown should also be stated. In fluids which do not have the desired degree of hydrolytic stability, special precautions must be taken in the preparation, storage, handling and system design for the satisfactory use of that fluid.

2.12.2 Hydroscopic Tendency: This characteristic is to a certain extent coupled with the hydrolytic stability of a fluid and is an indication of the necessity of special precautions in the preparation, storage, handling and system design for satisfactory use of a fluid. It should be stated in the fluid descriptive data.