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# AEROSPACE INFORMATION REPORT

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REV. B

## DEGRADATION LIMITS OF HYDROCARBON-BASED HYDRAULIC FLUIDS, MIL-H-5606, MIL-H-6083, MIL-H-83282, AND MIL-H-46170 USED IN HYDRAULIC TEST STANDS

1. GENERAL:

Previous versions of AIR810 were devoted exclusively to MIL-H-5606, since it was the most widely used hydraulic fluid in military aircraft at that time. Since the latest revision of AIR810A, however, which appeared in 1968, MIL-H-5606 has been replaced in many applications by the less flammable synthetic hydrocarbon-based fluid MIL-H-83282. MIL-H-6083, a rust-inhibited version of MIL-H-5606 has found use in the hydraulic systems of tanks and armored vehicles, along with MIL-H-46170, a rust-inhibited version of MIL-H-83282. Thus, the scope of this revision of AIR810 has been expanded to include all four of these fluids.

The purpose of this report is to offer guidelines for deciding when the respective fluid has degraded to an extent that warrants replacement in hydraulic test stands. The most sensitive hydraulic components in systems using the subject fluids will dictate the limits of contamination or degradation permitted for each case. The guidelines incorporated in the AIR are the general concerns of knowledgeable professionals. However, the experience and judgment of engineers and operators responsible for the equipment must be relied upon to determine when hydraulic fluid is to be replaced.

## 2. MIL-H-5606 AND MIL-H-6083 FLUID CHARACTERISTICS:

Although hydraulic fluid manufacturers are reluctant to reveal the exact formulas of their products, the approximate compositions of these fluids are well known, and numerous details can be found in the texts of the actual specifications. MIL-H-5606, and MIL-H-6083 are both based on a low-viscosity naphthenic petroleum base stock with a flash point of around 82°C (closed cup). This base stock is thickened to the required viscosities by the addition of polyacrylate viscosity index improver. The fluids must supply a certain degree of antiwear protection, which is achieved by the addition of approximately 0.5% tricresyl phosphate. Up to 2% antioxidant may be present. Until recently, no pour point depressants could be used in either fluid, however, the latest E-revision of MIL-H-5606 permits them. MIL-H-6083 must provide rust and corrosion protection, and this is accomplished by the use of sulfonate additives such as barium dinonyl naphthalene sulfonate or calcium alkylbenzene sulfonate. The specification sets out limits on the amount of chloride and sulfate that can be present in the sulfonate used. Both fluids must meet limits on the amount of particulate contamination present.

Some required properties for the two fluids are summarized in the table below:

Properties of
MIL-H-5606E, MIL-H-6083D

| | MIL-H-5606E | MIL-H-6083D |
|---|---|---|
| Viscosities (centistokes) | | |
| 100°C | 4.90 | |
| 40°C | 13.2 | |
| 100°C | -- | 14 minimum |
| Flash Point, ASTM D92 | -- | 200°F (93°C) minimum |
| Flash Point, ASTM D93 | 82°C minimum | -- |
| Acid or Base No. (ASTM D664) | 0.2 maximum | 0.2 maximum |
| Water (Karl Fischer) | 100 ppm maximum | 0.05% (500 ppm) maximum |

Along with the degree of particulate contamination, these are properties likely to be monitored by the hydraulic fluid user.

### 2.1 Change in Fluid Properties of MIL-H-5606 and MIL-H-6083 During Use:

2.1.1 Viscosity: The use of polyarcrylate viscosity index improvers in these fluids is necessary in order to achieve the desired viscosities, but their presence creates the problem known as shear instability. Under conditions of high shear, such as are normally found in a high pressure aircraft hydraulic system pump, the acrylate polymer is gradually sheared down in to lower molecular weight fragments, with a resulting loss in fluid viscosity at operating temperature. Actually, both temporary and permanent losses in viscosity occur. In the region of high shear, there is often a temporary loss with the result that the pump or component does not see the same fluid viscosity that would be observed in the

2.1.1 (Continued):

laboratory. Since a loss in fluid viscosity may adversely affect the lubricating properties of the fluid, this form of shear instability must be considered by design engineers, however, since it is only temporary, it would not be observed by personnel monitoring the fluid viscosity. The permanent viscosity loss, on the other hand, must definitely be considered in deciding when the fluid is to be changed out. In one study, samples of used MIL-H-5606, drained from operational F-4 aircraft by Wright-Patterson Air Force Base personnel, were found to have 100°F viscosities ranging from 13.76 centistokes to 12.12 centistokes. In many cases, the viscosity loss is even worse, and 100°F viscosities as low as 10 centistokes are not uncommon. Some hydraulic systems are designed in such a way that the effects of such a viscosity change are minimal; others, however, are more sensitive.

Oxidation can also affect the viscosity of these fluids. A slight degree of fluid oxidation may result in a viscosity increase; an excessive degree of oxidation may result in polymer degradation, with a viscosity loss similar to that caused by mechanical shear. If the system is open or vented to the atmosphere, some of the napthenic base oil, which is relatively low boiling, may evaporate, and the remaining fluid, which contains all the polymer, will increase in viscosity. Occasionally, a "hot spot" in the system may cause enough of the base oil to evaporate so that the polymer is actually deposited in a solid or semisolid state, causing plugging of filters and freeze-up of valves and servos. Finely dispersed metal particles in hydraulic fluids may act as a catalyst to oxidize the fluid.



2.1.2 Acid Number: Fluid degradation is often accompanied by an increase in the acid number. Oxidation, for example, converts susceptible hydrocarbon components of the base oil into carboxylic acids, which may cause corrosion of susceptible metal components. How much acidity can be tolerated will again depend upon the configuration and metallurgy of the individual system.

A buildup in the base number (that is, an increase in alkalinity) would normally not be expected during fluid use. Should it occur, contamination should be suspected. A high base number in fresh MIL-H-6083 suggests the presence of excess base in the sulfonate rust inhibitor. Also, an abnormally low base number would indicate a loss of corrosion inhibitor during service. Quality assurance procedures should, of course, detect and reject such fluid before it is ever introduced into a system.

2.1.3 Flash and Fire Point: One of the major drawbacks of both MIL-H-5606 and MIL-H-6083 is the low flash point of the base stock. A further drop in flash point during use would obviously be undesirable, and would probably reflect contamination by some low-boiling flammable solvent. An increase in the flash point could indicate evaporative loss of base oil, or possible excessive contamination with nonflammable solvents such as trichlorotrifluorethane or trichloroethylene.

2.1.4 Water Content: The water content on both fluids is controlled by the specifications. MIL-H-6083, because of the nature of the sulfonate rust inhibitor, has more of a tendency to pick up excess water from the environment, but paradoxically the sulfonate tends to protect the system from the adverse effects of the water it picks up. However, hard precipitates of barium sulfate may be formed, which can cause wear of component surfaces during fluid circulation. Also gels may be formed, which can result in system blockage. MIL-H-5606 is not particularly hygroscopic, but inasmuch as it is not a rust-inhibited fluid, an increase in moisture content beyond the specification limits could be more serious. Unlike the phosphate ester type hydraulic fluids, which have often contained controlled amounts of water, gross amounts of water in hydrocarbon hydraulic fluids are usually undesirable and should be removed.

It should be noted that a maximum of 500 ppm H20 by-weight in MIL-H-6083 may lead to cold weather operating problems for this fluid owing to ice crystal formation. Ice crystals can clog small orifices and filter elements in hydraulic systems. As an alternate, MIL-H-6083 can be vacuum dehydrated to maintain water levels below 200 ppm H20 by-weight.

## 3. MIL-H-83282 AND MIL-H-46170 FLUID CHARACTERISTICS:

Although MIL-H-83282 was designed for hydraulic systems that previously used MIL-H-5606, and MIL-H-46170 was likewise designed to replace MIL-H-6083, these two fluids are significantly different from the two petroleum-based fluids discussed in section 2. Both MIL-H-83282 and MIL-H-46170 are formulated with a polyalphaolefin synthetic hydrocarbon base stock. The specifications require that this base stock have flash and fire points of 205 and 245°C (open cup) respectively. Thus, these two fluids are significantly less flammable than MIL-H-5606 and MIL-H-6083 and are often referred to as "fire resistant." In order to meet the seal swell and the low temperature viscosity requirements, the specifications permit the addition of blending fluids such as diesters in concentrations up to 33%. Tricresyl phosphate is recommended to meet the antiwear requirements, and oxidation inhibitors of the phenolic type are specified in amounts not to exceed 1%. MIL-H-46170, like MIL-H-6083, must provide significant rust and corrosion protection to susceptible components. No particular inhibitor is required, but the original versions of the specification suggested that acceptable results could be obtained by the use of barium dinonyl naphthalene sulfonate. Viscosity index improvers and pour point depressants are not permitted in either fluid. Both fluids have to meet particle count requirements usually denoted as classes defined in NAS 1638.

3. (Continued):

Some required properties for the two fluids are summarized below:

Properties of
MIL-H-83282C and MIL-H-46170B

| | MIL-H-83282C | MIL-H-46170B |
|---|---|---|
| Viscosities, centistokes (ASTM D445) | | |
| 100°C | 3.5 minimum | 3.4 minimum |
| 40°C | 14.0 minimum | 19.5 maximum |
| -40°C | 2200 maximum | 2600 maximum |
| Flash/Fire Points (ASTM 92) | 204.4°C/245°C minimum | 218°C/246°C minimum |
| Water (Karl Fischer) (ASTM D1744) | 100 ppm maximum | 0.05% maximum (500 ppm) |
| Pour Point (ASTM D99) | -55°C maximum | -54°C maximum |
| Acid or Base Number | 0.10 maximum (ASTM D664) | 0.2 maximum (ASTM D974) |



3.1 Change in Fluid Properties of MIL-H-83282 and MIL-H-46170 During Use:

3.1.1 Viscosity: Neither of these fluids contains a viscosity index improver and, as a consequence, neither is subject to the shear instability and viscosity loss observed in MIL-H-5606 and MIL-H-6083. Oxidation of MIL-H-83282 and MIL-H-46170 normally leads to an increase in viscosity, although under ordinary operating conditions the increase will be low. Finely dispersed metal particles may act as a catalyst to oxidize the fluid. A decrease in viscosity, on the other hand, usually indicates the presence of some low-viscosity contaminant such as fuel or solvent.

3.1.2 Acid Number: Degradation of the two synthetic hydrocarbon fluids may be accompanied by an increase in acid number. Oxidation is one cause; but, with MIL-H-83282 and MIL-H-46170, the possibility of acid generation through hydrolysis must be taken into account. Both fluids conventionally contain substantial amounts (up to 33%) of lubricant diesters, in order to achieve the desired low temperature and seal swell characteristics. Esters are manufactured by the reaction of alcohols and acids, with water being formed as a byproduct. However, at high temperatures, the reverse reaction can also occur; esters can react with water to form alcohols and acids, with a resultant increase in acid number. This reaction, called hydrolysis, is extremely slow, and rarely presents a problem except where gross contamination by water is a factor.

3.1.3 Flash and Fire Points: The relatively high flash and fire points of MIL-H-83282 and MIL-H-46170, compared to those of MIL-H-5606 and MIL-H-6083, have been a major reason for the increased use of synthetic hydrocarbon fluids. In the field, the changeover of aircraft hydraulic systems from MIL-H-5606 to MIL-H-83282 was often carried out by simple attrition, with the synthetic base fluid being added as make-up when the level of MIL-H-5606 became low. Thus, there are many aircraft flying with

3.1.3 (Continued):

mixtures of MIL-H-83282 and MIL-H-5606 having flash and fire points intermediate between the two. When MIL-H-83282 or MIL-H-46170 are the only fluids in the system, lower flash points would reflect contamination by low-boiling solvents or fuel.

3.1.4 Water Content: The water content of the two fluids is controlled by the specifications at 100 ppm maximum for MIL-H-83282 and 500 ppm maximum for its rust-inhibited counterpart MIL-H-46170. Diesters are slightly hygroscopic, and tend to pick up moisture if drums or containers are allowed to remain open for extended periods of time prior to filling a system. Compressed air if used for reservoir super charge may also be a source of moisture. Since MIL-H-83282 contains no rust inhibitor, the presence of excess moisture could present a problem for susceptible metal parts and, of course, over long periods of time, the possibility of hydrolysis must also be considered. If the fluid temperature is high enough that the moisture can evaporate from the system, there is usually no problem. Because of the presence of the rust inhibitor, MIL-H-46170 is less susceptible to problems caused by moisture, however, gross amounts of water are obviously undesirable. It should be noted that a maximum of 500 ppm H20 by-weight in MIL-H-46170 may lead to cold weather operating problems for this fluid owing to ice crystal formation. Ice crystal can clog small orifices and filter elements in hydraulic systems. As an alternate, MIL-H-46170 can be vacuum dehydrated to maintain water levels at or below 250 ppm H20 by weight.



4. EFFECTS OF CONTAMINATION:

Contamination of the fluids can occur from many sources. The effects of moisture have already been discussed in 2.1.4 and 3.1.4. This section will deal with particulate and solvent contamination.

4.1 Particulate Contamination: Modern hydraulic systems are extremely sensitive to the presence of small particles. Certain systems components have tolerances in micrometer range and can be plugged or scored by microscopic-sized debris in the fluid. Particles may also lodge in seals and gaskets where they can act as abrasives on moving parts. All four fluids when originally packaged meet rigid particle count standards, but this cleanliness is compromised as soon as the fluid containers are open. Once in the system, wear debris such as particles of metal and seal material rapidly reduce the cleanliness of the fluid. In-line filters partly compensate for this problem, but, nonetheless, an increase in particulate contamination is a common cause for fluid change-out.

4.2 Solvent Contamination: Two types of solvents have traditionally been used in flushing hydraulic systems and cleaning components, and both periodically find their way into hydraulic fluid. Hydrocarbon solvents such as Federal Specification P-D-680, if present in sufficient quantities, can lower the flash and fire points of the fluid. They may also cause excessive swell of seals and gaskets. Chlorinated solvents such as trichlorotrifluoroethane and trichlorethylene can cause serious corrosion and sludging problems in hydraulic systems. There are well documented cases of valve sticking in MIL-H-5606 fluid, which were eventually traced to the presence of

4.2 (Continued):

chlorinated solvent and moisture at elevated temperature. Gelatinous sludges containing chlorine have been reported in systems where MIL-H-83282 had been contaminated with trichlorotrifluoroethane. As a result, the Air Force has moved away from the use of chlorinated solvents in servicing hydraulic systems, but these solvents still persist in many industries. The amount of chlorinated solvent that can be tolerated in a fluid without causing corrosion and sludge is not known with any degree of certainty; it depends to some extent on the system design characteristics. Contamination by solvent is another common cause for fluid change-out. Chlorinated solvent contamination removal from the fluid by purification is an alternative to fluid change-out. The use of vacuum dehydration equipment, has, in many cases, proved a suitable alternative to fluid replacement.

5. <u>RECOMMENDATIONS-SUGGESTIONS FOR CHANGING OUT A HYDRAULIC FLUID</u>:

It should be noted again that there are no absolute rules for determining when a hydraulic fluid has become sufficiently degraded or contaminated and can no longer perform satisfactorily in a given system. It is better, however, to be conservative when a doubt exists. Usually the cost of the fluid is considerably less than the cost of the hydraulic system, and it is better to sacrifice a few gallons of fluid that may still be usable than to risk failure of a key pump, valve, or servo. An alternate action would be to condition the fluid with purification equipment. With that in mind, the following guidelines summarized in the attached Tables I and II are offered.

5.1 <u>MIL-H-5606 and MIL-H-6083</u>: MIL-H-5606 and MIL-H-6083 should be changed out when the viscosity at 40°C drops to 10 centistokes, or when the acid number has increased by 0.2 over its original value. Usually substantial degradation will have occurred by the time either of these two limits is met. A drop in the flash point below specification limits is also cause for changing out the fluid. An increase in viscosity or flash point could signal evaporation of the base oil. A change in system design or operating temperature, rather than a change of fluid, is suggested here. When the moisture content of MIL-H-5606 exceeds 150 ppm, the fluid should be changed. A higher amount of water can be tolerated in MIL-H-6083 because of the presence of the sulfonate rust inhibitor; 550 ppm is the suggested maximum for this fluid. The total chlorine content, an indication of the amount of chlorinated solvent contamination, should be kept below 200 ppm. Purification to undersaturate the fluid with respect to chlorine and water contamination is a safeguard.

5.2 <u>MIL-H-83282 and MIL-H-46170</u>: MIL-H-83282 and MIL-H-46170 should be changed out when the viscosity at 40°C has increased by 10%, or when the acid number has increased by 0.2 over the original values. A drop in the flash point below the specification limits is also cause for change-out. Any significant decrease in the fluid viscosity at 40 or 100°F, for example, 15% is usually an indication of solvent contamination and the fluid should be changed promptly. For MIL-H-83282, a moisture content above 300 ppm is grounds for removal. For MIL-H-46170, higher levels of water can be tolerated, and 600 ppm is the recommended maximum for this fluid. The total chlorine content, an indication of the amount of chlorinated solvent contamination, should be kept below 200 ppm.

5.3 Particulate Contamination: The tendency to generate debris that shows up as particulate contamination in the hydraulic fluid varies considerably from one hydraulic system to another. Likewise, the sensitivity of individual systems to the degree of particulate contamination in the fluid differs greatly. A rapid increase in differential pressure across an in-line filter is an indication that the fluid is excessively contaminated with particulate matter and further analysis of the fluid is recommended. In this area, the individual must, to a large extent, establish his own guidelines as to when the hydraulic fluid is excessively contaminated.

6. REFERENCE:


1. Military Specification MIL-H-5606 "Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance": Revision E, 29 August 1980, Amendment 1, 2 March 1984.

2. Military Specification MIL-H-6083 "Hydraulic Fluid, Petroleum Base, For Preservation and Operation": Revision D, 28 September 1973, Amendment 3, 5 May, 1982.

3. Military Specification MIL-H-83282 "hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft" Revision B, 10 February 1982.

4. Military Specification MIL-H-46170 "Hydraulic Fluid, Rust Inhibited, Fire-Resistnat, Synthetic Hydrocarbon Base": Revision B, 18 August 1982, Amendment 1, 24 March 1986.

5. Lipp, L. C. "Halogenated Solvent-Induced Corrosion in Hydraulic Systems," Preprint No. 78-AM -42A, American Society of Lubrication Engineering.

6. ASTM STP No. 382, "The Effects of Polymet Degradation on Flow Properties of Fluids and Lubricants," American Society for Testing and Materials, Philadelphia.

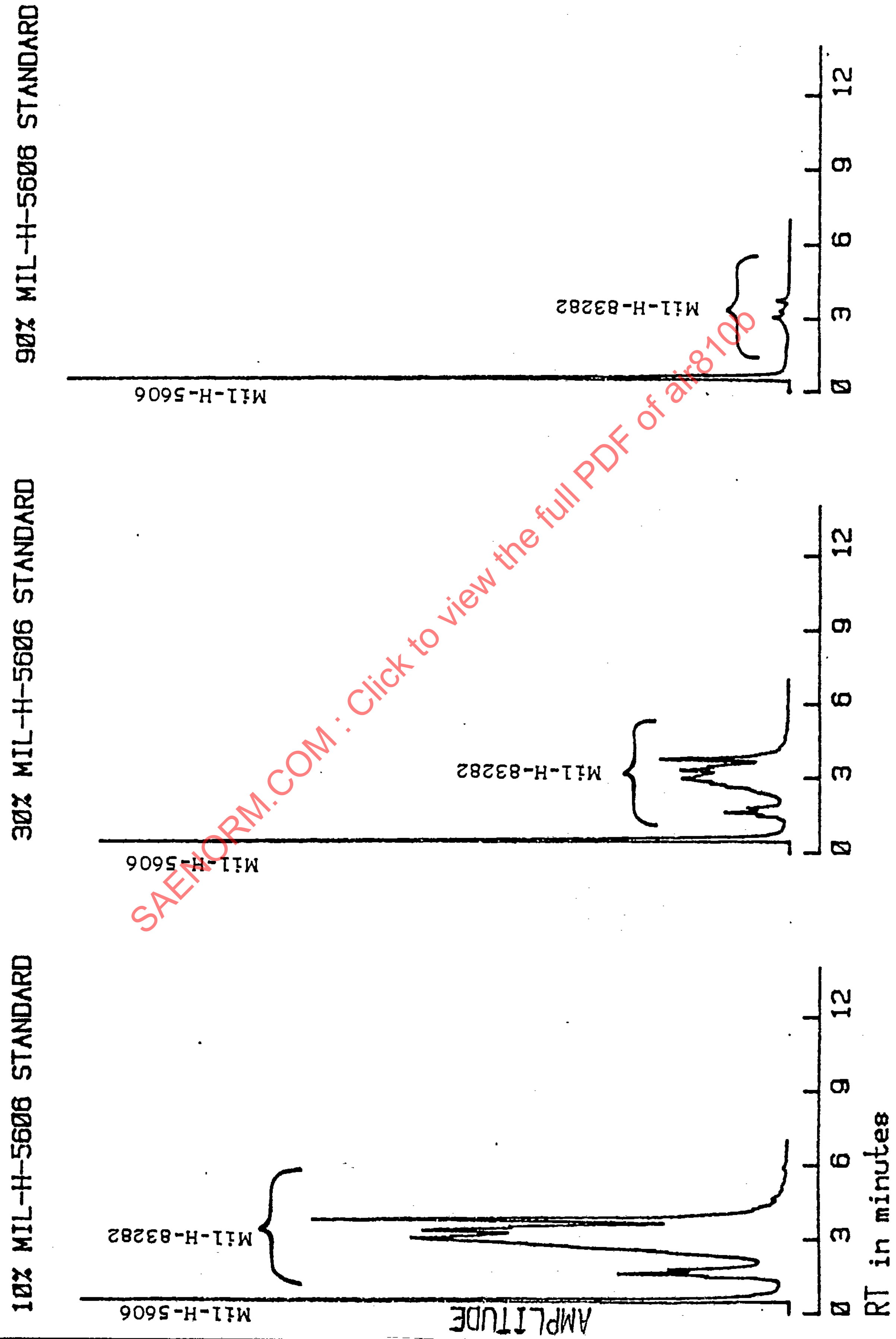


FIGURE 1 - Capillary Gas Chromatograms (FID)

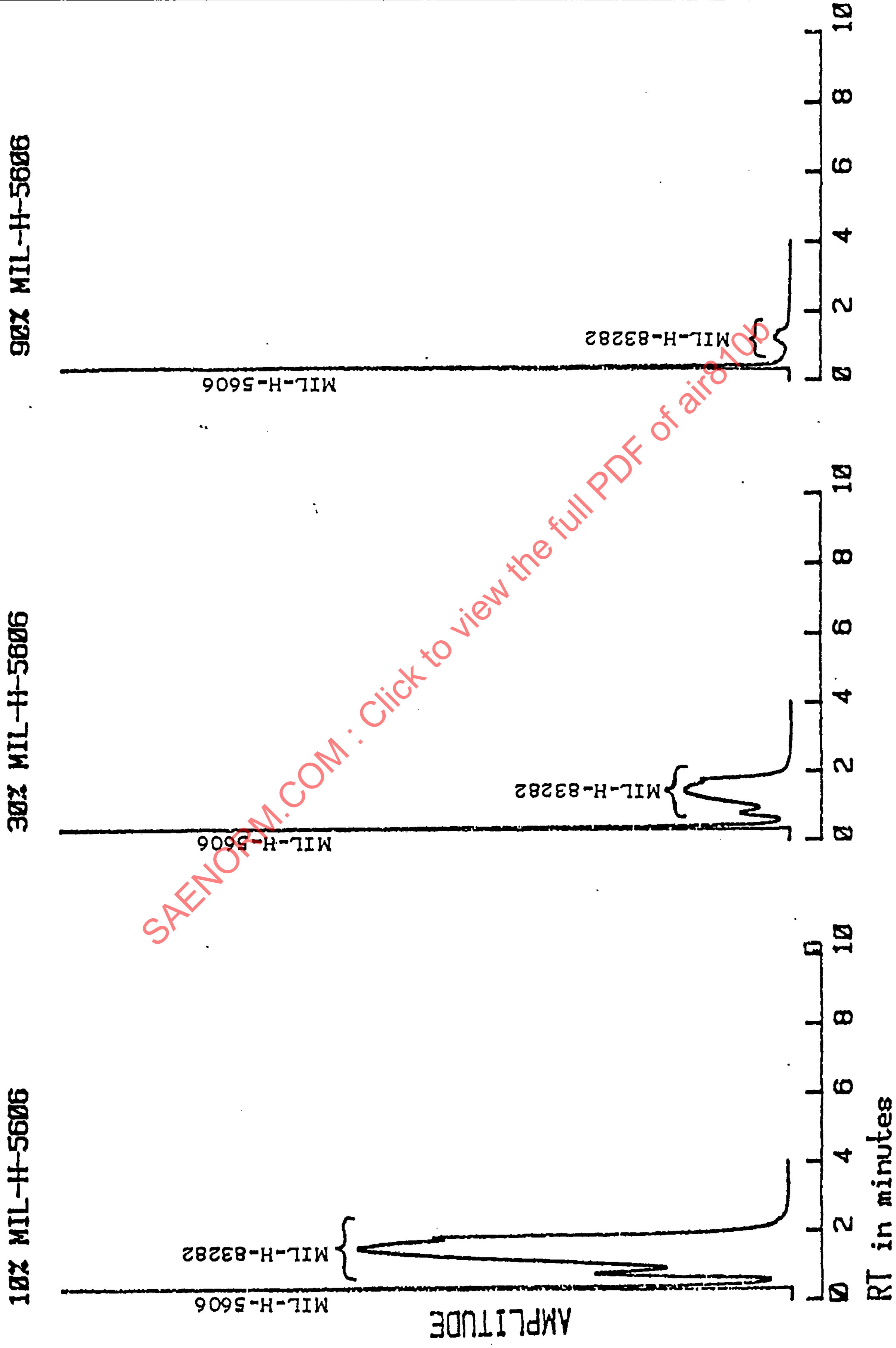


FIGURE 2 - Gas Chromatograms (FID) Packed Column

TABLE I
MIL-H-83282 HYDRAULIC FLUID CHARACTERISTICS AND SUGGESTED USE LIMITS

| Property | Test Method | Unit & Limit | New Fluid | In-Service Limit |
|---|---|---|---|---|
| Viscosity | ASTM D445 | Centistokes, Min, @ 40°C | 14 | +10, -15% |
| Flash Point | ASTM D92 (Open Cup) | °C, Min | 205 | 205 |
| Acid Number | ASTM D664 | MG KOH/Gram Max | 0.10 | 0.30 |
| Total Water | ASTM D1744 (Karl Fischer) | PPM Max | 100 | 300 |
| Free Water | ASTM D2709 (Centrifuge) | Percent By Volume, Max | None | No Measurable Free Water (<.01%) |
| Total Chlorine | Gas Chromatographic | PPM Max | 50 | 200 |
| Particulate Contamination | SAE ARP598 Counter Automatic | Max Count Per 100ML Sample Size Range Micrometers | NAS 1638 Class 4-6 | 1638B Class 7 |
| | | 5-15 | 10K | 64K |
| | | 16-25 | 1K | 11.4K |
| | | 26-50 | 150 | 2025 |
| | | 51-100 | 20 | 360 |
| | | Over 100 | 5 | 64 |

MIL-H-46170B HYDRAULID FLUID CHARACTERISTICS AND SUGGESTED USE LIMITS

| Property | Test Method | Unit & Limit | New Fluid | In-Service Limit |
|---|---|---|---|---|
| Viscosity | ASTM D445 | Centistokes, Max, @ 40°C | 19.5 | +10, -15% |
| Flash Point | ASTM D92 (Open Cup) | °C, Min | | |
| | | Type I | 218 | 218 |
| | | Type II | 204 | 204 |
| Acid Number | ASTM D664 | MG KOH/Gram Max | 0.20 | 0.40 |
| Total Water | ASTM D1744 (Karl Fischer) | PPM Max | 500 | 600 |
| Free Water | ASTM D2709 (Centrifuge) | Percent By Volume, Max | None | No Measurable Free Water (<.01%) |
| Total Chlorine | Gas Chromatographic | PPM Max | 50 | 200 |
| Particulate Contamination | SAE ARP598 Counter Automatic | Max Count Per 100ML Sample Size Range Micrometers | NAS 1638 Class 4-6 | 1638B Class 7 |
| | | 5-15 | 10K | 64K |
| | | 16-25 | 1K | 11.4K |
| | | 26-50 | 150 | 2025 |
| | | 51-100 | 20 | 360 |
| | | Over 100 | 5 | 64 |

TABLE II
MIL-H-5606 HYDRAULIC FLUID CHARACTERISTICS AND SUGGESTED USE LIMITS

| Property | Test Method | Unit & Limit | New Fluid | In-Service Limit |
|---|---|---|---|---|
| Viscosity | ASTM D445 | Centistokes, Min, @ 40°C | 13.2 Min | 10.0 Min |
| Flash Point | ASTM D92 (Open Cup) | °C, Min | 82 | 82 |
| Acid Number | ASTM D664 | MG KOH/Gram Max | 0.20 | 0.40 |
| Total Water | ASTM D1744 (Karl Fischer) | PPM Max | 100 | 150 |
| Free Water | ASTM D2709 (Centrifuge) | Percent By Volume, Max | None | No Measurable Free Water (<.01%) |
| Total Chlorine | Gas Chromotographic | PPM Max | 50 | 200 |
| Particulate Contamination | SAE ARP598 Counter Automatic | Max Count Per 100ML Sample Size Range Micrometers | NAS 1638 Class 4-6 | NAS 1638B Class 8 |
| | | 5-15 | 10K | 64K |
| | | 16-25 | 1K | 11.4K |
| | | 26-50 | 150 | 2025 |
| | | 51-100 | 20 | 360 |
| | | Over 100 | 5 | 64 |

MIL-H-6083E HYDRAULIC FLUID CHARACTERISTICS AND SUGGESTED USE LIMITS

| Property | Test Method | Unit & Limit | New Fluid | In-Service Limit |
|---|---|---|---|---|
| Viscosity | ASTM D445 | Centistokes, Min, @ 40°C | 13.0 Min | 10.0 Min |
| Flash Point | ASTM D92 (Open Cup) | °C, Min | 82 | 82 |
| Acid Number | ASTM D664 | MG KOH/Gram Max | 0.20 | 0.40 |
| Total Water | ASTM D1744 (Karl Fischer) | PPM Max | 500 | 550 |
| Free Water | ASTM D2709 (Centrifuge) | Percent By Volume, Max | None | No Measurable Free Water (<.01%) |
| Total Chlorine | Gas Chromotographic | PPM Max | 50 | 200 |
| Particulate Contamination | SAE ARP598 Counter Automatic | Max Count Per 100ML Sample Size Range Micrometers | NAS 1638 Class 4-6 | 1638B Class 8 |
| | | 5-15 | 10K | 64K |
| | | 16-25 | 1K | 11.4K |
| | | 26-50 | 150 | 2025 |
| | | 51-100 | 20 | 360 |
| | | Over 100 | 5 | 64 |