

# SKYDROL<sup>®</sup>

*Type IV Fire Resistant Hydraulic Fluids*

*LD-4 / 500B-4*



**Technical Bulletin**





# CONTENTS

Page	Section
2	<b>I</b> Aircraft Hydraulics – Historical Perspective
3	<b>II</b> Specifications and Properties of Skydrol Fluids
7	<b>III</b> Materials Compatibility
10	<b>IV</b> Fluid In-Service Quality Limits
12	<b>V</b> Fluid Performance
20	<b>VI</b> Shelf Life, Storage and Handling
22	<b>VII</b> Safety and Emergency Procedures
24	<b>VIII</b> Disposal of Used Skydrol Fluids
24	<b>IX</b> Customer Technical Service

NOTICE: Although the information and recommendations set forth herein (hereinafter "Information") are presented in good faith and believed to be correct as of the date hereof, Solutia Inc. makes no representations or warranties as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Solutia Inc. be responsible for damages of any nature whatsoever resulting from the use of or reliance upon Information or the product to which Information refers. Nothing contained herein is to be construed as a recommendation to use any product, process, equipment or formulation in conflict with any patent, and Solutia Inc. makes no representation or warranty, express or implied, that the use thereof will not infringe any patent. NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OF ANY OTHER NATURE ARE MADE HEREUNDER WITH RESPECT TO INFORMATION OR THE PRODUCT TO WHICH INFORMATION REFERS.

# Aircraft Hydraulics – Historical Perspective

## Brief History of Aircraft Hydraulics

**E**arly aviation hydraulic systems were used to apply brake pressure. These systems used a vegetable oil-based hydraulic fluid. As aircraft design produced larger and faster aircraft, greater use of hydraulics was necessary. These advances led to development of petroleum-based hydraulic fluids such as Mil-O-3580 and, later, Mil-H-5606.

Shortly after World War II, the growing number of aircraft hydraulic fluid fires drew the collective concern of the commercial aviation industry and the public. In 1948, Monsanto Company worked with Douglas Aircraft Company to develop a fire-resistant hydraulic fluid based on phosphate ester chemistry, which was named Skydrol® 7000.

As the transport industry moved toward jets, Skydrol® 500A fluid was developed to

meet the environmental needs of the new aircraft, and with the continuous development of more advanced aircraft further modifications to Skydrol fluid formulations were made. These changes, required by the aircraft manufacturers, are known as modifications to the fluid specification ... or simply as Type I, II, III and now Type IV fluids.

Skydrol® LD-4 and Skydrol® 500B-4 hydraulic fluids are Type IV fluids formulated to exceed the rigid specifications of the aircraft manufacturers. They have been in commercial usage since 1978 and have demonstrated outstanding performance.

In 1997, Solutia Inc. was formed from the chemical businesses of Monsanto. Solutia continues as the world leader in aviation hydraulic fluid service and support.





# Specifications and Properties of Skydrol Fluids

**S**kydrol fluids are approved by all airframe manufacturers specifying phosphate ester hydraulic fluids including:

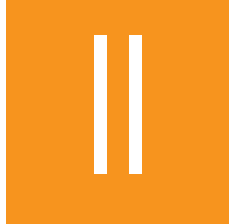
- Airbus Industrie  
NSA307110
- Boeing Commercial Airplane Co.  
BMS3-11
- McDonnell Douglas Corp.  
DMS2014
- Lockheed Aircraft Corp.  
LAC C-34-1224
- Society of Automotive Engineers  
AS1241
- British Aerospace  
BAC M.333.B
- Fokker
- Embraer
- Bombardier  
BAMS 564-003

Many business aircraft manufacturers utilize one or more of these material specifications. Business aircraft manufacturers that have designed aircraft models for use with phosphate ester fluids include:

- Westwind
- Cessna
- Gulfstream

Specifications* for Skydrol® Fluids		
Property	Skydrol® LD-4	Skydrol® 500B-4
Appearance	Clear, purple liquid	Clear, purple liquid
Neutralization number	0.10 max	0.10 max.
Moisture content (wt.%)	0.20 max	0.20 max
Specific gravity, 77 °F/77 °F	1.003-1.013	1.050-1.062
Viscosity in cSt at 210 °F/99 °C at 100 °F/38 °C at -65 °F/-54 °C	3.66-4.00 10.65-11.65 2000 max.	3.68-4.00 11.4-12.4 4200 max.
Flash point, COC, min.	320 °F/160 °C	350 °F/177 °C
Refractive Index @ 25 °C	1.443 to 1.451	1.466 to 1.474
Cleanliness Level	NAS 1638 Class 7 or better	

\*Specifications are subject to change. Write us for our latest specifications.



Typical Physical and Chemical Properties*			
Property	Skydrol® LD-4	Skydrol® 500B-4	Test Method
Viscosity in cSt -65 °F/-54 °C 100 °F/38 °C 210 °F/99 °C	1185 cSt 11.42 cSt 3.93 cSt	2765 cSt 11.51 cSt 3.78 cSt	ASTM D445
Pour Point °F °C	<-80 °F <-62 °C	<-80 °F <-62 °C	ASTM D97
Specific Gravity, 25 °C/25 °C Density at 100 °F/37 °C, g/cm <sup>3</sup> (See Pg. 6)	1.009	1.057	Solutia 116-B
Coefficient of Expansion**	5.1x10 <sup>-4</sup> /°F 9.2x10 <sup>-4</sup> /°C	4.7x10 <sup>-4</sup> /°F 8.5x10 <sup>-4</sup> /°C	
Weight, 75 °F/24 °C lb/gal kg/m <sup>3</sup>	8.41 1008	8.82 1,057	
Moisture, %	0.15	0.15	ASTM D1744
Acidity (neutralization number)	0.10 max	0.10 max	ASTM D974
Bulk Modulus psi	221,000 psi or 15,237 x 10 <sup>5</sup> Pa	242,000 psi or 16,685 x 10 <sup>5</sup> Pa	As described in BMS3-11
Foam (ml foam/sec. collapse) Sequence 1 75 °F/24 °C Sequence 2 200 °F/93 °C Sequence 3 75 °F/24 °C	50 cm <sup>3</sup> /25 s 10 cm <sup>3</sup> /5 s 40 cm <sup>3</sup> /20 s	100 cm <sup>3</sup> /35 s 20 cm <sup>3</sup> /15 s 110 cm <sup>3</sup> /40 s	ASTM D892-63
Specific Heat 100 °F/38 °C 200 °F/93 °C 300 °F/149 °C	0.437 kcal/(kg·°C) 0.472 kcal/(kg·°C) 0.507 kcal/(kg·°C)	0.418 kcal/(kg·°C) 0.453 kcal/(kg·°C) 0.487 kcal/(kg·°C)	Perkin-Elmer Differential Scanning Calorimeter Model DSC-1
Thermal Conductivity 100 °F/38 °C 200 °F/93 °C 300 °F/149 °C	Btu/(h·ft·°F) kcal/(h·m·°C) 0.0764 1.89 x 10 <sup>-3</sup> 0.0722 1.79 x 10 <sup>-3</sup> 0.0670 1.66 x 10 <sup>-3</sup>	Btu/(h·ft·°F) kcal/(h·m·°C) 0.0761 1.89 x 10 <sup>-3</sup> 0.0723 1.79 x 10 <sup>-3</sup> 0.0672 1.67 x 10 <sup>-3</sup>	Non-steady Transient-Method (Hot Wire)
Surface Tension, 77 °F/25 °C	28.2 dyn/cm	26.7 dyn/cm	Du-Nouy Balance
Conductivity, microsiemens/cm	0.43	0.41	Conductivity Bridge
Heat of Combustion	13,200 Btu/lb 7.33 kcal/g	13,000 Btu/lb 7.23 kcal/g	ASTM D240

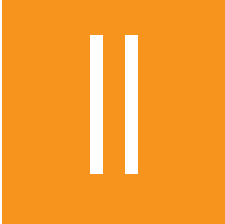
\*These data are based upon samples tested in the laboratory and are not guaranteed for all samples.

\*\*Calculated for 100-300 °F/37-149 °C range using  $C = \frac{V_2 - V_1}{V_1 (T_2 - T_1)}$

C=coefficient of expansion

V<sub>1</sub>=volume at temperature, T<sub>1</sub>

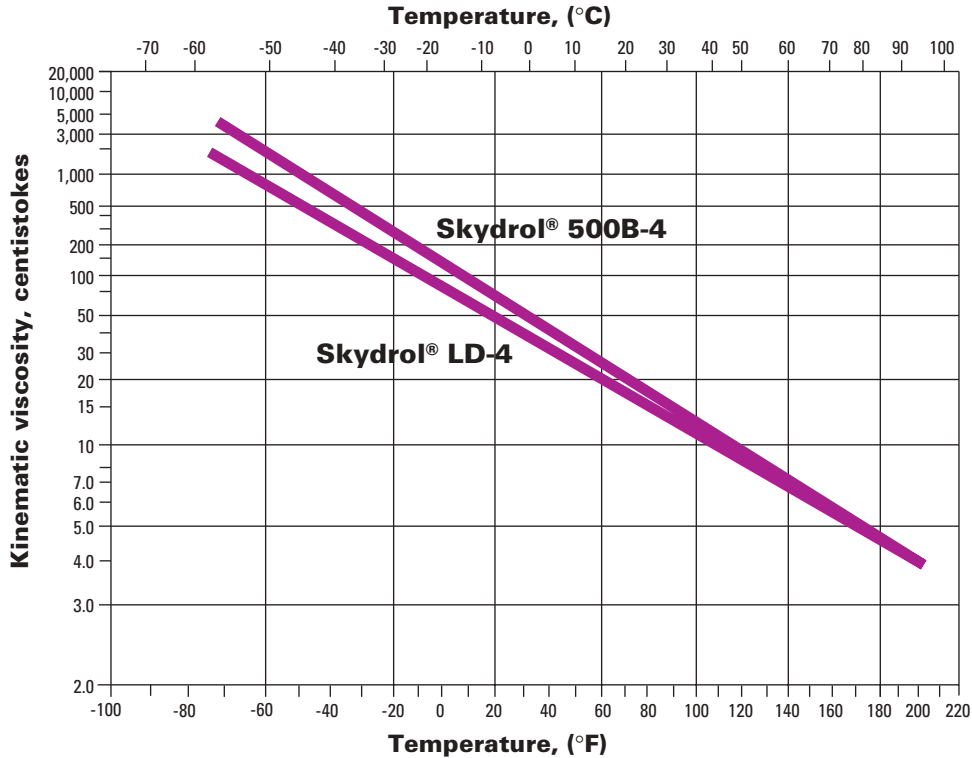
V<sub>2</sub>=volume at temperature, T<sub>2</sub>

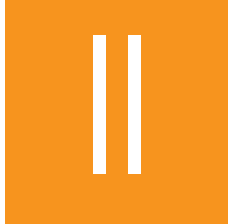


Typical Fire Resistance Properties*			
Property	Skydrol® LD-4	Skydrol® 500B-4	Test Method
Flash Point	340 °F/171 °C	360 °F/182 °C	ASTM D92
Fire Point	360 °F/182 °C	410 °F/210 °C	ASTM D92
AIT	880 °F/471 °C	945 °F/507 °C	ASTM D2155
Hot Manifold Drip Manifold Temp. Results	1300 °F/704 °C Equivalent to Std.	1300 °F/704 °C Better than Std.	AMS 3150C
Hot Manifold Spray Fluid Temp. Manifold Temp. Fluid Pressure Results	167 °F/75 °C 1100 °F/593 °C 1000 psi/68.9 bar No flashing or burning	167 °F/75 °C 1200 °F/649 °C 1000 psi/68.9 bar No flashing or burning	Solutia Modified AMS 3150C
High Pressure Spray	Equivalent to Std.	Better than Std.	AMS 3150C
Low Pressure Spray	Better than Std.	Better than Std.	AMS 3150C
Wick Flammability	Equivalent to Std.	Equivalent to Std.	AMS 3150C

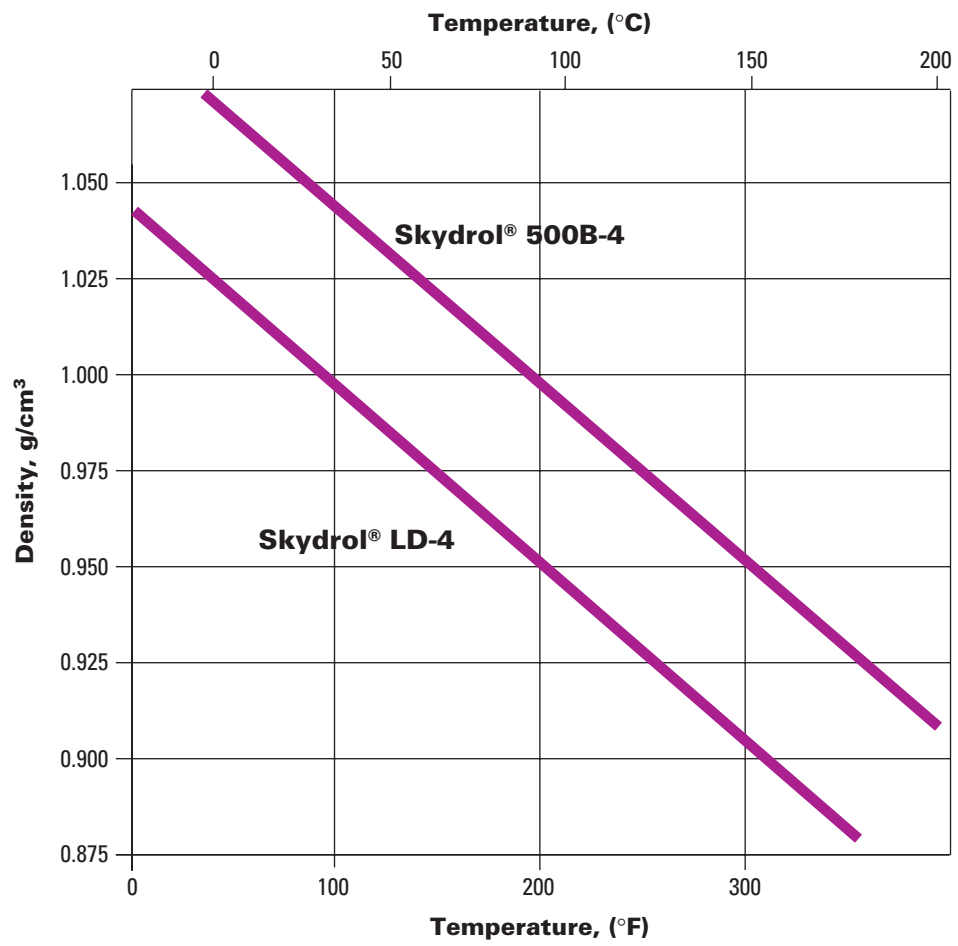
\*These data are based upon samples tested in the laboratory and are not guaranteed for all samples.

## Viscosity/Temperature





## Density/Temperature







# Materials Compatibility

**M**aterials used in the hydraulic system and surrounding it must be compatible with the hydraulic fluid. The fluid must not degrade their performance; neither should the materials degrade the fluid. The materials and components used in and near any aircraft hydraulic system are carefully selected by the airframe manufacturer. The aircraft industry uses many synthetic materials – many are

resistant to Skydrol fluids and some are not. Many that are not totally resistant require long exposure before damage results. Deviations from the recommended materials should not be made without prior consultation with the airframe manufacturer and the materials components suppliers. The table below contains the general rating of compatibility of various materials with Skydrol fluids.

## General Guidelines for Compatibility of Aviation Phosphate Ester Hydraulic Fluids with Various Materials\*

### Ratings of Compatibility

**EXCELLENT RESISTANCE** – Material may be used in constant contact with the fluid.

**GOOD RESISTANCE** – Withstands exposure to the fluid with minimum swell (for plastics and rubber) or loss of integrity.

**POOR RESISTANCE** – Should not be used near the fluid.

**NO RESISTANCE** – Disintegrates in the fluid.

Resistance to Attack by Aviation Phosphate Ester Fluids				
	Excellent	Good	Poor	No
<b>Fabrics</b>				
Acrylic (Acrilan®, Creslan®, Orlon®)			■	
Cotton, Wool, Rayon		■		
Fiberglass, Nylon, Polyester (Dacron®, Fortrel®)		■		
Carbon (Graphite)	■			
<b>Coated Fabrics</b>				
Buna N-coated Cotton or Nylon			■	
Butyl-coated Nylon	■			
Ethylene Propylene-coated Nylon	■			
Chlorosulfonated Polyethylene Nylon				■
Neoprene-coated Nylon, Cotton, Polyester				■
Silicone-coated Fiberglass		■		
Silicone-coated Polyester		■		
Vinyl-coated Cotton, Nylon, Polyester				■
Vinyl-coated Fiberglass				■
Fluoroelastomer-coated Nylon		■		
<b>Metals</b>				
Aluminum	■			
Brass		■		
Bronze		■		



### Resistance to Attack by Aviation Phosphate Ester Fluids (cont.)

	Excellent	Good	Poor	No
<b>Metals (continued)</b>				
Cadmium		■		
Chromium	■			
Copper <sup>1</sup>			■	
Ferrous	■			
Lead <sup>2</sup>		■		
Magnesium <sup>1</sup>		■		
Noble (Gold, Silver)	■			
Stainless Steel	■			
Zinc <sup>2</sup>		■		
Titanium <sup>3</sup>		■		
Exotic (Hastelloy, etc.)	■			
Beryllium Copper	■			
<b>Conversion Coatings</b>				
Anodizing (Aluminum)	■			
Dow 7 and 17 (Magnesium)	■			
<b>Paint Finishes</b>				
Alkyd <sup>4</sup>			■	
Acrylic				■
Asphaltic				■
Cellulosic Lacquer				■
Epoxy	■			
Epoxy-Amide	■			
Heat-resistant Aluminized				■
Latex			■	
Polyurethane		■		
Linseed Oil			■	
Shellac	■			
Silicone		■		
Urethane		■		
Varnish			■	
Vinyl			■	
<b>Thermoplastics</b>				
ABS			■	
Acetal			■	
Acrylic			■	
Cellulosic			■	
ETFE Copolymer (Tefzel®)	■			
FEP (Fluorocarbon)	■			
Nylon	■			
Polycarbonate (Lexan®)			■	
Polyetheretherketone (PEEK)		■		
Polyetherketone (PEK)		■		
Polyethylene	■			
Polyphenylene Oxide (PPO)			■	
Polyphenylene Sulfide (PPS)		■		
Polypropylene	■			
Polystyrene				■
Polyvinyl Chloride				■
Polyvinylidene Chloride		■		



Resistance to Attack by Aviation Phosphate Ester Fluids (cont.)				
	Excellent	Good	Poor	No
<b>Thermoplastics (cont.)</b>				
Polyvinyl Fluoride (PVF) (Tedlar®)	■			
Reinforced TFE	■			
TFE (Fluorocarbon)	■			
<b>Thermosets</b>				
Melamine		■		
Polyester		■		
Phenolic		■		
Polyamide	■			
Polyimide	■			
<b>Elastomers</b>				
Butadiene Acrylonitrile (Buna N)				■
Chlorosulfonated Polyethylene (Hypalon®)		■		
Epichlorohydrin		■		
Ethylene Propylene (EPR, EPDM)	■			
Fluorinated Hydrocarbon (Viton®, Fluorel®)			■	
Polyacrylic			■	
Polybutadiene			■	
Polychloroprene (Neoprene)			■	
Polyisoprene (Natural & Synthetic Rubber)			■	
Polysulfide			■	
Polyurethane				■
Isobutylene Isoprene (Butyl)		■		
Silicone		■		
Styrene Butadiene (Buna S)			■	
PerfluoroHydrocarbon (Kalrez®, Chemraz®)	■			
Fluoroethylene (TFE, FEP)	■			
<b>Misc. Materials</b>				
Cork			■	
Leather			■	
Vinyl Floor Tile				■

\*Based on material previously published in Machine Design.

**Footnotes**

1. Copper and magnesium are not recommended for use in a hydraulic system. Long-term corrosion rates are excessive.
2. Lead and zinc are not recommended for use in a hydraulic system. Their oxidation products can form soaps and cause emulsions.
3. Titanium should not be used at temperatures above 325°F/163°C. Hydrogen embrittlement may occur.
4. Includes alkyd-phenolic, alkyd-silicone and alkyd-urethane finishes.

## Fluid Compatibility

All approved Type IV phosphate ester hydraulic fluids are miscible and compatible and may be used with each other in any and all proportions. In the past, when Type IV phosphate ester fluids were mixed with previous phosphate ester fluids

(i.e., Type I, Type II or Type III), it was recommended that a minimum of 20% or more of the fluid be drained and replaced by the Type IV fluids. Since then, qualification testing has been modified to ensure complete fluid compatibility.

*Acrlan is a registered trademark of Solutia Inc. Creslan is a registered trademark of Sterling Fibers, Inc. Orlon, Dacron, Tefzel and Tedlar are registered trademarks of E.I.DuPont de Nemours. Fortrel is a registered trademark of Wellman, Inc. Lexan is a registered trademark of General Electric. Hypalon, Viton and Kalrez are registered trademarks of DuPont Dow Elastomers. Fluorel is a registered trademark of Dyneon, LLC. Chemraz is a registered trademark of Greene Tweed.*

## Fluid In-Service Quality Limits

The airframe manufacturers have established in-service limits for Type IV hydraulic fluids. These limits are listed on the following page. Continued use of a fluid that does not meet one or more of the limits can adversely affect the life of system components.

During aircraft operations, hydraulic fluid is subjected to an environment which, in time, alters certain properties of the fluid. No two types of aircraft hydraulic systems operate under the same conditions. The heat that is produced during system operations, the moisture from the environment to which

the fluid is subjected, and the cleanliness of the system (i.e., freedom from solids and liquid contaminants), will affect the operating life limit of the hydraulic fluid. Therefore, the operating life of Skydrol fluids is determined on the basis of both physical and chemical properties rather than by a fixed number of operating hours.

Solutia's Technical Service fluid sampling program offers comprehensive analysis and evaluation of the fluid, with recommendations for corrective action when required.

### Fluid Sampling

Solutia suggests that hydraulic fluid be analyzed periodically to assure that it meets airframe manufacturer in-service limits.

**ROUTINE SAMPLING** – Each system should be sampled about once a year and/or whenever the airframe manufacturer suggests.

**UNSCHEDULED MAINTENANCE** – When malfunctions may have a fluid relationship, samples should be taken.

**SUSPICION OF CONTAMINATION** – Usually fluids should be drained and replaced, with samples taken before and after the maintenance procedure.

### Fluid Contamination

Contamination in the hydraulic system can affect the performance of both the hydraulic fluid and the system components. Common liquid contaminants are chlorinated cleaning solvents, water, petroleum-based or synthetic oils, and engine lubricants. Liquid contaminants can alter the fluid's fire resistance properties, affect seal performance, cause gel formation, and lead to acid development.

Common solid contaminants include component wear particles as well as contamination

external to the hydraulic system. Solids can cause physical damage to components as well as line and filter pluggage. Certain solids accelerate fluid degradation.

Proper in-line filtration is required to maintain a low solids contamination level. Filters should be checked and replaced as required. If a high contamination level persists, procedures outlined by the aircraft manufacturer and component manufacturer should be followed.

# IV

## Airframe Manufacturers' Service Limits for Type IV Fluids

Analysis	Boeing – Seattle	Boeing – Long Beach (Douglas)	Airbus	Bombardier	Gulfstream	Lockheed	BAE	Fokker
Appearance	No cloudiness, phase separation or precipitation, any color is acceptable					No cloudiness or precipitation Color: Blue/purple to gray	–	–
Specific Gravity @ 25 °C/25 °C	0.995-1.066	0.900-1.066	0.995-1.066	0.995-1.066	0.995-1.066	0.989-1.065	0.995-1.066	0.999-1.057
Moisture % (max)	0.8	0.5	0.8	0.6	0.8	1.0	0.6	0.6
Neutralization No. mg KOH/gm (max)	1.5 <sup>2</sup>	1.5	1.5	1.0	1.5	1.5	1.0	1.0
Kinematic Viscosity @ 100 °F/38 °C, cSt	6.0-12.5	7.0-12.0	6.0-12.5	7.0-12.5	6.0-12.5	7.0 (min)	6.0 (min)	7.0 (min)
Elemental Contamination <sup>1</sup>								
Calcium	50 ppm max	–	–	–	50 ppm max	–	–	–
Potassium	50 ppm max	–	–	–	50 ppm max	–	–	–
Sodium	50 ppm max	–	–	–	50 ppm max	–	–	–
Chlorine	200 ppm max	200	200	200	200 ppm max	200	200	–
Sulfur	500 ppm max	–	–	–	500 ppm max	–	–	–
Particle Contamination #/100 ml (max)								
Class	9	9	9	8	9	8	9	9
5-15 microns	128,000	128,000	128,000	64,000	128,000	64,000	128,000	128,000
15-25 microns	22,800	22,800	22,800	11,400	22,800	11,400	22,800	22,800
25-50 microns	4,050	4,050	4,050	2,025	4,050	2,025	4,050	4,050
50-100 microns	720	720	720	360	720	360	720	720
>100 microns	128	128	128	64	128	64	128	128

<sup>1</sup>Contamination means quantities in excess of those introduced as a part of the basestock or the additive package.

<sup>2</sup>Neutralization number for B-757 Center System is .5 mg KOH/gm (max).

## Fluid Color

Phosphate ester-based aviation hydraulic fluids are purple fresh out of the can and may change color during service. Color is not a reliable indicator of fluid quality,

and there is no in-service specification for fluid color. The fluid should be clear with no cloudiness or suspended solids.

# Fluid Performance

## Lubricating Ability

**W**ithin an aircraft hydraulic system, moving parts generate fluid pressure and convert this pressure into useful work. The hydraulic fluid must prevent wear of these moving parts by allowing them to move in relation to each other with a minimum of friction and power loss.

Investigations of hydraulic fluid lubricating ability have been conducted using bench test devices, which measure friction and wear, and using hydraulic test rigs in which the hydraulic pump functions as a wear-test device. Although bench wear machines and the test pump rigs test lubricating ability of the fluid,

final evaluation for total performance must come from operational experience in actual aircraft hydraulic systems.

Skydrol Type IV hydraulic fluids have demonstrated excellent lubricating ability in millions of flight hours in a wide range of aircraft types. This experience has verified results from bench pump tests which show Skydrol Type IV fluids to be excellent lubricants.

One commonly used bench test is the Four Ball Wear Test. Typical results with the Skydrol hydraulic fluids are given in the table below. Test conditions were 600 rpm, 167 °F (75 °C) and one hour at various loads.

Scar Diameter,* mm Steel on Steel		
Load	Skydrol® LD-4	Skydrol® 500B-4
4 kg	0.33 mm	0.36 mm
10 kg	0.43 mm	0.45 mm
40 kg	0.69 mm	0.68 mm

*\*These data are based on samples tested in the laboratory and are not guaranteed for all samples.*

## Pump Testing

**P**ump testing is considered to be the best simulative method for evaluating the lubricating and stability characteristics of the fluid. Solutia's pump test rigs are similar to and duplicate the test method described in SAE Specification AS1241. The airframe manufacturers use similar test methods. (See page 3 for specification listings.)

Solutia's pump testing facility uses either an Abex AP10V-58A or a Vickers PV3-160-4 pump in the test circuit. The test results obtained with Skydrol LD-4 and Skydrol 500B-4 are shown in Table A on page 14.

During the tests there were no system operational problems. Post-test inspection of the pumps revealed that the clearances

were within overhaul specifications indicating normal wear, and no deposits were found on the pump parts. The analyses of the fluid samples showed the expected decrease in viscosity with time due to the normal shear of the viscosity index improvers. Acid number increases were negligible.

Since performance in the specified 500 hour test was excellent, the fluids were overstressed beyond the BMS3-11 requirement by running pump tests on the fluid from the first pump test, for an additional 521 hours. The test results are summarized in Table A on page 14. Performance of equipment and the quality of fluid were excellent.

## Air Sweep Pump Test

**A** significant aspect of fluid performance is the effect of air on the fluid at moderately high temperatures. Since aircraft hydraulic systems differ in reservoir design resulting in varying exposures of the fluid to air, Solutia conducted a number of "air sweep pump tests" which were designed to determine the deposit forming characteristics and stability of fluids. The first results of this work were reported to the SAE A6 Commercial Jet Panel in April 1976.

The pump test circuit was modified so that a slow stream of air could be introduced into the reservoir during the test. Table B on page 15

summarizes test conditions and results for Skydrol 500B-4 and Skydrol LD-4. Deposit formation is measured by increases in pressure drop across the filters during the test and post-test examination of the filters, the pump and the test circuit. The Skydrol Type IV hydraulic fluids showed no deposits by any of these criteria. It should be noted that actual field experience with deposit problems using various hydraulic fluids correlates well with air sweep pump test results. Longer-term air sweep pump tests (up to 1300 hours) have also shown no deposit-forming tendencies with either Skydrol LD-4 or Skydrol 500B-4.

**TABLE A\***  
**Pump Test Per BMS3-11 at 250 °F/121 °C**

Test Conditions	
Pump outlet pressure	2850 ± 50 psig, 196.5 ± 3.4 bar
Test section temperature	250 °F/121 °C, 275 °F/135 °C last 5 hrs.
Reservoir pressure media	Nitrogen
Filters, absolute rating (Pressure and case drain)	15 microns
System volume	8 gal, 30.3 L
System flow rate	8 gal/min, 30.3 L/min
Test duration	505 h

Test Results				
Fluid	Skydrol® LD-4		Skydrol® 500B-4	
Test time, h	505		506	
Pump condition at end of test	Excellent, normal wear, no deposits, trace stain		Excellent, normal wear, no deposits	
Filter Δ P increase, psi				
Pressure	None		None	
Case drain	0.5		0.3	
Shaft seal leakage, total ml	25		40	
Fluid parameters at time, h	Viscosity, at 100 °F/38 °C	Acidity	Viscosity, at 100 °F/38 °C	Acidity
0	11.0 cSt	0.04	11.8 cSt	0.02
100	8.0	0.05	7.7	0.03
300	7.4	0.07	7.0	0.03
505	7.4	0.07	6.8	0.03

Extended Pump Test Results (1026 Hours Total)				
	Used Skydrol® LD-4 from Table A		Used Skydrol® 500B-4 from Table A	
Added test time, h	500		521	
Pump condition at end of test	Excellent, normal wear, no deposits		Excellent, normal wear, no deposits	
Fluid parameters at time, h	Viscosity, at 100 °F/38 °C	Acidity	Viscosity, at 100 °F/38 °C	Acidity
0	7.4 cSt	0.07	6.8 cSt	0.03
200	7.2	0.07	6.8	0.05
500/521	7.1	0.07	6.7	0.05

\*These data are based upon samples tested in the laboratory and are not guaranteed for all samples.



**TABLE B\***  
**Air Sweep Pump Test**

Test Conditions	
Pump outlet flow	5 gpm, 18.9 liters/min
Pump outlet pressure	3000 psig, 206.8 bar
Pump outlet temperature	160 °F/71 °C
Pump case drain temperature	180 °F/82 °C
Filters (absolute rating)	
Main flow	15mm Purolator Posipure
Pressure	3mm Pall Ultrapore
Reservoir	Air sweep type
Air flow rate	5 liters air/h
Pressure	30 psig
System volume	2.5 gal, 9.46 liters
Test duration	500 hours

Test Results (500 hours)		
	Deposits	Final Acid Number (mg KOH/g)
Skydrol 500B-4		
Test 32	None	0.35
Test 64	None	0.57
Skydrol LD-4	None	0.51

*\*These data are based upon samples tested in the laboratory and are not guaranteed for all samples.*

## Fluid Stability

**F**luid stability affects total system performance including reliability and overall operational costs. Other hydraulic fluid properties, such as lubricating ability and corrosive tendencies, are also major factors in determining fluid performance.

Thermal stability is concerned with changes in the fluid and with its reactions with the environment caused by thermal stress. The changes that can occur include (1) increase or decrease in viscosity, (2) formation of corrosive products such as acid, (3) generation of insoluble material and (4) formation of volatile products.

Since aircraft hydraulic fluids can be exposed to air or to moisture, oxidative and hydrolytic reactions of the fluid can take place, hence, air and water contamination

should be minimized. In the presence of air and/or water, the fluid degradation rate observed by heat alone is accelerated.

Fluid stability can be measured in the laboratory under a variety of conditions. However, the test results must be confirmed by pump and rig tests simulating aircraft hydraulic systems and, finally, in actual service in aircraft.

One of the more useful stability tests involves heating the fluid at a constant temperature in a stainless steel container. The container is partially filled with fluid containing predetermined water contamination levels. Various metal specimens are added to simulate an aircraft hydraulic system environment. The container is sealed with air present and the test started. At the end of the test, the metal specimens are

examined for corrosion. The fluid is analyzed for acidity and other properties related to fluid degradation at intervals during the test.

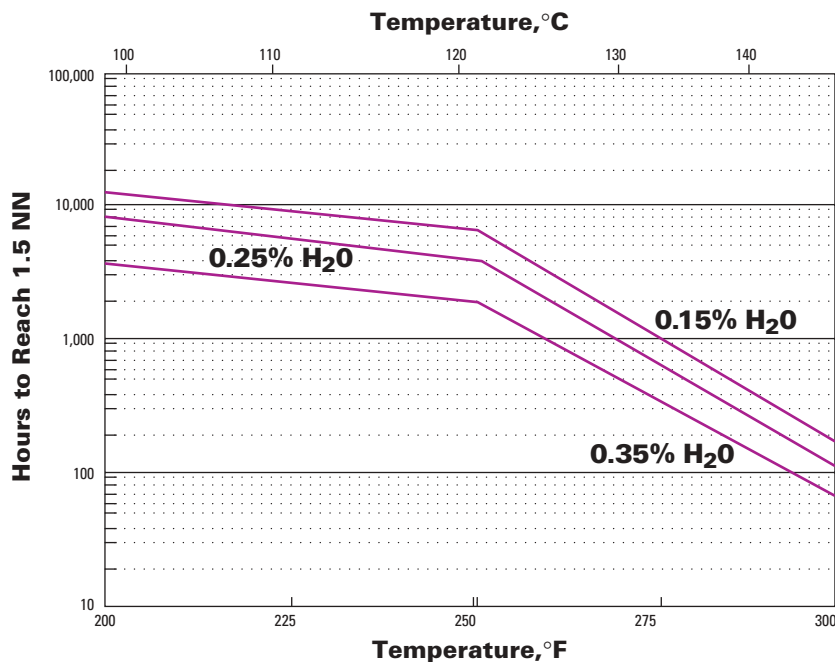
Figure 1 (below) provides details of Skydrol LD-4 fluid life at various temperatures and water contents. Fluid life is defined as the time required for fluid neutralization number to reach a value of 1.5, which is the limit set by most airframe manufacturers. These data demonstrate the excellent thermal stability of Skydrol LD-4. Note that small increases in water content have a significant effect on fluid stability. Introduction of air has also been shown to have a detrimental effect on fluid life.

The stability characteristics of Skydrol fluids are also shown by tests specified by AS1241 and airframe manufacturer specifications. The “Corrosion Hydrolytic and Oxidation Stability Test” procedure exposes the fluid to various

metals at 180 °F (82 °C) and 0.8% water for 168 hours, while the “Thermal Stability Test” procedure exposes fluid to various metals at 250 °F (121 °C) for 168 hours with no water added. Skydrol LD-4 and Skydrol 500B-4 easily pass metal weight-loss limits while showing essentially no increase in neutralization number and no buildup of deposits.

Skydrol hydraulic fluids are stable under the conditions of use as demonstrated by years of successful operation in airline service. In an aircraft hydraulic system, the upper temperature limit for continuous operation for Skydrol 500B-4 and Skydrol LD-4 fluids is 225 °F (107 °C). Portions of the system can operate for a short period of time at slightly higher temperatures without rapid deterioration of the fluids. Note from Figure 1 that at 300 °F (149 °C) the expected fluid life is only 100-200 hours.

**FIG. 1 Skydrol® LD-4\* Thermal Stability Fluid Life vs. Temperature and Moisture**



## Erosion Resistance

**P**rior to development of Type IV hydraulic fluids, servo valves in aircraft hydraulic systems containing phosphate ester-based fluids experienced corrosion on the high pressure side of the valve metering edge. This corrosion caused increasing internal valve leakage resulting in decreased pressure and premature valve failure. During the early 1970s it was discovered that the localized pitting corrosion (sometimes referred to as “erosion”) was a result of a unique combination of factors including (1) a very high fluid velocity at the upstream side of the valve metering edge, (2) the slight ionic character of phosphate esters and (3) the steel metallurgy of the slide and sleeve construction.

Additionally, the presence of chlorine compounds often used as cleaning solvents was found to aggravate the “erosion.” The mechanism involved relates to development of a localized electrical current during periods of high fluid flow, leading to localized pitting of the valve metering edge. This phenomenon is commonly referred to as “Streaming Current Induced Erosion.”

Phosphate esters, unlike mineral or petroleum oils, are slightly ionic in nature. This property results in the development of an electrical double layer at the metal-liquid interface under static conditions. The negatively charged portion of the double layer is held firmly to the steel surface which provides positive charges. The fluid further away from this surface (diffuse layer) has a positive charge. Under static conditions the total sum of all charges on both sides of the interface is zero.

Under high flow conditions the positively charged diffuse layer is swept away by the rushing fluid, creating a streaming current in

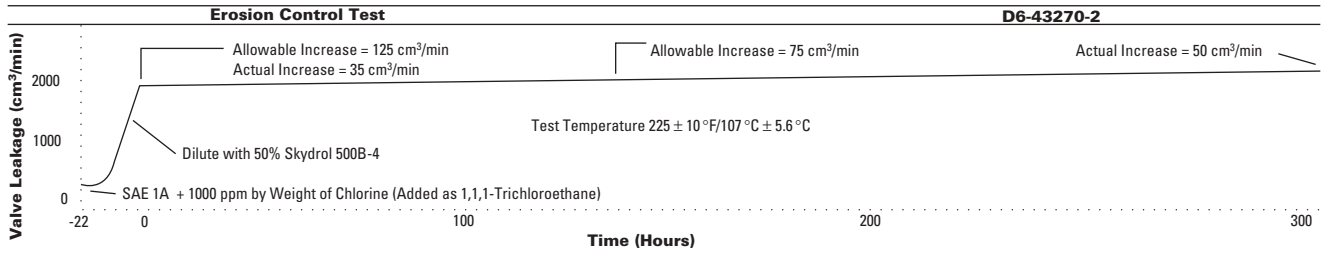
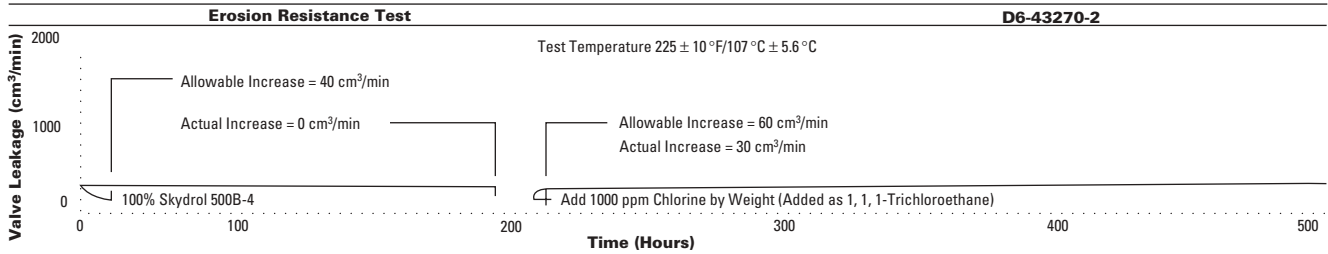
the fluid. At the same time, the steel surface with its associated negatively charged fluid layer becomes electrically unbalanced by the same magnitude as the streaming current. This imbalance creates a wall current which is responsible for the localized oxidation of the steel surface leading to metal loss (pitting). The electrochemical reaction taking place involves the conversion of elemental iron to the ferrous ion which is carried away by the fluid ( $\text{Fe}^0 \rightarrow \text{Fe}^{++}$ ).

During development of Type IV hydraulic fluids, it was found that certain additives could alter the electrical potential at the metal surface and prevent its electrochemical oxidation under high fluid flow conditions. These unique additives are known as anti-erosion additives. The additive used in Skydrol LD-4 and Skydrol 500B-4 has provided excellent “erosion” protection of servo valves in aircraft around the world since the late 1970s. Per Boeing specification BMS3-11, Skydrol fluids are qualified to provide erosion protection to steel metering edges at 225 °F (107 °C) and 3000 psi pressure drop. (See Figures 2 and 3.)

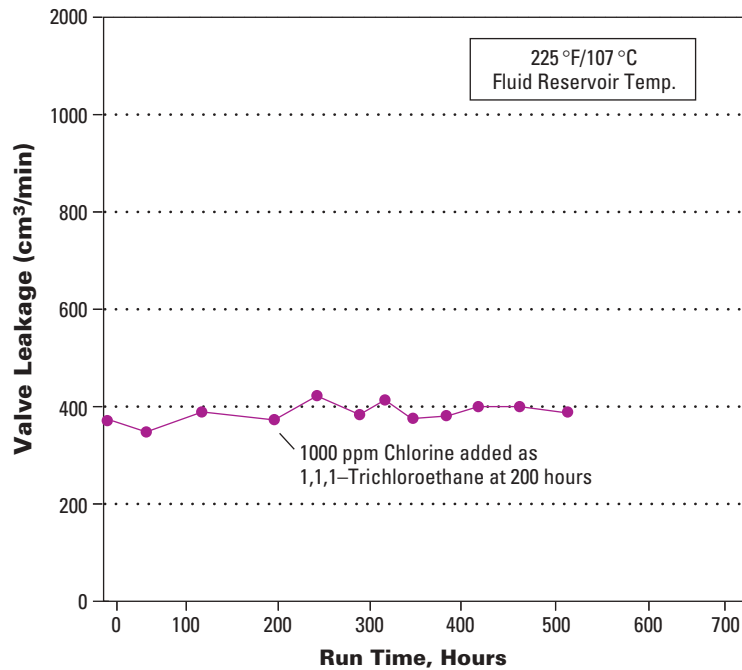
The anti-erosion additive used in Skydrol hydraulic fluids has the added property of extreme thermal and oxidative stability. This stability results in long-term continuous protection against servo valve “erosion” even in aircraft with the highest hydraulic fluid temperature profiles.

Numerous tests for measurement of erosion resistance to servo valves have been suggested over the years and have been used for screening purposes. As a prerequisite, all involve rapid fluid flow through an orifice. The most useful tests have been those using actual or simulative aircraft hydraulic system valves.

**FIG. 2 Valve Erosion Tests Per BMS3-11E**  
**Skydrol® 500B-4 Fluid**  
*Performed by Boeing*



**FIG. 3 Erosion Resistance Test Per BMS3-11**  
**Skydrol® LD-4 Fluid**



Solutia has performed extensive testing using as test devices a typical aircraft reduction and relief valve, a Solutia-developed flat orifice and the Boeing test valve defined in BMS3-11. Solutia's pump/valve/erosion test rigs are designed after the Boeing BMS3-11 and Aerospace Specification AS1241 test rigs.

Using test conditions of 3000 psi supply pressure, 225 °F (107 °C) reservoir temperature and 500 hour run times, no valve erosion resulted with any of the above test valves with Skydrol LD-4 or Skydrol 500B-4. The test values showed that flow increases were well under the specification limits. Visual examination of the valve metering edges also showed no erosion.

In similar pump/valve tests incorporating a 5 liter/hour air sweep in the reservoir at 160 °F (71 °C), Skydrol LD-4 and Skydrol 500B-4 showed no increase in valve leakage during 1250 operating hours.

Figure 2 on page 18 demonstrates erosion resistance and erosion control properties of Skydrol 500B-4 at 225 °F (107 °C) as determined by Boeing during qualification. The Erosion Resistance Test in Figure 2 demonstrates that Skydrol 500B-4 surpasses the test requirements both initially and after addition of 1,1,1-Trichloroethane (TCE), a common cleaning solvent fluid contaminant. The Erosion Control Test in Figure 2 demonstrates that when 50% Skydrol fluid is added to an erosive fluid which is rapidly eroding the Boeing test valve, erosion is quickly brought under control.

Figure 3 on page 18 is a repeat of the Erosion Resistance Test in Figure 2, using Skydrol LD-4 fluid and Solutia test equipment certified to the BMS3-11 Specification. Again, superior erosion resistance of the Boeing test valve metering edge is demonstrated.

# Shelf Life, Storage and Handling

## Storage and Shelf Life of Skydrol Fluids

Improper storage of hydraulic fluid can result in water and dirt contamination of the fluid which eventually ends up in an aircraft hydraulic system. This can cause premature failure of the fluid and corrosion of system components.

By following proper storage and transfer procedures of the hydraulic fluids, the contamination problem can be eliminated. The recommended practice is as follows:

- Store drums indoors whenever possible, and always keep lids securely tightened except when transferring fluid. Smaller containers such as 5 gallon, 1 gallon and quart cans should be stored indoors only.
- When transferring fluid, take care that pumps, filters and transfer lines are clean and dry.
- Store drums horizontally, if possible, to prevent water collection on the drum lid. If the drums cannot be stored horizontally, they should be blocked up and tilted so that any water collection on the lid will not cover the bungs.
- For all size containers, the use of pallets, racks or shelves is suggested to prevent contact with ground moisture.
- Fluids should be sampled and analyzed whenever there is a question of useability.
- The shelf life of all Skydrol hydraulic fluid is five years from the date of manufacture. This applies only to factory-sealed, unopened containers with proper storage.



## Handling of Skydrol Fluids

**S**kydrol hydraulic fluids are based on phosphate ester basestocks, which are good solvents and plasticizers. Care should be taken in handling Skydrol fluids to keep them from spilling on certain plastic materials and paints, which might tend to soften. (See the Compatibility Table on pages 7-9.)

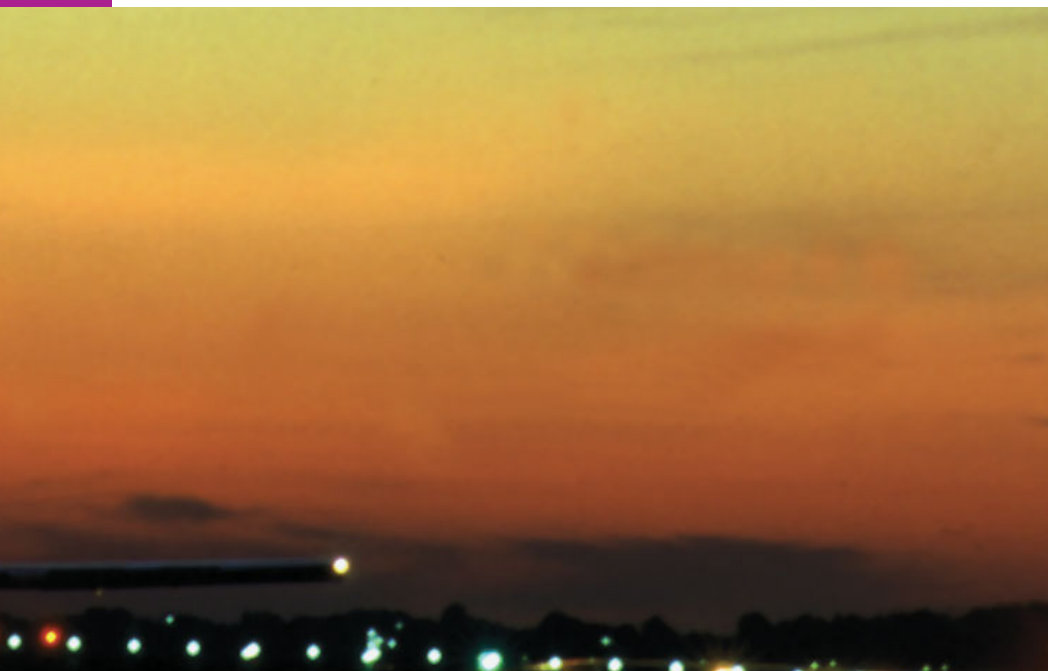
If a small amount of Skydrol fluid is spilled during handling, wipe it up immediately with a dry cloth. When large pools form, an absorbent sweeping compound is recommended. Then remove any traces of fluid with an approved solvent (see list on page 23). Finally, wash the area with water and a detergent.

Tools should not be allowed to soak in Skydrol fluids if they have painted areas or polyvinyl chloride (PVC) plastic handles. Many nonmetallic materials are resistant to

Skydrol fluids and will not be adversely affected by it. The Compatibility Table on pages 7-9 should be consulted. Since it is difficult to visually distinguish between materials that are resistant and those that are not resistant, it is highly recommended that all materials wet with Skydrol fluids be wiped off and cleaned as soon as possible.

Skydrol fluids will not harm clothing with the exception of a few materials such as rayon acetate. Some types of rubber-soled shoes may soften and deteriorate when exposed to Skydrol fluids.

Material Safety Data Sheets (MSDS) from Solutia should be consulted for all health and safety concerns. Solutia has a dedicated full-time technical service staff available to assist you in answering questions regarding Skydrol hydraulic fluids.



# Safety and Emergency Procedures

## Product Safety

**S**kydrol fluids are phosphate ester-based fluids blended with performance additives. Phosphate esters are good solvents, and as such, will dissolve away some of the fatty materials of the skin.

Repeated or prolonged exposure may cause drying of the skin, which if unattended, could result in complications such as dermatitis or even secondary infection from bacteria.

Skydrol fluids have not been known to cause allergic-type skin rashes.

Animal studies have shown that repeated exposure to tributylphosphate, one of the phosphate esters used in Skydrol fluids, may cause urinary bladder damage. The relationship of these results to human health is not clear. Thus, recommended personal protection measures should always be followed to minimize potential exposure.

## Skin Protection

**T**o avoid skin exposure, a worker should wear gloves that are impervious to Skydrol hydraulic fluids.

Some manufacturers claim “Nitrile” gloves are suitable for this purpose. Nylon latex and polyethylene “throw-aways” are

also acceptable. Consult Solutia’s “Glove Facts” publication for more details.

Solutia does not generally recommend the use of protective barrier creams as they do not provide complete protection.

## Proper First Aid Treatment for Eye Exposure

**S**olutia is not aware of any case of eye damage resulting from Skydrol fluid exposure, although severe eye pain may occur. First aid should consist of washing the fluid from the eye with potable tap water or a standard eye irrigation fluid (such as dacroise solution). Copious flushing is advisable. Addition of sterile mineral

oil or castor oil which is approved for ophthalmic treatment to the washed eyes aids in relieving the pain. Any additional treatment would not be considered first aid and should be administered under the supervision of a physician.

Where splashing or spraying is possible, chemical-type goggles should be worn.

## Inhalation of Skydrol Fluids

**U**pper respiratory tract irritation, including nose and throat irritation and tracheitis and/or bronchitis, can occur from inhalation of a Skydrol fluid mist. People with asthma may demonstrate a more marked reaction.

When mist or vapor is possible because of high pressure leaks, or any leak hitting a hot surface, a respirator capable of removing organic vapors and mists should be worn.



## Ingestion of Skydrol Fluid

Ingestion of small amounts of Skydrol fluid does not appear to be highly hazardous. Should ingestion of a full swallow or more occur, we suggest the immediate ingestion

of a large volume of milk or water, followed with hospital-supervised stomach treatment, including several rinses of saline solution and milk.

## Skydrol Fluid Safe Handling Summary

- Avoid direct exposure to Skydrol fluids.
- Impervious gloves and chemical-type goggles should be worn.
- Eye baths should be available when there is a potential for eye contact.
- When mist or vapor exposure is possible, a respirator capable of removing organic vapors and mists should be worn.
- Consult the Material Safety Data Sheet (MSDS) or contact Solutia for health/safety information.

## Cleaning Skydrol Fluid Spills

- Wipe up excess Skydrol fluid using disposable toweling.
- Spread an approved oil absorption floor sweep and allow sufficient time to soak up the fluid before sweeping.
- Wipe the floor with an approved solvent followed by a soapy solution and clear water rinse.
- Dispose of the towels, floor sweep compound and solvents by approved disposal methods.
- Aircraft tires should be cleaned of any Skydrol spillage with soap and water only per the manufacturer's recommendation.

## Cleaning Solvents

Components containing Skydrol fluid can be cleaned with non-halogenated cleaning solvents. These cleaning solvents do not contain chlorine, a serious hydraulic fluid contaminant, and should be used in the cleaning of all critical hydraulic fluid

components.

Although noncritical hydraulic fluid components can be cleaned with halogenated solvents, the use of such solvents is discouraged due to waste disposal problems and the possibility of hydraulic system contamination.

## Non-halogenated Cleaning Solvents

- SkyKleen® Aviation Solvent
- NTA-L (NSN 6850-00-264-9039)
- PD-680
- Safety Kleen Solvent
- Stoddard Solvent (85% nonane and 15% trimethylbenzene)
- Odorless Mineral Spirits
- White Spirits
- Safety Solvent
- Varnoline
- Isopropyl Alcohol

A green square containing the Roman numeral VIII in white, centered between two horizontal black lines.

## Disposal of Used Skydrol Fluids

There is no approved reclamation system or any known practical technology to reclaim Skydrol fluids for return to aircraft hydraulic system usage. It is therefore recommended that the waste fluid be disposed of by approved disposal methods in accordance with federal, state and local guidelines. Presently, the most universally accepted practice is incineration.

Decontamination of Skydrol fluid for use on ground equipment is sometimes practiced. Equipment is available which can effectively remove excess water, chlorinated cleaning solvents and particulates. It is noted that this procedure does not improve fluid which has become acidic or which is deficient in performance additives.

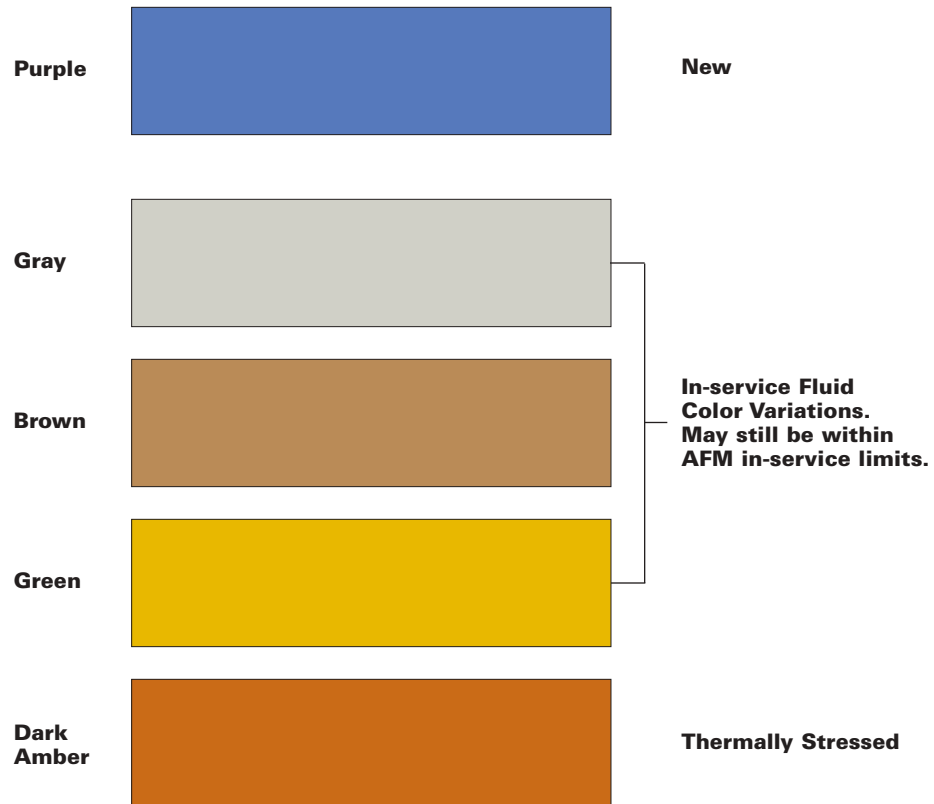
A teal square containing the Roman numeral IX in white, centered between two horizontal black lines.

## Customer Technical Service

- Fluid Analysis Program
- Phone Response System
- Troubleshooting Support
- Pump Test Rig Facility
- Technical Presentations
- Training Seminars
- Technical Literature
- Product Safety and Handling Literature

Contact your local Solutia representative for details.

# Aviation Hydraulic Fluid Color Scale



Color is not a reliable indicator of fluid quality! Fluid should be clear and bright. If fluid is suspected to be degraded or contaminated beyond in-service limits, collect a sample and send to Solutia for a comprehensive fluid analysis.



# WORLDWIDE SALES OFFICES

## UNITED STATES/ CANADA

### For order assistance

Please call our Customer Service Department, toll free at (800) 260-4150.

### For technical assistance

Please call our Technical Service Hotline, toll free at (800) 426-7022.

### Houston

1800 West Loop South  
Suite 1360  
Houston, Texas 77027  
Tel: (713) 850-0088  
Fax: (713) 850-0096

### St. Louis

P.O. Box 66760  
St. Louis, Missouri 63166-6760  
Tel: (314) 674-1000  
Fax: (314) 674-6331

## LATIN AMERICA

### Argentina

Solutia Argentina S.R.L.  
Alicia Moreau de Justo, 1960  
2nd Floor – Office 203  
Buenos Aires, Argentina  
Tel: +54-11-4515-0709  
Fax: +54-11-4515-0728

### Brazil

Solutia Brazil Ltda.  
Rua Gomes de Carvalho  
1306-60. Andar 04547-005  
Sao Paulo, SP, Brazil  
Tel: +55-11-3365-1800/1839  
Fax: +55-11-3365-1833

### Mexico

Solutia Mexico, S. de R.L. de C.V.  
Torre Cuadrata  
Paseo de la Reforma  
No. 2654 Piso 3 Apartado "A"  
Col. Lomas Altas  
11950 Mexico, D.F.  
Tel: +52-55-5570-8578  
Fax: +52-55-5570-9847

### Venezuela

Solutia Venezuela S.R.L.  
Av. Francisco de Miranda, Centro Lido,  
Torre D, piso 4, Ofic. 40 – HQ Global Workplaces  
Urb. El Rosal,  
Caracas, Venezuela  
Tel: +58-212-9056370 / 9056375  
Fax: +58-212-9056365

## EUROPE

Solutia Europe N.V./S.A.  
Rue Laid Burniat, 3  
Parc Scientifique - Fleming  
B-1348 Louvain-la-Neuve (Sud)  
Belgium  
Tel: +32-10-481547  
Fax: +32-10-481198

## AFRICA/ MIDDLE EAST

Solutia Europe S.A. – Branch Office  
Tatoiou 122 and Parthenonos St.  
14371 Nea Erithrea  
Athens  
Greece  
Tel: +30-210-625-03-10  
Fax: +30-210-625-03-13

## ASIA/PACIFIC

### China-PRC

Solutia International Trading Co., LTD. (Shanghai)  
Unit 1806, Harbour Ring Plaza  
18 Xi Zang Zhong Road  
Shanghai, 200001, P.R. China  
Tel: +86-21-6386-7500  
Fax: +86-21-6385-1882

### India

Solutia Chemicals India Pvt. Ltd.  
205-207, 'Midas' Sahar Plaza Complex  
Andheri-Kurla Road  
Andheri (East),  
Mumbai 400 059 India  
Tel: +91-22-830-2860  
Fax: +91-22-830-2859

## Japan

Solutia Japan Ltd.  
Shinkawa Sanko Building  
Second Floor  
1-3-17, Shinkawa, Chuo-ku  
Tokyo 104-0033, Japan  
Tel: +81-03-3523-2080  
Fax: +81-03-3523-2070

## Korea

Solutia Korea Ltd.  
3rd Floor, Anglican Church Building  
3-7, Jeong-dong, Joong-gu  
Seoul 100-120, Korea  
Tel: +82-2-736-7112  
Fax: +82-2-739-5049

## Malaysia

Solutia Hong Kong Ltd.  
Malaysia Branch  
12th Floor (1309-B)  
Kelana Parkview Tower  
No. 1 Jalan SS 6/2  
Kelana Jaya  
47301 Petaling Jaya  
Selangor, Malaysia  
Tel: +60-3-7804-5766  
Fax: +60-3-7804-4067

## Singapore

Solutia Singapore Pte. Ltd.  
101 Thomson Road  
#19-01/02 United Square  
Singapore 307591  
Tel: +65-6357-6100  
Fax: +65-6357-6194

## Taiwan

Solutia Taiwan Inc.  
7F-1, 122 Chung-Cheng Rd.,  
Shih-lin Dist.,  
Taipei 111, Taiwan  
Tel: +886-2-8866-6183  
Fax: +886-2-8866-2703

Visit our Web site at  
[www.skydrol.com](http://www.skydrol.com)



*Solutions for a better life.*

Solutia  
P.O. Box 66760  
St. Louis, MO 63166-6760  
Tel: (314) 674-1000

Litho in U.S.A.  
© Registered Trademark of Solutia Inc.  
© Solutia Inc., 2003. All rights reserved.