FIRE RESISTANT HYDRAULIC FLUIDS

SELECTION AND APPLICATION

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Fire resistant hydraulic fluids have been commercially available for over twenty years and their use has grown dramatically in the past ten years. Millions of gallons of these fluids are consumed each year reflecting industry's increasing awareness and emphasis on safety. Safer operations affect not only the lives of employees but equipment utility, where a fire can cause extensive damage as well as costly downtime.

Despite the widespread use of fire resistant hydraulic fluids, it is estimated that only about 5% of all hydraulic fluid used is of the fire resistant type. Petroleum oil is the standard for most fluid powered industrial equipment and it is extremely important that this be recognized by anyone using or considering the use of fire resistant fluids. Good hydraulic performance is being achieved with fire resistant fluids where the differences between these fluids and petroleum oil are recognized. Fire resistant fluids are here to stay and it is the purpose of this paper to discuss the selection and application of these fluids to industrial hydraulic equipment.

When considering the use of fire resistant fluids, a number of questions arise which should be answered:

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What constitutes a fire hazard near hydraulic equipment?

In what industries do these hazards exist?

What are the types of fire resistant hydraulic fluids?

What are the properties of these fluids?

What changes should be made to equipment to accommodate their use?

All of these questions will be treated and some conclusions drawn regarding the important factors to consider when choosing a fire resistant hydraulic fluid.

FIRE HAZARDS

Petroleum type hydraulic fluids contribute to fire hazards wherever sources of ignition are present. These may be open flames, sparks from electrical equipment or metal working and high temperature surfaces. As long as the fluid is confined to the hydraulic system there is no problem. However, hose and line breaks, leaking joints or accidental spillage onto ignition sources can result in sustained burning which may spread to other equipment, buildings and people.

Some common ignition sources, form or condition of fluid when contacting ignition source and environmental conditions are presented in TABLE I. Where these conditions may be present it is desirable to use fire resistant hydraulic fluids. The subject of fire resistance and how it is measured is treated separately following the fluid properties section.

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TABLE 1

FIRE HAZARD CONDITIONS

Source of Ignition

- Flames
- Sparks
- Hot Metal Surfaces

Fluid Condition

- Pools and Puddles
- Sprays - stream and highly atomized
- Vaporized
- Wick - insulation, packaging

Environment

- Air Temperature
- Draft
- Equipment and building spacing

Hazardous Industrial Applications

TABLE II lists typical industrial applications where fire resistant fluids are being used. There is a concentration of use in the primary metal and metalworking industries due to the high temperatures involved in producing and forming of steel, aluminum, copper, brass, zinc, magnesium and rare metals such as titanium, tantalum and beryllium.

Hydraulic power is used extensively in the basic steel and aluminum industries, in foundries and is the primary means of transmitting large forces in diecasting, forging and extrusion. Metal temperatures in or near hydraulic equipment range from 800°F. to 3000°F. and the fire hazard is severe. Hydraulics are also used extensively in coal mining and plastic injection molding though fire resistant fluids are the exception rather than the rule. Electrical arcing and flammable gases (which, if ignited could ignite hydraulic oil) are the hazards in mining while electrical heaters for the higher melting plastics are the primary concern in injection molding. Recent legislation will require further use of fire resistant fluids in coal mines, particularly in unattended equipment.

Fire resistant hydraulic fluids are also used in air compressors and as bearing lubricants in rotating equipment such as steam and gas turbines.

The use of fire resistant fluids in turbines will not be discussed since this is a separate discipline and should be covered in detail. Synthetic

fire resistant fluids have been used as air compressor lubricants for many years. Both reciprocating and centrifugal compressors can be hazardous when petroleum oil lubricants are present. In reciprocating compressors, oils can oxidize and build up carbon deposits on valves, cylinders and in air lines. The high temperature of the compressed air can cause the carbon deposits to become hot enough to ignite oil mists present in the system. In centrifugal compressors, where fire resistant fluids are used as a bearing lubricant, seal failures can cause spraying of fluid onto high temperature surfaces of the compressor. In both types of compressors, synthetic fire resistant fluids greatly reduce the hazard since they have a strong resistance to ignition and have much higher thermal stability than petroleum oils to prevent carbon deposit formation.

TABLE 2

FIRE RESISTANT HYDRAULIC FLUID APPLICATIONS BY INDUSTRY

Primary Metals
(Steel, Aluminum, Copper)

- Continuous Casters
- Rolling Mills
- Furnace Controls
- Stripper Cranes
- Automatic Welders
- Charging Equipment
- Mobile Equipment
- Hydraulic Shears

Forging and Extrusion

- Forging Presses
- Extrusion Presses
- Mobile Equipment

Coal Mining

- Continuous Miners
- Shuttle Cars
- Conveyors
- Car Spotters

Chemical-Petroleum-Power

- Valve Operators and Controls
- For High Temperature Equipment
- Air compressors
- Steam and Gas Turbines

Diecasting

- Diecasting Machines
- Trim Presses
- Mobile Equipment

Foundries

- Molding Machines
- Furnace Controls

Fabrication

- Forming Presses
- Automatic Welders
- Furnace Controls
- Conveyors

Injection Molding

- Molding Machines

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TYPES OF FIRE RESISTANT HYDRAULIC FLUIDS

There are three major types of fire resistant hydraulic fluids which are being used today:

Synthetic Fluids

Straight Synthetic

Synthetic Base

Water Glycols

Water-Oil Emulsions (Invert Emulsions)

A possible fourth type are the soluble oils which are water plus corrosion and lubrication additives. These fluids find use in large central systems for low speed hydraulic equipment and will not be treated here.

Synthetic Fluids

The synthetics can be divided into two categories, straight synthetic and synthetic base fluids. The straight synthetics are phosphate esters or a mixture of phosphate esters and chlorinated hydrocarbons. The synthetic base fluids, which have been commercially available for about seven years, are solutions of synthetic fluids and selected high viscosity petroleum fractions.

Synthetic fluids are inherently fire resistant due to the phosphorus and/or chlorine content. They have high film strength and are equivalent in lubrication to the best petroleum oils. Synthetics exhibit excellent thermal stability and can operate at temperatures well in excess of 200°F. without fluid breakdown or carbonization. Generally, non-metal components such as seals, hoses and paints common to petroleum oil systems are <u>not</u> compatible with synthetic

fluids. Synthetics are compatible with common metals of construction.

Water Glycols

Water glycols are true solutions of water, polyglycols and high molecular weight thickeners to increase viscosity. They derive their fire resistance from water (usually 40-50%), which acts as a snuffer and inhibits ignition of the glycol, which is flammable. Because of the water content, film strength is lower than that of petroleum oil or synthetics and this limits their use in higher pressure applications (above 2000 psi). However, the water glycols are compatible with seals and hoses common to petroleum oil systems and this is an advantage when converting existing equipment.

Water-Oil Emulsions

The water-in-oil emulsions, commonly called invert emulsions, are mixtures of tiny water droplets dispersed in a continuous phase of petroleum oil. Like the water glycols, emulsions derive their fire resistance from the water content. Again, due to the water, film strength of the emulsions is relatively low and this limits their use in higher performance applications. One of the primary problems with water-oil emulsions is separation or "breaking" of the emulsion. This can be caused by long periods of standing, extreme temperatures or contamination. If separation occurs, the water phase can cause serious pump damage and premature failures.

The primary advantage of the emulsions is their compatibility with system components used with petroleum oil. This includes elastomers for seals and hoses as well as paints and common metals of construction (except magensium).

COMPARISON OF PROPERTIES

The many properties important to hydraulic fluid performance are shown in TABLE 3 and TABLE 4. Petroleum oil is included as a reference fluid and each type of fire resistant fluid is shown. It is important that this table be recognized as a general classification of commonly used fire resistant fluids rather than an all-inclusive or exhaustive study. When specifying fire resistant fluids, suppliers should always be consulted for specific recommendations on their products.

Physical Properties

As shown in the physical property comparison, all fire resistant fluids have a higher density than petroleum oil. Because of this, a fluid starvation condition may be created at the pump inlet if the system was not designed for a fire resistant fluid. Increasing the line size on the pump suction or changing to a flooded suction will usually eliminate this condition. Supercharging of the pump may be necessary if an extreme "high lift" condition can not be avoided. Suction line filtration of fluid should always be avoided and only a 50 - 60 mesh strainer should be used to protect the pump.

The viscosity index (VI) of fire resistant fluids varies according to type. The straight synthetic fluids have a low VI, synthetic base fluids are intermediate and water glycols are quite high. Emulsions are non-Newtonian, exhibiting a different viscosity in motion than at rest, and viscosity index can not be measured. Viscosity index is usually not critical unless system temperatures are very low ($<40°F.$) or very high ($>175°F.$). If VI is low, it

may be necessary to go down or up one viscosity grade (compared to a high VI fluid) to provide satisfactory low temperature pumpability or adequate high temperature viscosity for pump lubrication.

Vapor pressure or volatility is very important from the standpoint of pump performance as well as fluid maintenance. Temperatures above 150°F. with the water base fluids cause excessive water evaporation and a tendency to vaporize at the pump inlet, resulting in pump cavitation. Water make-up control is discussed under the fluid maintenance section.

All fluid types exhibit satisfactory liquid phase corrosion protection but there is still a need for better vapor phase corrosion inhibitors, particularly for water base fluids. Vapor phase rusting usually occurs in reservoirs and rust particules falling into the system can damage pumps and cause erratic valve operation. Maintaining adequate fluid level in the reservoir is the best way to avoid vapor phase corrosion. Adequate filtration can do much to prevent rust particle damage.

The storage stability of all fluids, except emulsions, is good. Emulsions will separate into three phases (oil, emulsion, water) upon standing, the severity of separation and the time necessary to produce separation depending upon the particular formulation or brand. Even when emulsions are stored at room temperature, drum rolling is recommended by most suppliers before the fluid is put into a system. If the emulsion has been stored at lower temperatures, high speed stirring is recommended before the fluid is used.

TABLE 3

PHYSICAL PROPERTIES

	Petroleum Oils	Synthetic Fluids	Synthetic Base Fluids	Water Glycol	Water-Oil Emulsions
Density	0.85 - 0.9	1.1 - 1.3	1.1 - 1.2	~1.05	~0.95
Viscosity Index	High	Low	Intermediate	High	Non-Newtonian
Vapor Pressure	Low	Low	Low	High	High
Corrosion Resistance					
Liquid Phase	Good	Good	Good	Good	Good
Vapor Phase	Fair	Fair	Fair	Fair to Poor	Fair to Poor
Storage Stability					
Room Temperature	Good	Good	Good	Good	Requires Care
Low Temperature	Good	Good	Good	Good	Poor

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Functional Properties

The lubrication characteristics vary markedly between synthetic fluids (and petroleum oils) and water base fluids. The significance of this difference depends on the type of pump used, the pressure and the temperature. As shown in the table, water base fluids are generally not used above 2000 psi and in many cases 1500 psi is the practical limit. Temperatures with water base fluids should be controlled to 120 - 130°F. for best performance and 150°F. is the maximum due to excessive water evaporation and tendency to vaporize at the pump inlet. Synthetic fluids may be used at pressures up to 5000 psi with no sacrifice in pump life when compared to petroleum oil. 200°F. is defined as the maximum fluid temperature for synthetics only because the viscosity of most fluids is reduced to a point which is marginal for good pump lubrication. The synthetic fluids have thermal stability well in excess of 200°F. so this is not a limiting factor.

The type of pump used in a hydraulic system may also limit the choice of fire resistant fluid used. Though all types of fluids are used in vane and gear pumps, axial piston pumps must be derated 30-40% in outlet pressure when used with water base fluids and radial piston pumps should not be used with water base fluids at all. Synthetic fluids may be used with both types of piston pumps.

Most common metals of construction are compatible with all types of fire resistant fluids. Aluminum should not be used for load bearing surfaces with any of the fire resistant fluids. Other exceptions are shown in TABLE 4.

TABLE 4 FUNCTIONAL PROPERTIES

	Petroleum Oil	Synthetic Fluid	Synthetic Base Fluid	Water Glycol	Water Oil Emulsions
Lubrication					
Pressure, psi	Up to 5000	Up to 5000	Up to 5000	Usually 2000 maximum	Usually 2000 maximum
Temperature, max. recommended	200°F.	200°F.	200°F.	150°F.	150°F.
Compatibility					
Common Metals	Good	Good*	Good*	Exclude Zn,* Cd, Mg	Exclude Mg*
Common Seals	Neoprene Buna N	Viton Silicone Teflon Fluorel Butyl EPR	Viton Silicone Teflon Fluorel Butyl** EPR**	Neoprene Buna N Butyl	Neoprene Buna N
Common Hoses	Neoprene Buna N	Butyl EPR Nylon	Butyl EPR Nylon	Neoprene Buna N Butyl	Neoprene Buna N
Paints	Oil Resistant	Special(epoxy base)	Special (epoxy base)	Special (epoxy base)	Oil Resistant
Filtration, Min. Size micron	< 10	< 10	< 10	< 10	< 10
Fluid Cost/Gallon	$. 25-$1. 00	$3. 25-$5. 00	$2. 00-$3. 00	$1. 50-$2. 50	$. 50-$1. 50

*Caution should be used in the use of aluminum for load bearing surfaces with any fire resistant fluid.

**Satisfactory under certain [illegible]

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The most common elastomers used for seals and hoses are neoprene and buna N since these materials are compatible with petroleum oil. Both water glycols and water-oil emulsions are compatible with these elastomers and this is a significant advantage of these fluids, particularly when converting an operating system. The synthetic fluids soften and swell both neoprene and buna N and this makes these elastomers particularly unsuitable for use as dynamic seals (cylinder packing, pump shaft seals) with the synthetics. When converting an operating system to a synthetic or synthetic base fluid, it is strongly advisable to convert dynamic seals to a compatible elastomer (Viton is most common) to prevent premature failure of components and excessive fluid leakage. Static seals of neoprene and buna N generally need not be changed when converting to a synthetic fluid since swelling of the seals serves to prevent leakage. However, these seals should be replaced with a compatible elastomer when components are disassembled for maintenance.

For hydraulic hoses, buna N and neoprene are the most common hose liner materials and are satisfactory for use with water glycols and water-oil emulsions. Synthetic and synthetic base fluids require butyl, EPR or nylon lined hoses.

Paints commonly used in the reservoirs of petroleum oil systems are not compatible with synthetic, synthetic base or water glycol fluids. These fluids cause peeling of oil resistant paint, resulting in fluid contamination and erratic valve performance. Due to this fact, reservoirs should be stripped of paints before conversion to any synthetic or water glycol fluid.

Repainting of the reservoir is not necessary but if this is done, an epoxy base paint should be used.

When converting from petroleum oil to fire resistant fluid or from one type of fire resistant fluid to another, fluid suppliers should be consulted for recommendations on proper procedures. USA Standard B 93.5 - 1966 also gives complete details on conversion procedures and copies may be obtained from the National Fluid Power Association, Thiensville, Wisconsin 53092.

Filtration of hydraulic fluids is extremely important and can dramatically affect pump life. Synthetic, synthetic base and water glycol fluids tend to be more detergent than petroleum oil or emulsions and will carry dirt and wear particles in suspension rather than dropping them to the bottom of the reservoir. This makes good filtration important to long component life. All of the fluids listed are easily filtered and pressure side filtration of 10 micron or smaller is advised for any industrial hydraulic system regardless of the fluid used. The only caution in this area is that absorptive type filters containing active earth or clay should not be used with water base fluids since corrosion and wear additives can be removed.

Fluid costs are given in TABLE 4 and cover a wide range. You must expect to pay a premium for safety since fire prevention in any form costs money. Fire resistant hydraulic fluids, while more expensive than petroleum oil, can save many times their cost when a hydraulic line breaks and sprays fluid on an ignition source. Nearly all insurance companies recognize the need for fire resistant fluids and adjust their rates accordingly. If you are

not using fire resistant fluids in a hazardous area, a check with your insurance company may reveal the price you are paying for petroleum oil is higher than you think.

FIRE RESISTANCE.

Safety of a given fluid is directly related to its relative fire resistance. This leads to the question: What is fire resistance and how is it measured?

The term fire resistant is used to describe these fluids rather than terms such as non-flammable or fire proof. The common commercial fire resistant fluids will all burn under some condition. Key words used to describe these conditions are ease of ignition and propagation.

Fire resistant fluids are more difficult to ignite and once ignited, flames have much less tendency to spread from the ignition source than with petroleum oils.

There are many tests used to measure fire resistance. Private organizations, industrial companies, military branches, government departments, insurance underwriters and cooperative combinations of these groups have been doing work to measure fire resistance and standardize tests.

Although many individual tests exist, these may be classified into a small number of groups as follows:

Flash and Fire Points

Autogenous and Spontaneous Ignition Temperature

Spray Ignition and Propagation

Hot Metal Surfaces and Molten Metal

Wick Flammability

Special and Combined

Fire resistance of hydraulic fluids is a difficult property to define and measure. Several factors must be considered and weighed for relative importance to a given application. Fire resistance of a given fluid is made from an overall judgment of these factors. Generally fire resistance tests are empirical simulative tests which compare known and unknown fluids. Each test is designed to have some relationship to the actual hazard. Most ratings are by qualitative visual observations.

Typical fire resistance values for the commercial industrial fire resistant fluid classes are compared with petroleum oil in TABLE 5.

Except in large organizations which can justify their own fire test facilities, a fluid user relies on the supplier's fire tests. Insurance underwriters will approve or rate fire resistant fluids and require their use in certain installations.

FLUID MAINTENANCE

In normal use the fire resistant fluids can be divided into two groups for maintenance considerations. As with petroleum oil, straight synthetic and synthetic base fluids are relatively stable and require only simple filtration at the machine to remove solid contaminants. Water base fluids usually require water make-up and in some cases replenishment of additives.

In case of more severe service or external contamination, more extensive fluid renewal procedures will allow continued use of the fluid. Such procedures usually require a portable recovery unit which can be moved to each machine or removal of fluid to a central processing point. This can be done by the user or by a contract reclaimer.

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More specific comments on maintenance of each fluid class are as follows:

Straight Synthetic

Filtration at the machine is sufficient for long fluid life in most installations. Small amounts of moisture can be removed by paper or attapulgus earth filters. Use of active earth filtration is acceptable with straight synthetic fluids since they either contain no additives or have stable additive packages. Appearance, acidity, viscosity, specific gravity and moisture content are used to judge fluid condition. Yearly sampling is sufficient unless system malfunctions are thought to be fluid related.

In case of fluid degradation which is usually caused by local overheating, earth filtration will remove small amounts of acidic decomposition products. Where fluid has been severely degraded, contains large amounts of water or has been contaminated by accidental addition of other materials, the fluid should be removed for more extensive reclamation. Extent and ease of reclamation will vary and the supplier or a competent fluid reclaimer should be consulted for most economical reclaiming procedures.

A common contaminant is petroleum oil which will decrease fire resistance. Most straight synthetic fluids can tolerate some oil without complete fire resistance loss. This will vary with the oil viscosity grade. The fluid supplier will be the best source of information for reclamation of such fluids.

Synthetic Base

Maintenance of the synthetic base fluids is similar to that with straight synthetics. Since these usually contain selected petroleum fractions, their margin for tolerance of contaminating oil is less. For this reason greater

attention should be given to eliminate oil contamination.

As with straight synthetics, appearance, viscosity, acidity, specific gravity and moisture content are used to judge fluid condition. These should be obtained on a yearly basis or as required to check any system malfunction.

Water Glycol

Normal wear debris and solid contaminants can be removed by suitable water resistant filters. Earth or active clay type filters should not be used since these tend to remove additives.

Water glycol fluids should be checked at 3 to 6 months intervals for water content. Water is necessary both to insure adequate fire resistance and proper viscosity. Alkalinity and pH changes may require replenishment of part of the additive package to insure against rust and lubrication problems.

Water content can be found by direct measurement or on the basis of viscosity. As water evaporates, viscosity will increase. Fluid suppliers will furnish charts or tables showing the amount of water to be added to restore the fluid to its original viscosity.

Only distilled, deionized, steam condensate, or air conditioner condensate water should be used for make-up. Hard or impure water may cause inhibitor separation and lubrication problems. Operation of the system at the lowest practical temperature will decrease need for water make-up.

If alkalinity must be adjusted, the fluid supplier should be consulted for type and amount of additive to be used. The relatively low cost of water

glycol fluids has made reclamation of grossly contaminated or degraded fluid uneconomical. In these cases disposal by incineration or other acceptable means is recommended.

Water-in-Oil Emulsions

Water content measured at 3 to 6 month intervals is the primary maintenance check of water-in-oil emulsions. Amount of water to be added is done according to tables or charts furnished by the fluid supplier. As with water glycol fluids, only high purity water should be used to prevent additive separation and emulsion breaking. Low fluid temperatures will decrease need for water replacement.

Solid contaminants are removed by filtration; however, absorptive filters such as clay, cotton, felt, paper, or resin impregnated paper types should be avoided since they may remove additives and result in emulsion separation.

As indicated in the physical property section, emulsions have a tendency to separate into layers and should be remixed thoroughly before using in hydraulic systems.

The low cost of emulsion fluids prevents economical reclamation if gross contamination is present. Incineration or other accepted disposal methods should be practiced.

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POLLUTION

People in all industries are becoming increasingly aware of problems and pressures concerning pollution from manufacturing operations. The question

arises: Will use of fire resistant fluids cause more problems relative to pollution and plant effluent purification? The answer depends both on the type of fluid used and past practices of a particular industry.

Legislation and its enforcement is moving in a direction which prohibits presence of materials - even petroleum oil - in effluent streams above very low concentrations. This means no matter which fluid is used it must be removed from effluent streams or be readily decomposed to harmless materials without environmental changes.

This may be turned to advantage in that better maintenance practices reduce fluid use. Also, the stable straight synthetic and synthetic base fluids may be recovered, cleaned and reconstituted as needed and recycled. These actions will reduce overall fluid costs.

Straight synthetic and synthetic base fluids are usually readily removed from effluent streams. Water-in-oil emulsions may require oil separation before the water portion is further treated to remove remaining impurities. Water-glycol fluids present a problem in that the glycol components are not inexpensively separated. If large quantities of these solutions are discarded with water streams, biological oxygen demand limits may be exceeded. In some areas a maximum daily quantity restriction is a limitation.

If the various fire resistant fluids can not be reused, the best means of disposal is high temperature incineration. In this way the fluid is decomposed to relatively harmless materials. Where questions of proper disposal arise, the fluid supplier should be consulted.

CONCLUSION

Since many aspects of the application of various types of fire resistant fluids have been covered, it seems best to summarize the advantages and disadvantages of each type of fluid in a concise manner. TABLE 6 lists the various types of fire resistant fluids and is aimed at showing the relationship between cost and performance. Without question, synthetic fluids are the best performing fluids and are followed in order by synthetic base fluids, water glycols and water-oil emulsions. Likewise, synthetic fluids are the most costly and the other fluids follow in the same order.

There is a need for each of the types of fire resistant fluids. Selection of a fluid for a particular application depends on the most critical of the factors covered in TABLE 6, namely, degree of fire resistance desired, cost of the fluid, lubrication characteristics, stability, seals and hoses required, fluid maintenance required and fluid recoverability. Only when the critical factors are determined for a particular application can the fluids be evaluated on a cost/performance basis and the most economical fluid selected.

TABLE 6

Fluid Type	Advantages	Disadvantages
Synthetic Fluids	Excellent Fire Resistance Excellent Lubricant Excellent Stability Minimum Maintenance Readily Reclaimed	Higher Cost Special Seals, Hoses Required
Synthetic Base Fluids	Good Fire Resistance Excellent Lubricant Excellent Stability Minimum Fluid Maintenance Readily Reclaimed	Moderate Cost Special Seals, Hoses Required
Water Glycols	Low Cost Excellent Fire Resistance Compatible with standard seals and hoses Good Stability	Fair Lubricant Higher Fluid Maintenance Not Readily Reclaimed
Water-Oil Emulsions	Very Low Cost Compatible with standard seals and hoses	Fair Fire Resistance Fair Lubricant Higher Fluid Maintenance Poor Stability Not Readily Reclaimed