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"Environmentally Friendly Fluids for Successful Hydraulic Systems Operation"

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ENVIRONMENTAL FRIENDLY FLUIDS FOR SUCCESSFUL HYDRAULIC SYSTEMS OPERATION

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ABSTRACT

Hydraulic fluid is both the lubricant and the medium through which power is transmitted. Therefore, selecting the proper fluid is necessary for the successful operation and longevity of the hydraulic system. This paper will discuss the properties of fluids with an emphasis on environmental friendly fluids. In addition, practical experience regarding projects, which have used environmental friendly fluids will be discussed.

Introduction

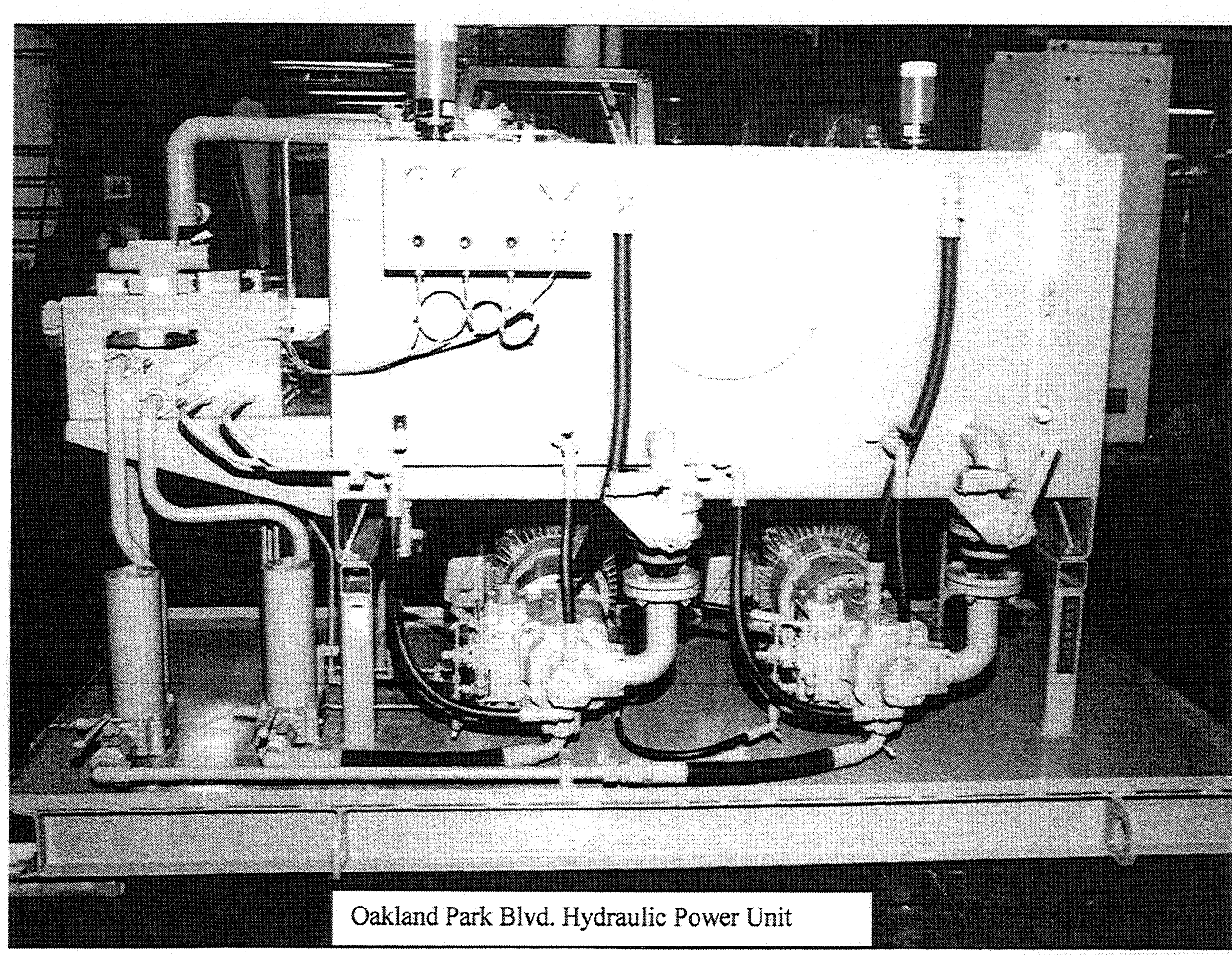
It is important to know how environmentally friendly fluids differ from the conventional anti-wear hydraulic fluids when recommending a fluid for a particular application. The limitations of environmentally friendly fluids and the differences between lubricant formulations of competing manufacturers need to be considered in order to establish fluid maintenance practices.

Hydraulic oils are formulated using primarily base oils and a small percentage of additives to enhance the properties of the base oil. The general types of environmentally friendly fluids that will be discussed in this paper are hydraulic fluids formulated with naturally occurring esters and synthetic esters. One naturally occurring ester is the oil from rapeseed. This is similar to cannola oil used in cooking but much more highly processed.

More commonly asked questions will be discussed: What are the properties of an ideal hydraulic fluid? What is biodegradability and how is it measured? What is toxicity and how is it measured? What will be the life of an environmentally friendly fluid in service? How does that service life compare to a conventional petroleum based anti-wear hydraulic fluid? What tests are used to measure the condition of the hydraulic fluids? Under what conditions, should containers of environmentally friendly fluids be stored? What is the expected shelf life of environmentally friendly fluids? Where are environmentally friendly hydraulic fluids being used successfully?

Ideal Hydraulic Fluid Properties

Possible configurations of a hydraulic system are as endless as the number of applications. Each system must consist of some prime mover such as an electric motor or diesel generator, a hydraulic pump, required valving, and the actuator such as a hydraulic cylinder or hydraulic motor. For example, in civil engineering type projects, a hydraulic power unit will supply fluid to cylinders to open bridges, regulate dam gates, or perhaps move the miter gates in a lock chamber.


Oakland Park Blvd. Hydraulic Power Unit

An often overlooked, but critical element to a hydraulic system, is the fluid which provides lubrication for the components and acts as the medium to transmit power. Since the applications and environments are diverse, a universal hydraulic fluid is not possible. However, if one is allowed to create the "ideal fluid", the following properties would surely be included:

Suitable Viscosity for System Viscosity is a fluid's resistance to flow. If the viscosity is too high power consumption would be too large and the components may even experience increased wear. If the viscosity index is too low lubrication will be decreased resulting in premature wear.
High Viscosity Index An ideal fluid would retain the same viscosity over a wide range of temperatures.
Incompressible If the fluid were 100 % resistant to volume changes with increasing pressure, there would be no "spring effect". The system would be highly responsive and control would be optimized.

Physically and Chemically Stable Fluid must retain its properties over time.
Low Volatility Fluid to resist fire.
Resistant to Oxidation Oxidation, the absorption of oxygen into fluid, will alter the fluid's chemical composition.
Good Lubricity Increases component longevity
Compatible with System Materials Some combination of seals and fluids can have dramatic repercussions. For example, a fluid may slowly wear a seal causing leaks. Or, a fluid may actually dissolve a seal both causing a leak, and then contaminating the fluid such that the components can be ruined.
Demusifying Ability Through either direct contact or just condensation, water may enter the fluid, which could then both decrease the lubrication properties of the fluid and even cause corrosion. Demusifying is the ability for water separation.
Low Foaming Tendency Foaming will expose the fluid to oxygen, thus limiting the resistance to oxidation. In addition, since air is very compressible, the system will not be very responsive.
Safe for Handling and Disposal Limits adverse effects on environment.

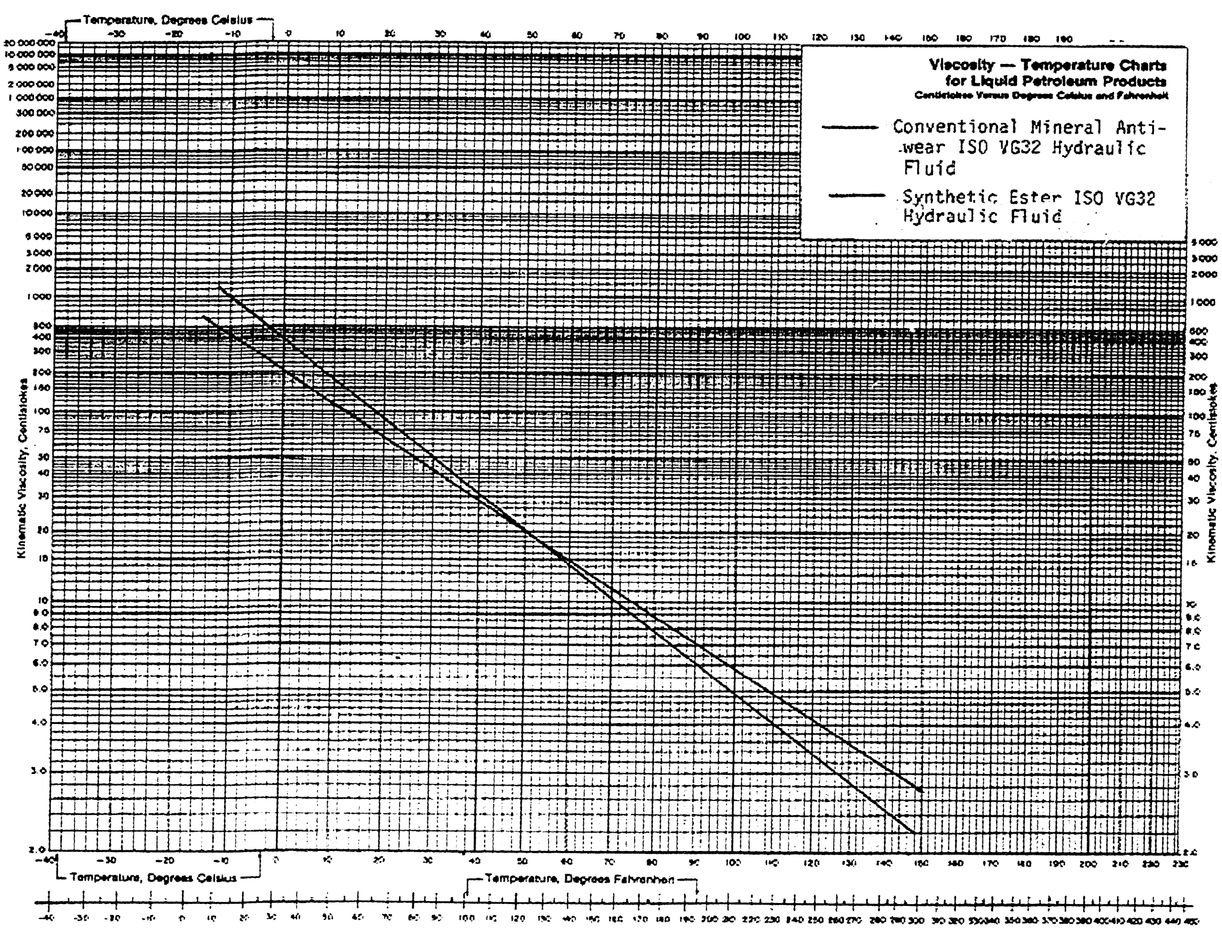
The above is simply a wish list, and in reality compromises must be made in selecting a fluid. Both the operating environment and the specific needs of the system must be considered. In a well-designed and constructed system, leaks should not occur, however accidents can happen. In many moveable bridge projects, the consequences of spills or leaks is a concern that can be addressed by selecting a fluid that readily biodegrades and is virtually non-toxic.

ENVIROMENTALLY FRIENDLY HYDRAULIC FLUIDS VERSUS CONVENTIONAL MINERAL HYDRAULIC FLUIDS

The physical properties of fluids that best illustrate the differences between environmentally friendly fluids and conventional fluids include viscosity, viscosity index

(VI), and pour point. In addition, the effects of water contamination, wear prevention, oxidation life and seal compatibility will vary from conventional fluids.

The single most important characteristic of a lubricant is its viscosity. Viscosity simply defined is resistance to flow at a specific temperature. The viscosity of the lubricant keeps the metal parts separated. Too low a viscosity will result in metal to metal contact between mating parts. Too high a viscosity will result in the excessive generation of heat. Typically, lubricant manufacturers provide ISO (International Standards Organization) Viscosity Grades for the lubricants they manufacture at two temperatures 40°C and 100°C. These values are kinematic viscosity measured in Centistokes which is abbreviated cSt. Often a hydraulic fluid's viscosity at 40°C is identified in its name, such as Hydraulic Oil 32. The typical ISO Viscosity Grades (ISO VG) at 40°C for hydraulic fluids are 15 cSt, 22 cSt, 32 cSt, 46 cSt, and 68 cSt. Pump manufactures specify the hydraulic fluids maximum start up viscosity and an ***ISO VG range at the operating temperature*** for the pumps they manufacture, such as 13 cSt to 36 cSt. Using ASTM (American Society for Testing Materials) "Viscosity Temperature Charts for Liquid Petroleum Products" the viscosity at any given temperature can be determined by knowing the viscosity of the lubricant at 40°C and 100°C since there is a linear relationship between temperature on semi-log graph paper.



The **viscosity index (VI)** measures the change of viscosity with temperature. The higher the number the less the viscosity of the lubricant will change with temperature. Typically, for conventional industrial mineral hydraulic oils the numbers are in the plus or minus 95 range. Mobile hydraulic oils, which operate with large swings of ambient temperatures usually, have an additive called viscosity index improvers. Typically, these oils have a VI in the plus or minus 140 range. Naturally occurring esters and synthetic esters typically have a VI of plus or minus 200 and 150 respectively.

The **pour point** of a lubricant is the lowest temperature at which a lubricant will flow when left undisturbed.

Table 2: Relative Pour Points of Hydraulic Fluids

Typical Pour Points	
Conventional Industrial Mineral Hydraulic Fluid	0°F
Mobile VI Improved Hydraulic Fluid	-45°F
Naturally Occurring Ester	-25°F
Synthetic Ester	-45°F

Systems must operate at temperatures significantly above the pour point.

Water in a hydraulic system can create many problems. One of the most obvious is the rusting of metal parts. The viscosity of the fluid will also be reduced and additives can be removed. Water is also a major component of the oxidation process where oils break down into acids resulting in oil thickening, varnish deposits and sludge. Hydraulic reservoirs are designed to provide a residence time so that water and air can separate from the fluid. With conventional mineral based hydraulic fluids this method is usually sufficient. Assistance may be required from a vacuum dehydrator or centrifuge if there is a large ingression of water. With naturally occurring ester and synthetic esters, we face an additional problem. These lubricants are hygroscopic, that is, they have the property of absorbing or attracting moisture. This can result in hydrolysis, which is a reaction with the water to form acids.

One of the commonly used tests which measure a lubricants ability to help prevent wear is the FZG test. The scale is 1 to 12 plus. The higher the number the better the wear protection of the lubricant. The test apparatus consists of two special designed gears to promote maximum sliding. This simulates the opportunity for scuffing or adhesive wear. Conventional hydraulic oils require the addition of zinc to provide typically an FZG number of 10 or greater. Naturally occurring ester and synthetic esters have an FZG number of 12 without the addition of zinc.

The oxidation life of fluids is often measured using the TOST (Turbine Oil Stability Test) ASTM D 943 " Standard Test Method for Oxidation Characteristics of Inhibited Mineral Oils." This test method evaluates the oxidation stability in the presence of oxygen, water, copper and iron at elevated temperatures. The test measures the time needed (hours) for the total acid number (TAN) to reach 2.0. TAN is the number of milligrams of potassium hydroxide to neutralize one gram of the lubricant. Typically, premium conventional anti-wear hydraulic fluids obtain 1,500 hours or better in this test. The TOST life of naturally occurring esters is relatively short compared to premium conventional anti-wear hydraulic fluids. However, environmentally friendly fluids comprised of synthetic esters offer better results than the naturally occurring counterparts.

In a hydraulic system for bridges, it is important to determine if there is any incompatibility between the hydraulic fluid and elastomer seals. These issues should be reviewed with the seal supplier and the lubricant supplier. Incompatibility can result in leaks and even contaminated oil, which can damage the components or clog orifices. As a rule of thumb, naturally occurring esters and synthetic esters are usually compatible with the same seal material used in mineral oil systems, such as Buna N (low to medium nitrile levels) and Viton®.

Biodegradability And Toxicity

In order to be an environmentally friendly lubricant, a lubricant needs to breakdown quickly to elements and be virtually non-toxic. There are a number of different methods used by worldwide to measure the biodegradability of a lubricant and its toxicity. Unfortunately, the results are not always consistent among the various test methods.

All lubricants eventually biodegrade, however some much faster than others do. During biodegradation, bacteria reduces the fluid to water and carbon dioxide. Therefore the biodegradability can be measured by the bi-products of water, carbon dioxide and heat, the reduction in mass of the substance, or the increase in bacteria. The ASTM, American Society for Testing Materials, defines biodegradation as " the process of chemical breakdown or transformation of material caused by organisms or their enzymes." Table 1, "Relative Biodegradability of Lubricant Base Oils" shows typically the relative rate of biodegradability for base oils used in the manufacture of lubricants. All hydrocarbon-based lubricants will ultimately breakdown to carbon dioxide and water with the release of heat.

Table 1: Relative Biodegradability of Lubricant Base Oils

Most Degradable			Least Degradable
Vegetable Oils	Synthetic Esters	Petroleum Mineral Oils	Polyalphaolefins, PAO (synthetic hydrocarbons)

Primary biodegradation testing is used in Europe to measure biodegradation while in the United States *ultimate biodegradation testing* is used.

In Europe, the CEC (Coordinating European Council) method, CEC L-33-A-93, measures the primary biodegradation of a lubricant by measuring the percent disappearance of the lubricant's methylene carbon-hydrogen bands in the infrared (IR) spectrum after 21 days. The higher the percentage the greater the degree of primary degradation. Percentages of 90 or above, indicating that no methylene carbon-hydrogen bands exist, were believed that the lubricant were biodegraded. However, tests by two major oil companies and others determined that in some of the tests the lubricants were not completely broken down all the way to carbon dioxide. As a result, in the US, ultimate biodegradation testing is preferred.

Ultimate biodegradation testing measures the consumption of oxygen and the formation of carbon dioxide during a 28 day test. This is only one of many test methods in use. However, each are based on the same principles; the consumption of oxygen and release of carbon dioxide. The US EPA, Environmental Protection Agency defines one of those methods, namely EPA 560/6-82-003, CG-2000, Aerobic Aquatic Biodegradation Test (US EPA Shake Flask Test). Another method is the OECD, Organization for Economic Development, 301B (Modified Strum) Test. Values of 60 percent are typically required for carbon dioxide release and 70 percent for oxygen uptake in the OECD ultimate biodegradability test.

HANDLING AND STORAGE

To obtain the maximum shelf for lubricants, it is necessary to store the lubricants under the proper conditions. Lubricants require a sheltered environment with good housekeeping (clean), and temperatures from 40°F to 90°F. The shelf life of a lubricant should be obtained from the lubricant manufacturer. As a rule of thumb, conventional mineral oils stored under proper conditions may have a shelf life up to 10 years. For naturally occurring esters the typical shelf life is two years.

Since naturally occurring esters and synthetic esters are hygroscopic, one must ensure that containers are sealed after use. Ideally, container sizes should be matched to reservoir requirements to avoid partially filled containers that are more susceptible to water and moisture contamination.

Although environmentally friendly lubricants are much less adverse to the environment, it is necessary to be in compliance with federal, state and local regulatory agencies when a spill or disposal is required. These fluids do biodegrade, however anytime a large quantity of a foreign substance is introduced to an ecosystem, there can be repercussions.

Examples of Applications

In the United States there are many projects in operation which use a naturally occurring ester. In order for this type of fluid to be successful, it must both be a suitable location, and be subjected to good maintenance practices. All hydraulic fluids must be periodically monitored to confirm that neither contamination or degradation has occurred. For best results, fluid samples should be sent to the laboratories for analysis. These naturally occurring esters have a normal "optimum" life expectancy of approximately 2000 hours or one year, which ever occurs first. As discussed above, these fluids tend to be more sensitive to oxidation and water contamination. Therefore, to help extend the useable life, all filters should be changed as needed, and a desiccant type breather should be used. For the best results, the system should be designed to include a "sealed" reservoir. This uses a "lung" type breather which eliminates the introduction of outside air. If this fluid is not properly maintained, seals can loose their effectiveness, therefore causing leaks.

Sample installations using Naturally Occurring Esters:

Olmsted Prototype Project – Olmsted, KY.

Brickell Avenue Bridge - Miami, FL.

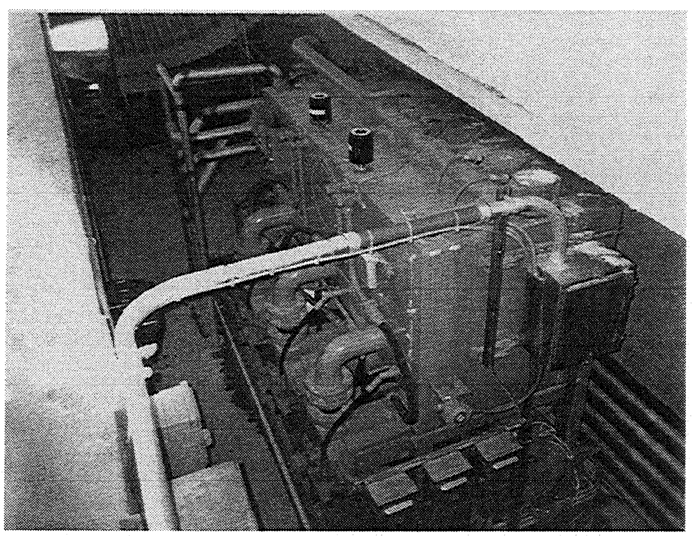
SR 693 – Corey Causeway - Pinellas County, FL.

SR 706 Bridge - Intercoastal Waterway, FL.

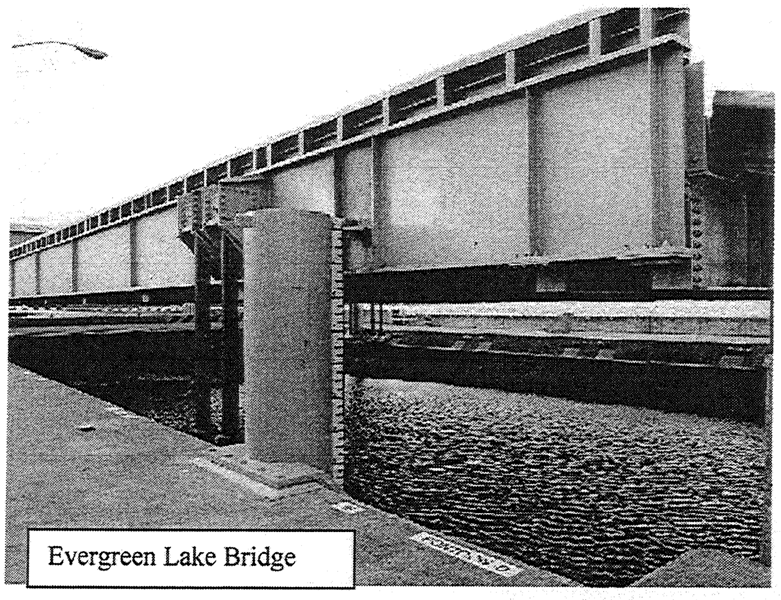
Oakland Park Blvd. Bridge-SR 816 - Fort Lauderdale, FL.

Venetian Causeway - Miami, FL.

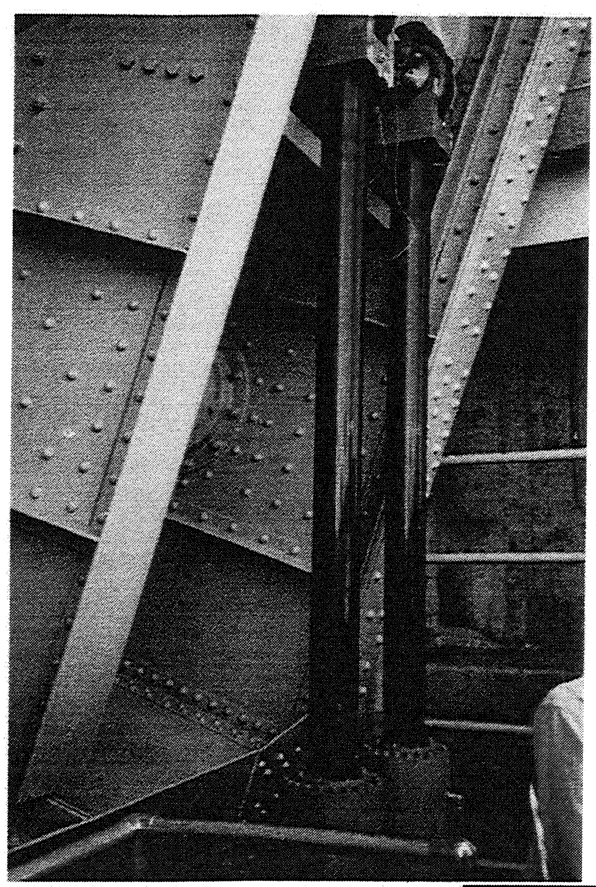
Donald Ross Road Bridge - Palm Beach County, FL.

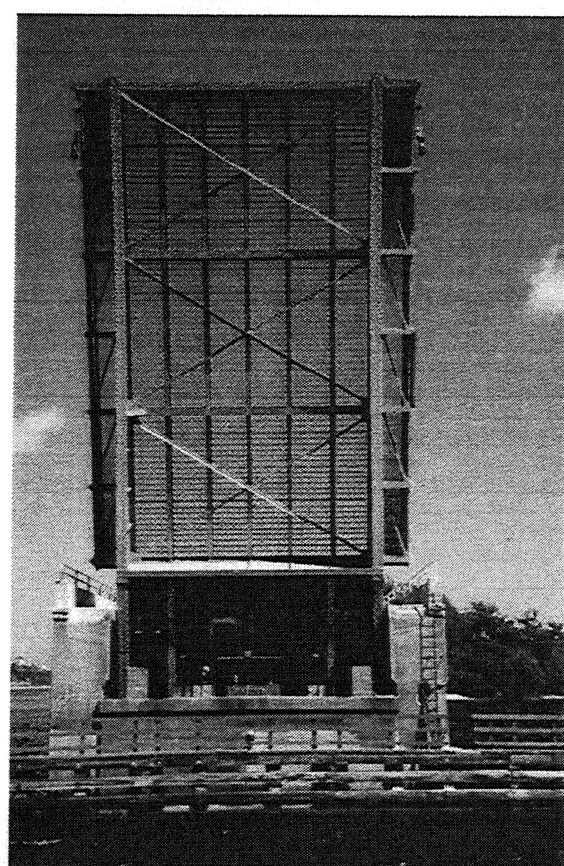


Hydraulic Power Unit for Donald Ross Bridge



Evergreen Lake Bridge





Brickell Avenue Bridge

Synthetic versions of these fluids, although are initially more expensive, often offer a better overall value. These fluids tend to be available in a large variety of viscosity grades that improve performance at lower temperatures and alleviate the need to oversize components for "cold starts". In addition, these fluids are more resistant to oxidation and water contamination which increases longevity. Many systems are successfully operatig with these fluids in Europe with temperatures as low as – 15°F (25° C).
Sample of installations using Polyglycol

Sample of installations using Esters

Installations with Polyglycol

Lock Steinbach	WMA – Nürnberg / WSA – Schweinfurt
Lock Harrbach	WMA – Nürnberg / WSA – Schweinfurt
Lock Viereth	WMA – Nürnberg / WSA – Schweinfurt
Lock Gruesgeun	WMA – Nürnberg / WSA – Aschaffenburg
Lock Offenbach	WMA – Nürnberg / WSA – Aschaffenburg
Lock Neckargemünd	WMA – Koblenz / WSA – Heidelberg
Lock Neckarsteinach	WMA – Koblenz / WSA – Heidelberg
Lock Guttenbach	WMA – Koblenz / WSA - Heidelberg
Lock Neckarzimmern	WMA – Koblenz / WSA – Heidelberg
Lock Hirschhorn	WMA – Koblenz / WSA – Heidelberg
Lock Pleidelsheim	WMA – Koblenz / WSA – Heidelberg
Lock Gundelsheim	WMA – Koblenz / WSA – Heidelberg
Lock Hofen	WMA – Koblenz / WSA – Stuttgart
Lock Horkheim	WMA – Koblenz / WSA – Stuttgart

Sample of Installations using Esters

Lock Detzem	WMA – Koblenz / WSA – Trier
Lock Trier	WMA – Koblenz / WSA – Trier
Lock Wintrich	WMA – Koblenz / WSA – Trier
Lock Koblenz	WMA – Koblenz / WSA – Koblenz
Lock Lehmen	WMA – Koblenz / WSA – Koblenz
Lock Heidelberg	WMA – Heidelberg
Lock Raffelberg	NBA – Dattein
Lock Rothensee	NBA – Magdeburg

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