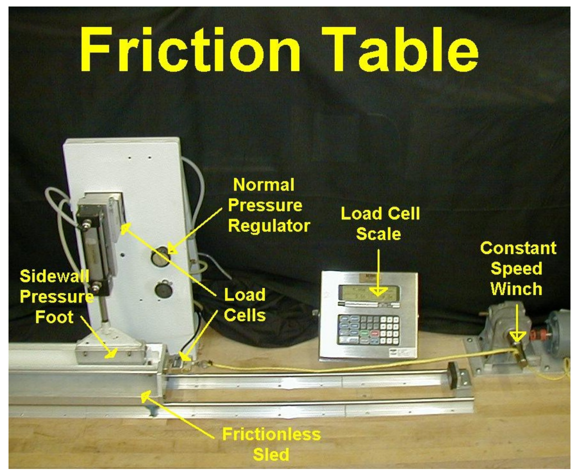
American Polywater's
Technical Talk
A Publication for Engineers Involved in Cable Installations

White Paper

Coefficient of Friction Measurement On Polywater's Friction Table

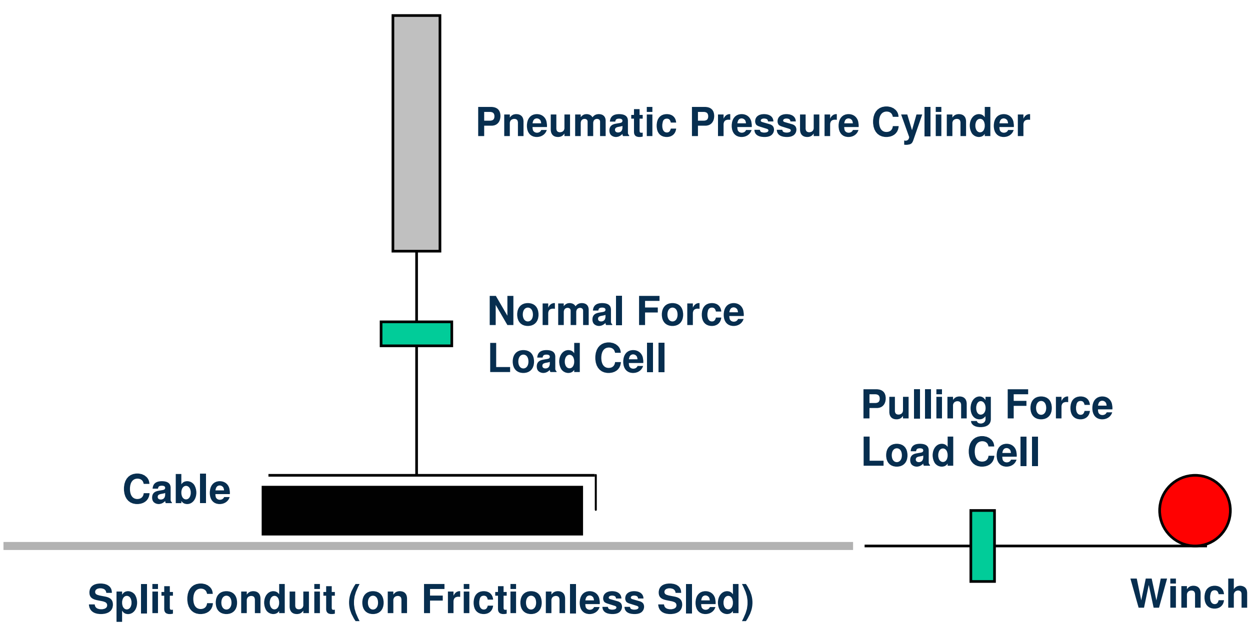
Polywater maintains a leadership position in cable pulling lubricants by focusing on a lubricant's primary function; the reduction of pulling tension and sidewall pressure through reduced friction. Lubricant "friction" is measured as a "coefficient of friction (COF)" or "friction coefficient". The COF is a dimensionless constant that can be used to estimate cable pulling tension. Accurate friction coefficients are best measured using real cables, conduits, and lubricants.

Several methods are used at Polywater to measure friction. One of the fastest and most convenient is called the Friction Table. Thousands of friction coefficients for all types of cable, conduit, and lubricants have been measured on the Friction Table. Most of Polywater's pulling lubricants were optimized using this device. The Friction Table is the primary source for the friction database in the Pull-Planner™ 2000 and 3000 (beta) Tension Calculation Software.



How the Friction Table Works

The basic Friction Table is diagrammed below:



To make a measurement, a section of cable, typically 6 inches (152 mm), is placed on the split conduit. If the test is “lubricated”, the cable and conduit are coated with a thin film of the lubricant. While any type of cable and conduit can be used, the cable must be rigid enough to allow the conduit to slide without the cable bending back on itself.

A pneumatic pressure cylinder pushes down on the cable and this “normal” force is measured with a load cell. A small winch pulls the conduit, and that force is measured with a second load cell. Note that the conduit is pulled under the cable. This makes no difference in friction determination, and enables data to be gathered with a relatively small piece of cable.

The coefficient of friction is calculated using the equation:

$$\mu = F/N$$

Where:

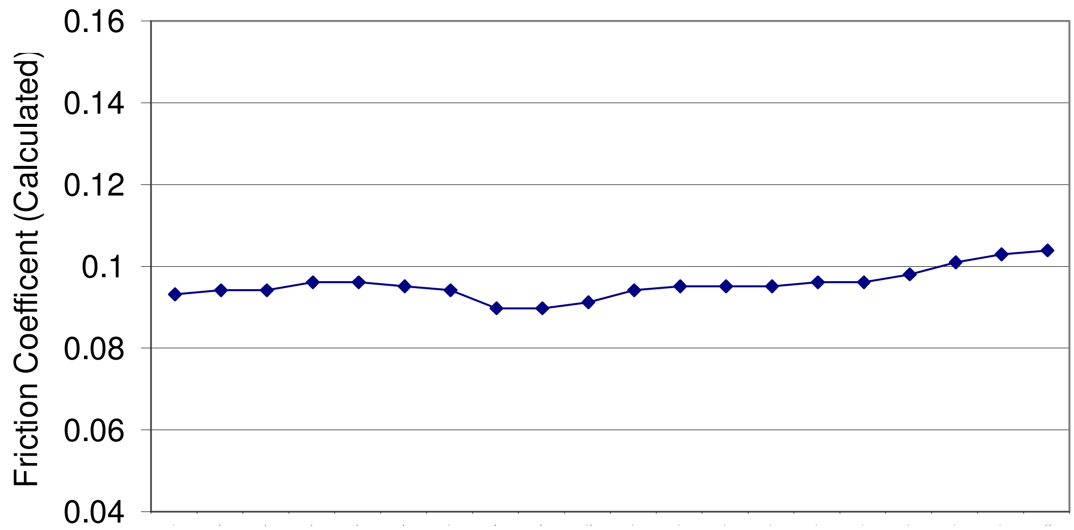
μ is the coefficient of friction
F is the measured pulling force
N is the measured normal force

Note that normal force also includes the weight of the cable. While this is often small compared to the measured applied force, it is added when significant.

The normal and pulling forces are typically measured every 0.1 second and are recorded by a PC for calculation and analysis. Most frequently, the “average” friction coefficient over the data points is determined and used.

Actual data from a single “pull” on the Friction Table device is shown below.

XLPE Jacket / PVC Conduit / Polywater® J
20 Data Points at 0.1 Second Readings



Averages
Normal Force: 110.70 Pulling Force: 10.59 COF: 0.096
Standard Deviation
Normal Force: 0.90 Pulling Force: 0.35 COF: 0.004

Statistical Analysis

While the COF data variance in the single pull above is low, this is not always the case. For instance, "non-lubricated" jackets can pull with significant variation (slip/stick).

A typical data point is the average of 3 consecutive pulls. The variance pull to pull, while higher than in a single pull, still tends to be relatively low.

However, a third source of variation can be more significant. This is the variation measured when multiple cable jackets in the same "generic" class are tested. For instance, PVC jackets vary significantly in formulation and demonstrate more variance in friction when all PVC jackets are averaged. Similarly, steel conduit, especially EMT (electro metallic tubing), shows considerable variance presumably from interior coating differences.

It is important to realize that most Friction Table data are "averages", and variance should be considered when the data are used.

Kinetic Versus Static Friction

The Friction Table is set up to measure kinetic or moving friction. The discrete data sampling of the PC prohibits a determination of static friction. Regardless, kinetic friction results are the most useful and have provided the best correlation with measured tension in field cable pulls.

Limitations of the Friction Table

While the Friction Table device has provided enormous insight on the variables affecting friction and tension, there are some limitations in what can be tested on the device.

1. The friction table represents a well-lubricated condition. Things like lubricant carrying properties cannot be measured on the machine.
2. While certain conditions (pulling through water-filled duct, etc) can be studied through repetitive pulls and comparative friction measurement, this is very cumbersome, and the results questionable.
3. Small, flexible cables "bunch" and do not give good results on the device.
4. The device only works with single cable, so variables like cable configuration or multi-size cables cannot be studied.
5. While the device can be run in various ambient conditions, its use in hot or cold rooms is not practical, so the data represent typical laboratory temperatures of 68° F to 72° F (20° C to 22° C)
6. While the normal pressure on the Friction Table can be adjusted, a great majority of the historical data has been taken with a normal pressure in the range of 100 lbs (445 N). While friction variation with normal pressure can be studied on the device, the use of low normal pressures raises the measurement variance significantly. So, normal pressure effects on friction have been studied via other methods.

General Results from the Friction Table

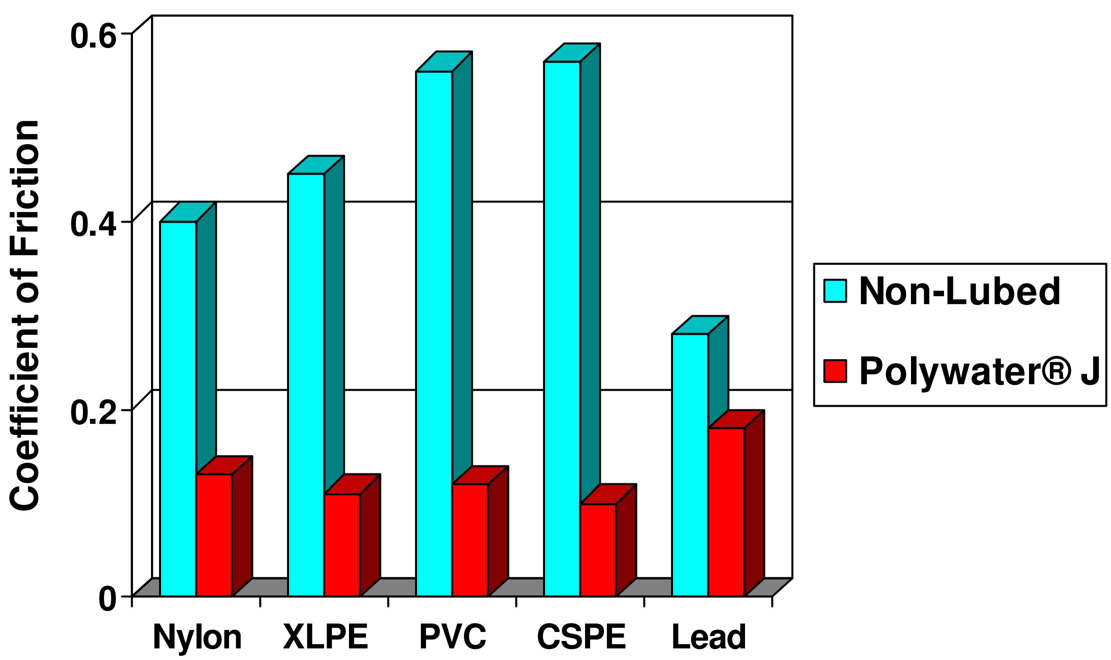
Analysis and presentation of all the data gathered from the Friction Table is beyond the scope of this paper. However, some generalized findings are highlighted below.

Cable Jacket Effects

Graph 1 shows average friction coefficients for various jackets in PVC conduit, both lubricated and not lubricated.

Interestingly, the exposed lead jacket had the lowest non-lubricated friction, but when lubricated, it shows the highest friction. The data shows the importance of high-performance lubricants with the switch to plastic jacketed underground cables. While the non-lubricated friction of the plastics is high, the lower COF's possible with Polywater® Lubricant indicate the longer and lower-tension pulls that are possible.

Note that non-lubricated friction and lubricated friction vary by jacket. While the high-performance lubricant Polywater® J is an equalizer, there is still a range in lubricated friction (0.10 to 0.18) among these jackets.

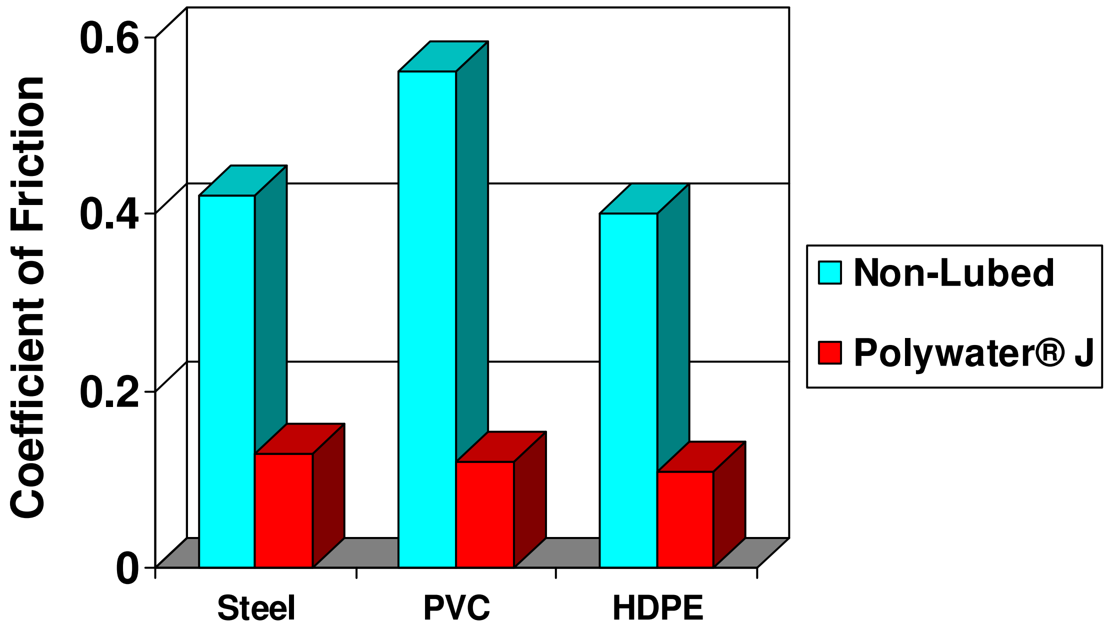


Graph 1

Conduit Effects

Graph 2 shows average friction coefficients for PVC jacket in several types of conduit, again both lubricated and non-lubricated.

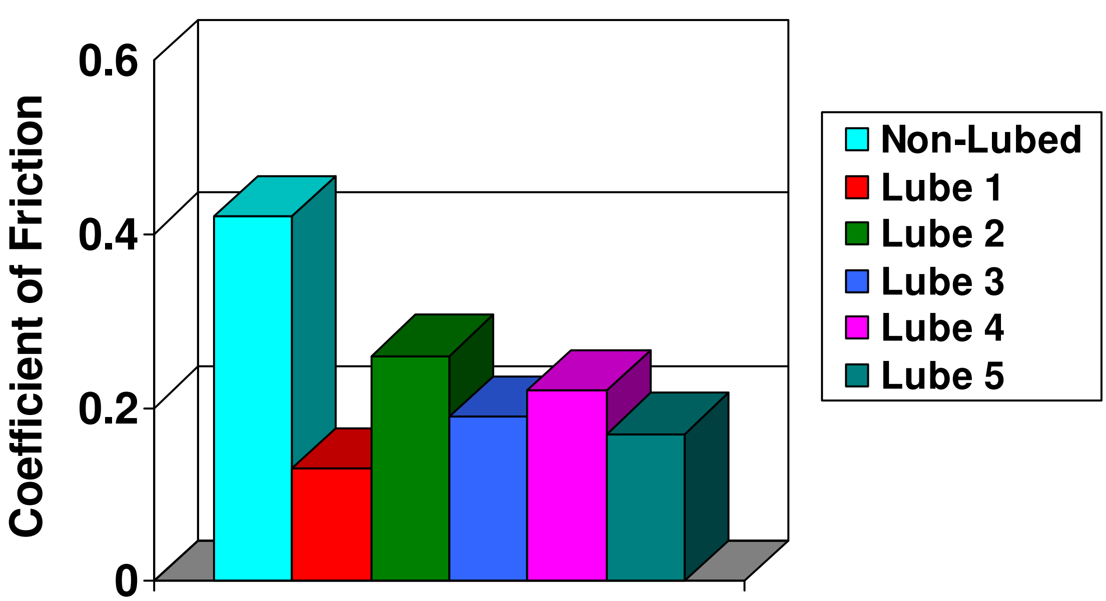
As expected, non-lubricated friction is several times higher than lubricated. Also note that there is a difference in lubricated friction based on conduit type (in this case - 0.11 to 0.13).



Graph 2

Lubricant Effects

Graph 3 shows average friction coefficients for PVC jacket in rigid steel conduit with 5 different commercially available pulling lubricants. While all the lubricants reduce friction (0.11 to 0.23), some are notably more efficient with this jacket and conduit combination.



Graph #3

Summary

The Friction Table offers a convenient and effective way to measure friction. Much has been learned on the device, including the extended pulling distances and lower tensions possible with Polywater® pulling lubricants. Friction Table data can help plan and optimize cable installation in conduit.

Topic Related Links

Pull-Planner Software Literature

Polywater Home Page Link