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OPTIMAL LUBRICANT QUANTITY IN CABLE PULLING

Survey a number of field crews with experience in pulling heavy electrical cable into conduit . . . and ask how much lubricant they would use on a hypothetical 500-foot pull into 4″ conduit. You might be surprised at the significant variation in answers you'd receive. The quantity estimated could vary by as much as a factor of 10!

Is there an optimal amount of lubricant for a given pull . . enough to do the job, but not waste lube by using excess? Is it possible to use too much lubricant? If there is an optimal amount, how do we determine it, and what factors influence the determination?

Film Thickness Calculations

One theoretical, but easy-to-understand way to estimate lubricant quantity is a "film thickness" approach. For instance, if a 10-mil (0.010”) film of Polywater® J provides good friction reduction, we can calculate the quantity of lubricant it takes for such a 10-mil film (or any other film thickness) to completely cover a cable's jacket or a conduit's interior wall.

The equation is:

$$Q = l \times D \times \pi \times t \times 0.052 \qquad \text{(Equation 1)}$$

Where:

Q = quantity in gallons
l = length of conduit in feet
D = OD of cable *or* ID of conduit in inches
t = desired film thickness (in inches)
0.052 = conversion factor (from $in.^2 \bullet ft.$ to gals.)

Solving this equation for a 10-mil film thickness, a 500-foot length pull, and various conduit/cable sizes gives the following:

Conduit ID or (Total) Cable(s) OD	Gallons of Polywater ® J
2.0"	1.6
3.0"	2.4
4.0"	3.2
5.0"	4.1

Field Reality

While these calculations are theoretical, they do bring us to a realistic result. Based on experience, typical field lubricant usage on a *routine* 500-foot pull in 4″ conduit is in the 2-to-5-gallon range. Working from either the nominal 4″ ID of the conduit, or the *total* OD of cables that might be installed in such a conduit [could vary from 2+ inches (single) to 4+ inches (triplex)], we see basic agreement between the calculation and field practice. Looking at it another way, typical practice today is to put an average film thickness of 10 to 15 mils of lubricant on the conduit interior (or cable exterior).

Basis for Recommendations

If you are familiar with American Polywater's applications literature, you may recognize our published recommendation on lubricant amount comes from Equation 1, which is further simplified to:

$$Q = 0.0015 \times l \times D$$
(Equation 2)

This recommendation has served end-users well, whether estimating how much lubricant to use for a routine pull or how much to purchase for a large job with many pulls. Recent gamesmanship by other lubricant manufacturers attempting to "cost justify" high cost lubes, by modifying the equation, are misdirected when one knows how the equation was developed, as well as the realities of field application, where lubricant use is not often measured. The equation is a helpful theoretical calculation--no more and no less.

Lab Research Enlightening

A logical area for applications research is the film thickness *needed* for effective lubrication; or, put another way, how does the coefficient of friction vary with lubricant film thickness?

American Polywater has done such research using a "multiple-bend duct" technique to determine friction. In this test, a back-load is put on a cable that has been threaded thru six consecutive 90° conduit bends. The force required to pull the threaded cable is measured. From this pulling force, the coefficient of friction (COF) can be calculated using the following modified pulling equation:

$$COF = 1/3\pi \times \ln(\text{Pulling tension}/\text{Back tension}) \qquad \text{(Equation 3)}$$

Obviously, the "multiple-bend technique" can be used to measure and study numerous pulling parameters. Results of other studies will be covered in future issues of "Technical Talk."

When the "multiple-bend duct" was used for lubricant quantity studies, a measured amount (weight or volume) of lubricant was carefully and evenly applied to the test cable as it was threaded. A series of pulls was made using differing amounts of applied lubricant. The pulling tension was measured and the coefficient of friction calculated. Since the lubricant was spread evenly on the cable, a film thickness was also calculated based on the amount of lubricant, the cable OD, and the conduit length.

Results from this test are presented below. The cable used had a rubber jacket (type RHH), the conduit was PVC, the back tension was 120 lbs. (sidewall pressures in the 100 to 500 lbs./ft. range), and the lubricant was Polywater® J.

Grams of Polywater® J on Cable	Average Film Thickness (calculation)	Measured COF
None	None	> .7
3 gms.	0.0006"	.11
10 gms.	0.002"	.11
50 gms.	0.010"	.11
198 gms	0.038"	.11
350 gms.	0.068"	.11

The results are surprising . . .with the Polywater® J Lubricant . . .a film thickness of 1/2 mil has the same coefficient of friction as a 10-mil or a 70-mil film!! Does this mean that we should use 1/10 of the quantity of lubricant recommended in Equation 2?? No . . .because an effective quantity of lubricant is governed by what's needed to get lubricant to all points of cable rub . . .rather than how much must be there . . .but we'll get to that later.

How Low Can You Go?

An obvious question based on the test results above is: What will happen with .1 mil, .01 mil, etc.? . . .sooner of later logic tells us that the coefficient of friction must rise towards the unlubricated value (greater than .7). Unfortunately, one cannot practically apply quantities of lubricant of under 1/2 mil to a cable . . .because the lubricant can't be rubbed on any thinner . . .so this test can't answer that question.

There is another important factor to consider when evaluating this data. The lubricant was Polywater® J, which has extraordinary friction reduction under high shear conditions. Other types of pulling compounds can behave quite differently, so test results for Polywater® J *should not be generalized* to all pulling lubricants.

Field Experience

Field experience precludes the use of very small quantities of lubricant for difficult pulls. There are a number of documented situations where the use of ~~too little~~ lubricant resulted in high tensions, with lots of resulting problems.

We are not familiar with any situations where "liberal" lubrication caused problems. So there is no indication that the use of large quantities of lubricant causes any practical pulling problems (other than the possible mess).

The lab research indicates that we only need to get a thin film of Polywater® J at all points of cable/conduit rub for optimal friction reduction. However, the amount of lubricant needed to get such a film is dependent not on the mathematics of coating thickness, but the dynamics of a cable "carrying" lubricant through continuous rubbing over hundreds of feet of conduit.

The "carry" of a lubricant through a conduit depends on the total run length, the number of bends and resultant shear, the absorptivity of the conduit, the presence of dirt or sand, and the nature of the lubricant itself. The field craftspeople handle these variables in a simple, but effective, way . . .for the "tough" pull, they "really lube the cable, . . .put on as much as they can, . . . etc."

Lubricant Properties and Application Methods

Certain properties of a lubricant play a major part in its ability to carry through conduit and continue to lubricate. The most important of these properties are the lubricant's viscoelastic nature and drying behavior . . .that is . . .how well does it adhere to the cable. . .does it flow off, drop off, or rub off . . .does a thin film maintain a low friction coefficient after drying for 10 minutes or 20 minutes? The engineering of these characteristics into Polywater® J results in its superior field performance . . .as well as . . its somewhat limited aesthetics. The stringiness of Polywater® Lubricant J provides the advantage that once you get it on the cable; it will cling and be pulled far into the conduit.

Sound application methods are also important to insure that lubricant in sufficient quantity gets to all points of rub. While space does not permit an extensive review of application methods here . . .a brief look will demonstrate some of Polywater's unique concepts. Polywater® Front End Packs™ preload the conduit . . .to get lubricant far *into* the pull, so the cable front is lubricated throughout the run. Polywater's lubricant pumps and applicator heads completely coat cable jacket with lubricant. This not only lowers cable-to-conduit friction, but also cable-to-cable friction in multiplex pulls.

Summary

We believe the final determination of appropriate quantity of pulling lubricant should be left to the field, and should be based on the difficulty of the pull. The formula

$$Q = 0.0015 \times l \times D$$

is a good starting estimate on quantity. Engineers should consider recommending conduit prelubrication and Front End Pack™ use for long or especially difficult installations.

If you would like more detailed information on American Polywater® application recommendations, please call our Customer Service Department toll free at 1-800-328-9384. We'd be happy to send you application literature.

Comments, questions, or editorial requests, please contact:

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