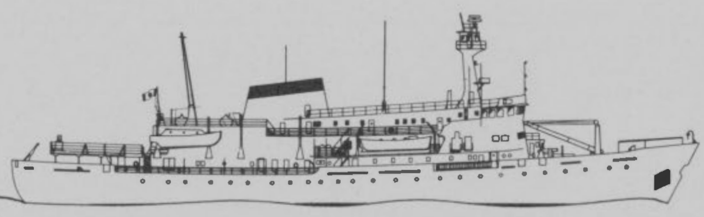
Energy, Mines and Resources
Energie, Mines et Ressources

# BEDFORD INSTITUTE OF OCEANOGRAPHY
# INSTITUT OCÉANOGRAPHIQUE DE BEDFORD

[redacted]



Canada

WIRE PROTECTION PROGRAM
BROOKE OCEAN TECHNOLOGY LTD.
UNDER CONTRACT TO:
THE ATLANTIC GEOSCIENCE CENTRE
PROGRAM SUPPORT SUBDIVISION
BEDFORD INSTITUTE OF OCEANOGRAPHY
DARTMOUTH, N.S.
JULY 1985

ABSTRACT

The Wire Protection Program was implemented to improve oceanographic cable maintenance procedures at the Bedford Institute of Oceanography. These maintenance procedures can be easily justified when one realizes the losses of equipment and data which can occur in the event of rope failure.

Three phases have been carried out to date:

Part 1 Criteria For Lubricant Selection

Part 2 Testing of Lubrication Equipment

Part 3 Lubricant Analysis

The first phase involves the identification of wire rope lubricants suitable for testing, and determines through a literature review and correspondence with users what properties are required to produce a good field dressing. In Part 2, lubrication equipment was tested, and in Part 3, tests were carried out in the lab and in the field which compared lubricant properties and formed the basis for a conclusion.

# PART 1

# CRITERIA FOR LUBRICANT SELECTION

INDEX

## 1.0. INTRODUCTION.

The Atlantic Geoscience Centre, Bedford Institute of Oceanography possesses many long lengths of wire rope used primarily for towing and lowering oceanographic instrumentation. When either in use or in storage this rope is subject to an extremely corrosive enviroment while often being stressed at high tension loads. Unless a wire rope is properly maintained, substantially decreased rope life will result, which is an important consideration because replacement costs are very high.

On behalf of A.G.C., Brooke Ocean Technology Ltd. will be establishing a Wire Protection Program for use at the Institute. The first part of this program deals with re-lubrication and cleaning of the wire to protect against mechanical wear and corrosion. A second part involves utilization of non-destructive testing (N.D.T.) techniques to establish wire rope retirement criteria.

This report reviews the selection of lubricant to be used as field dressing on wire rope. Because of the adverse conditions involved in its use, this lubricant must have exceptional qualities.Some of these include protection against abrasion and corrosion, water-washout resistance, and an "anti-drip" capability, which is especially important to those working at sea where spilled lubricant could lead to serious injury.

The decision of what lubricant to select cannot be made on the basis of recommendations and collected literature alone. Testing must be done to compare some of the more important properties that are related to the specific needs of the wire rope, and the results combined with other evidence before selecting a suitable field dressing.

A list of references has been included; however, only a few of these are referred to in the text. All of the references were useful in assessing and compiling information for this report. Also included is a list of defined terms, some of which may be familiar.

## 2.0. CORROSION AND ITS EFFECTS.

Perhaps the most important single factor influencing wire rope life is the effect of salt water on the rope. The high ion content of salt water makes it an excellent electrolyte in which the corrosion process can occur.

The word corrosion comes from the Latin work "corrodo", which means gnaws into pieces. Corrosion occurs when a difference in electrical potential results in a flow of ions from the negatively charged area, called the anode, to the positively charged region (cathode). This process, of course, must occur in some sort of electrolyte situation; in this case, seawater. Corrosion and the resulting deterioration occurs at the anode.

The majority of the wire rope to be maintained under the Wire Protection Program is improved plough steel (I.P.S.), with each individual wire galvanized with a thin zinc coating. Seawater contains soluble salts which can be very corrosive to zinc. However, magnesium and calcium ions form a layer of magnesium and calcium salts on the zinc, protecting it greatly against further corrosion.

When not used to tow or lower instrumentation, the wire rope will be stored for relatively long periods of time either on ship or at B.I.O. For each condition, the rope will be exposed to a combination of salt spray and the atmosphere. Zinc is very stable in dry air; a protective layer of zinc oxide forms which almost totally discourages corrosion. However, salt spray can increase the corrosion rate because of the formation of 1) zinc chlorides, and 2) zinc hydroxides, which then converted into a form of zinc carbonate by carbon dioxide. In these wet conditions the corrosive product is known as "white rust"; to prevent "white rust" from forming it is advisable to store the rope in a dry, ventilated area, at least until a protective layer has formed.

Industrial atmospheres can accelerate zinc corrosion where moisture contaminated with acids such as sulphur dioxide can attack the protective coatings. It is not known if pollution in the Halifax area would be severe enough to have an effect on B.I.O.'s wire rope.

Corrosion of wire rope can be divided into three types by area: (Ref: 1,2 & 3).

## 2.1. SPLASH ZONE CORROSION.

This is a combination of corrosion due to immersions in sea water, exposure to salt spray,and exposure to the atmosphere. Dynamic conditions and the abundance of oxygen can make this region the most corrosive of enviroments.

## 2.2. MARINE ATMOSPHERE CORROSION.

This type of corrosion is not as destructive as splash zone corrosion, but as mentioned previously is important to consider since wire rope is stored on ship or near the shore for long periods of time.

2.3. WIRE IMMERSION CORROSION.

Severe corrosion can occur to some ropes which are immersed in seawater for long periods of time; however, the ropes covered under this study are in the water for short periods of time only, so the effects of wire immersion corrosion in the long term need not be considered.

Wire rope in use is subjected to constant bending, stress, and abrasive wear which can be accelerated by insufficient lubrication. These conditions can give rise to several kinds of corrosion:

2.3.1. CREVICE CORROSION: Crevices are found in the contact of any two pieces of material, and a limited supply of electrolyte to this area results in the formation of a concentration cell, which gives rise to a difference in potential between the crevice and the rest of the rope. This difference in potential leads to a corrosive process; however, because galvanized steel relies on sacrificial protection, they are not as susceptible as other wire ropes to crevice corrosion.

2.3.2. CORROSION FATIGUE: This phenomena occurs under simultaneous exposure to corrosion and fatigue stress, such as cyclic bending around a sheave.

2.3.3. STRESS CORROSION CRACKING: This type of corrosion is basically the same as corrosion fatigue except that the wire rope is subjected to axial stresses.

2.3.4. FRETTING CORROSION: Fretting is caused by the abrasive action of two surfaces slipping or sliding over one another, resulting in fine surface cracks, some of which can propogate into fatigue cracks. The results of fretting leave the metallic surface susceptible to corrosion.

The galvanized zinc coating covering wire ropes that this study is concerned with is superior to unprotected steel in that 1) zinc can reduce internal friction in the individual wire, and 2) zinc is a better corrosion inhibitor than steel. In fact, the corrosion rate of zinc in marine enviroments is only a fraction that of steel. In addition, if the zinc coating is pierced, exposing the steel, the zinc acts as a sacrificial anode, protecting the steel from corrosion.

Although zinc is superior to steel as a corrosion inhibitor it does have its weaknesses. The corrosion of zinc galvanizing increases with water flow, as it does in seawater in the absence of oxygen, such as in very deep water.

## 3.0. PURPOSE OF LUBRICATION.

A wire rope consists of strands of wire which are wrapped around a central fiber or wire rope core. Each strand is made up of a number of individual wires, resulting in a relatively large surface area of metal per unit length. When in use, wire rope could be considered to be a dynamic piece of machinery with many moving parts interacting with one another. These moving parts are the individual wires, and each wire in in contact with several others along its entire length.

As in any other piece of machinery, the moving parts must be lubricated. In the case of wire rope, lubrication offers protection from corrosion due to the marine enviroment and reduces friction abrasion between wires. This resulting mechanical wear produces a loss of metallic area and a corresponding reduction in rope strength and life. Also, pits and other unconformities caused by this wear are susceptible to corrosion, further accelerating the deterioration process.

Most wire rope is lubricated during manufacture, but internal pressures in a working rope cause lubricant to be squeezed out of the rope. When used in the sea a washing effect can take place which, combined with large hydrostatic pressures, also removes lubricant. These factors, combined with the general wear and tear that the rope is exposed to, necessitates the need for periodic re-lubrication. It is also important to ensure that wire rope is lubricated prior to storage, since corrosion is more likely over longer periods of time.

The importance of lubricating wire rope when in use and storage cannot be stressed enough. With proper re-lubrication, an increase in rope life of up to five times that of an unprotected rope can be realized (Ref: 4) and an investment protected.

4.0. LUBRICANT SEARCH.

Initial steps in the search for a suitable lubricant included contacting lubricant suppliers to obtain literature and other information regarding their products. More than two dozen companies were contacted, and information was received from all but two. A list of companies contacted is shown in Table 1. It is believed that a good cross-section of the market was reached from this search.

From the literature received, lubricants that appeared to meet a few of the following criteria were singled out and entered in Table 2. These criteria include:

- ability to stay on without dripping, not messy;
- evidence of use in marine enviroments;
- ease of application;
- allows for visual inspection of rope;
- good corrosion protection;
- durability;

- high flash point, good high temperature properties;

- low pour point, good low temperature properties;

- good penetration;

- compatability with lay-up lubricant.

The literature, of course, did not have information regarding many of these criteria. Suppliers claimed that their particular lubricant would meet most or all of the stated requirements. However, these claims will have to be verified.

In order to become more familiar with the subject of wire rope lubrication in a marine enviroment, a literature search was conducted at the at the B.I.O. library, which produced little relevant material. This resulted in a library computer search, and much useful information was acquired. At the same time known lubricant users were contacted to obtain knowledge of how they lubricate their wire rope, what lubricants they use,and their general experience with lubricants (see Appendix 2).

Since a rather large number of lubricants were available, the following basis for deciding what lubricants were to be considered was established. Because of the fire hazard, any lubricants with a low flash point were excluded. A decision had previously been made that a liquid lubricant was desirable; however, greases with exceptional qualities and references were to be tested. Reference from users also weighed in this decision, but information received from a user with limited knowledge in this field might not be weighed heavily, as...." throughout the industry, the type of lubricant used will vary according to the amount of sales promotion given this product by various lubricating companies", (Ref:5), meaning that the most popular lubricant is not necessarily the best.

Lubricants are quite often "cut" with a solvent to allow easier application and deeper penetration into the wire. In a field dressing, solvents should be avoided because 1) it can pull the "lay-up" lubricant out of the rope, and 2) it creates a fire hazard.

As mentioned previously, a liquid lubricant was desirable over a grease. Workers complain that greases are messy and do not allow for easy visual inspection of wire rope, as do most liquids. Greases do not have the penetrating ability of liquid; however, they do not have to be re-applied as frequently, and they offer better resistance to mechanical wear than liquids (Ref:5).

A large amount of the wire rope covered under this program is Electro-Mechanical cable. Concern has been expressed about the effect of the lubricant on the insulating jacket of the electrical conductor. Insulating jackets are made up of plastics such as polyethylene and polypropylene, and possible effects of the lubricant might be a deterioration of the jacket, penetration through the jacket into the conductors, or hardening, resulting in cracking.

Mechanical cables can have several types of cores, including natural fibres, which provide flexibility and act as a lubricant reservoir. The selected lubricant must not have an adverse effect on these cores or the insulating jackets described above.

## 5.0. METHOD OF APPLICATION.

The application of a lubricant on a wire rope can be a dirty and time-consuming process. Traditionally, application has been by hand using gloves, brushes or mops. Poor penetration and loss of lubricant resulted. More recently lubrication has been done by passing the wire rope through a funnel or box filled with lubricant, or by dripping lubricant on to the rope when it is travelling around a sheave.

More recent developments have led to the design of an applicator which applies lubricant under pressure as wire rope is passed through the unit. Several of these applicators are on the market, and one, MASTO (TEXACO), has been acquired by A.G.C. The MASTO applicator will be used to apply various lubricants to be tested.

Inquiries were made about three other applicators on the market. Two were not readily available so they were not investigated any further. The third, C.L.A.S.S. (cable lubrication and servicing systems), is offered by SHELL and is believed to be the superior lubrication system on the market. This system comes by truck to the site, and the unit working pressure of 4000 p.s.i. cleans all dirt, rust and debris out while at the same time lubricating the rope. However, the price can be up to $.50/ft, and since none of these units are in the Maritimes, a travel cost of about $1/KM. would have to be included. This system was considered too expensive, but Shell will contact B.O.T. in the future if the system is implemented in the

Maritimes.

The MASTO applicator to be used can handle both grease and liquid lubricants. It is necessary to have a compressed air supply and some type of support on which to chain it. The MASTO system forces lubricant in between the individual wire while applying a thin, even coat on the wire rope with a minimum of leakage and mess. Rubber seals inside the MASTO whichare replaceable and sized for the wire used clean dirt and excess lubricant off the outside of the rope. The MASTO is used primarily in the mining industry by companies such as INCO with great success.

It is obvious that using an applicator to apply lubricant to wire rope should be superior to lubrication by hand. The only major advantage of lubricating by hand is that broken wire and other damage can be readily detected. However, a disadvantage of the pressure applicator may be the loss of lubricant due to leakage.

## 6.0. SUMMARY AND CONCLUSION.

Based on literature received and criteria established, a list of lubricants to be considered was drawn up. Table 3 gives details of properties, distributors, and references.

In order to give the test more credibility, it was decided to test a larger number of lubricants than what is listed in Table 3 (see Table 4). The selected lubricants are believed to represent a good cross section of what the market has to offer, and should provide a wide variety of test results.

Selection of the lubricants to be considered was made by ensuring that three of the most important previously discussed criteria were met: 1). high flash point, eliminating a fire hazard; 2). the absence of a solvent which can pull the lay-up lubricant out of the cable and also create a fire hazard; and 3). good references from lubricant users. A liquid lubricant was desirable, but one grease has been chosen because of its exceptional qualities and references.

As the wire rope covered under this program is in storage much more than in use, the corrosion resistance of the field dressing is more important to consider than its ability to lubricate. Therefore, any test results related to corrosion resistance will weigh heavily in the final decision.

Lubricant selection is only the first phase of the proposed Wire Protection Program. A good maintenance program including re-lubrication, cleaning and drying, periodic inspection to determine the condition of a rope and retirement criteria is essential for extending wire rope life and decreasing equipment and data loss while ultimately minimizing operational expenses.

## TABLE 1

## WIRE ROPE LUBRICANT SEARCH

This list is alphabetical using the known trade names or references. In some cases a second name is noted which is another product by the same company or sales office. Phone numbers are listed but persons names have not been listed in case of changes. The letter "L" or "G" alongside the name identifies the product as liquid or grease.

| NAME OF PRODUCT | | COMPANY/SALES OFFICE | PHONE NUMBER |
|---|---|---|---|
| AMPLW-2 | (L) | ALEGRIA OF FLORIDA LTD. | 305-763-2096 |
| APPLELUBE | (L/G) | JOHN APPLEBY SALES | 902-275-5531 |
| CAPACLUBE<br>SHELL GEAR ARCTIC | (G)<br>(L) | SHELL | 902-463-1799 |
| CHESTERTON SPRAFLEX | (L) | COASTAL EQUIPMENT AGENCIES | 902-469-0030 |
| DOW CORNING | (L) | NORMAN SANCTON & SON LTD | 902-435-5884 |
| GAMLEN LASH GEAR LUBE | (L) | MARITIME CHEMICALS | 902-466-2135 |
| HIGH CORE | (L) | NATIONAL CHEMSEARCH | 902-889-3254 |
| H-37 | (L) | HODSON CORP. | 312-767-8447 |
| KEYSTONE | (L&G) | FOULIS ENGINEERING SALES | 902-429-3330 |
| LOOBIT | (L) | LLOYDS | 416-236-2266 |
| LPS 3 | (L) | MACLEAN INDUSTRIAL SUPPLY | 902-454-7413 |
| MOBILRAMA<br>ELBAC 180 | (G)<br>(L) | ESSO and MOBIL | 902-424-6846 |

-continued on next page-

TABLE 1
( cont.)

| | | | |
|---|---|---|---|
| OPEN GEAR LUBRICANT | (G) | PETROCAN | 902-429-0580 |
| OPTIMOL SHF<br>VISKOGEN KL | (G)<br>(L&G) | OPTIMOL | 416-624-5636 |
| PRELUBE-6<br>PRELUBE-14 | (L)<br>(L) | ROMOR EQUIPMENT | 201-344-4433 |
| ROPELIFE | (G) | HALPEN ENGINEERING | 416-743-8533 |
| ROPETEX EP | (G) | TEXACO | 902-463-7941 |
| RUSTCHECK | (L) | RUSTCHECK | 902-455-6666 |
| SUPREME EP | (G) | GULF CANADA LTD. | 902-422-1741 |
| T-GREASE | (G) | IRVING | 506-632-2000 |
| TRB-525 | (G) | ATLANTIC CHEMICAL | 902-454-5884 |
| WRP 119 | (L) | CORSEN CO. | 214-241-4582 |

LITERATURE NOT RECIEVED

| | |
|---|---|
| CADILLAC PLASTIC | 902-463-7732 |
| SYNTHETIC LUBRICANTS UNLIMITED | 416-519-8833 |

TABLE 2

LUBRICANT SPECIFICATIONS

NOTE: * indicates lubricant that might be suitable.

| LUBRICANT | FLASH POINT C | VISCOSITY SUS @38C | ADDITIONAL |
|---|---|---|---|
| ELBAC FLUID No.24 | 150 | 128 | -39 PourPoint |
| *ELBAC FLUID No.180 | 150 | 950 | -24 C Pour Point;Used by D.N.D.; Recommended from DREP Tests. |
| ELBAC EP 9F | - | 75@ 100 C | -45 to 50 C Operating Range;30%Barium Soap;9F(Esso)consistency;Grease. |
| GAMLEN LASH | 70 | - | Should not be heated above 65 F. |
| GULF SUPREME EP1 | >300 | - | Aluminum complex grease;used by Toronto Transit. |
| HIGH-CORE | 460-High Temp. 110-Regular | | Effective from -46/66 C;good penetration;has molybdenum disulphide. |
| *HODSON'S H-37 | 170 | - | transparent liquid |
| KEYSTONE WRO-OW | 204 without solvent | Fluid Gel | -35 C Pour Point;blackliquid; non-flammable solvent |
| KEYSTONE | ditto. | Gel | as above |
| *LOOBIT | >210 | - | +9 C Pour Point;will not freeze at -100 C;will mix readily with any grease. |
| LPS 3 | 62 | 270 | -18 C Pour Point;no rust on steel panels after 134 hours of salt spray. |

-continued on next page-

TABLE 2.
(cont.)

| LUBRICANT | FLASH POINT C | VISCOSITY SUS @ 38C | ADDITIONAL |
|---|---|---|---|
| MOBILRAMA 798 | - | - | consistency of a No.1 Grease |
| MOLYKOTE 3400A | 35 | - | -163 to 232 C Temp.range;No corrosion after 500hrs.of salt spray. |
| MOLYKOTE 3402 | 35 | - | -198/+315 C Temp.range;> 200hrs. protection steel for salt spray test. |
| OPTIMOL SHF | - | - | semi-synthetic,high viscosity;-25/180 C Temp.range;Solvent. |
| PETROCAN ARCTIC | 60 | 240 | -40 C Pour Point after solvent evaporation.-45/12 C operating range Open Gear lubricant. |
| PETROCAN MEDIUM | 238 | 347@ 100C | -6 C Pour Point after solvent evaporation.-5/30 C operating range. Open Gear lubricant. |
| *PRE-LUBE 6,14 | 180 | - | -29 C Pour Point.Widely used by U.S. Miltary & Industry.ASTM Tested. |
| ROPELIFE | - | - | coated wire unaffected after 48 hrs. of cold salt spray. |
| *ROPETEX EP | - | - | black grease;slightly tacky, used by INCO |
| RUSTCHECK | - | - | has a solvent carrier;lubricating properties unknown. |
| SHELLGEAR ARCTIC | 116 | 286 | -40C pour point -45C to -12C temp. range |

-continued on next page-

TABLE 2
(cont.)

| LUBRICANT | FLASH POINT C | VISCOSITY SUS@ 38C | ADDITIONAL |
|---|---|---|---|
| SHELLGEAR MEDIUM | - | 1730 | -15C pour point<br>-20C to 15C temp. range |
| SHELLGEAR HEAVY | - | 7150 | -6C pour point<br>10C to 45C temp. range |
| SHELL CAPACLUBE | 204 | - | easily applied in low temps.; no melting point;grease. |
| SPRAFLEX (CHESTERTON) | 215 | - | petroleum base;USDA accepted;DND claims it hardens and flakes off at low temps. |
| TRB-525 | - | - | -40/260C operating temp.;contains petroleum distillate. |
| *WRP 119 | 215 | - | synthetic liquid, can be UV enhanced. |
| VISKOGEN KL | - | - | light to heavy liquid;will not affect EM cable insulation; used extensively in Europe. |

## TABLE 3

## LUBRICANTS TO BE CONSIDERED

| | |
|---|---|
| PRELUBE 6&14 | Grignard Chemical Co.<br>-widely used by American military and industry, 180c flashpoint, can be cut with a solvent, -29C pour point, used by Rochester Cable<br>-according to author of "Hoist Rope Lubrication Criteria", is an excellent corrosion inhibitor, but could have better boundary lubrication.<br>-clear liquid, will not affect insulating jacket on EM cables. |
| ROPETEX EP | Texaco Canada<br>-black grease, slightly tacky, contains molybdenum disulphide and graphite, used by Halterm Container Terminal, Inco, and many other mining operations<br>-head office believes there will be no effect on insulating jackets. |
| LOOBIT | Lloyd's Laboratories<br>-210C flash point, 9C pour point, won't freeze at -100C, used in Beaufort Sea and west coast, green liquid. |
| ELBAC 180 | Esso Canada<br>-150C flash point, -24C pour point, used by DND, Halifax on EM cables, recommended as a result of DREP tests. |
| WRP 119 | Corsen Co.<br>-215C flash point, synthetic liquid. |
| H-37 | Hodson Corp.<br>-170C flash point, clear liquid. |

TABLE 4

LUBRICANTS TO BE TESTED

| | |
|---|---|
| 1 | Elbac 180 |
| 2 | Hodson's H-37 |
| 3 | Loobit |
| 4 | Prelube 6 |
| 5 | Prelube 14 and #2 diesel |
| 6 | Ropetex EP |
| 7 | High Core |
| 8 | Ropelife |
| 9 | Supreme EP |
| 10 | Veedol Amaclac |
| 11 | Viskogen KL-9 |
| 12 | Viskogen KL-15 |
| 13 | Viskogen KL-23 |
| 14 | Viskogen KL-130 |
| 15 | Viskogen KL 300 |
| 16 | Rustcheck |
| 17 | AMPLW-2 Teflon lubricant |
| 18 | Vaseline |
| 19 | WRP 119 |
| 20 | WRP 119 AS |

## REFERENCES


1. LAQUE, F., MARINE CORROSION AND ITS PREVENTION, WILEY, 1975

2. BUTLER AND ISON, CORROSION AND ITS PREVENTION IN WATERS, REINHOLD PUBLISHING, 1966

3. SHRIER, L., CORROSION, VOLUMES 1&2, NEWNES BUTTERWORTH, 1977

4. DRISCOLL, A., HANDBOOK OF OCEANOGRAPHIC WINCH, WIRE AND CABLE TECHNOLOGY, 1982

5. JENTGEN, R.L., HOIST ROPE LUBRICATION CRITERIA, 1978

6. McGRAW-HILL DICTIONARY OF SCIENTIFIC TERMS, 3RD EDITION, McGRAW-HILL, 1984

7. G. GEDEKE AND B. NAUMANN, THE EFFECT OF ROPE LUBRICANTS ON SYNTHETIC FIBER CORES IN STEEL WIRE ROPE, WIRE, JUNE, 1972

8. FREEBORN, N., METHODS OF WIRE ROPE LUBRICATION, WORLD DREDGING AND MARINE CONSTRUCTION, JULY,1980

9. W. LUCHT AND F. DONECKER, FACTORS AFFECTING WIRE ROPE LIFE IN A MARINE ENVIRONMENT, OFFSHORE TECHNOLOGY CONFERENCE, 1977

10. BEREZHINSKII, KLUBKOVA, TEREBILO, AND CHESNOK, DETERMINATION OF ADHESION PROPERTIES OF WIRE ROPE GREASES, KHIMIVA, TEKHOLOGIYA TOPLIV, MASEL, JULY, 1977

11. SHUMACHER, M., SEAWATER CORROSION HANDBOOK, NOYES DATA CORP,1979

12. WIRE ROPE INDUSTRIES LTD., WIRE ROPE MANUAL

13. BAUMEISTER, AVALLONE, BAUMEISTER, MARK'S STANDARD HANDBOOK FOR MECHANICAL ENGINEERS, EIGHTH ED., McGRAW-HILL, 1978

14. MYERS, HOLM, McCALLISTER, HANDBOOK OF OCEAN AND UNDERWATER ENGINEERING, McGRAW-HILL, 1969

15. SHELL U.K. OIL, SHELL CANADA LTD., CABLE LUBRICATION AND SERVICING SYSTEMS (CLASS), 1983

16. LEWIS AND MERCER, CORROSION AND MARINE GROWTH ON OFFSHORE STRUCTURES, ELLIS, HORWOOD LTD. FOR THE SOCIETY OF CHEMICAL INDUSTRY, 1984

17. MARK, HERMAN, AND BIKALES, ENCYCLOPEDIA OF POLYMER SCIENCE AND TECHNOLOGY, WILEY

## TERMS

| | |
|---|---|
| Concentration Cell (Ref:6) | -an electrolytic cell in which the electromotive force is due to a difference in electrolytic concentrations at the anode and cathode |
| Electrolyte (Ref:6) | -a chemical compound which when molten or dissolved in certain solvents, usually water, will conduct electricity |
| Fatigue (Ref:6) | -failure of a material by cracking resulting from repeated or cyclic stress |
| Field dressing | -lubricant used for periodic re-application on wire rope |
| Flash Point (Ref:6) | -the lowest temperature at which vapors from a volatile liquid will ignite momentarily upon the application of a small flame upon specified conditions |
| Fretting Wear (Ref:3) | -wear occuring at the interface of two closely fitting surfaces when subject to a slight oscillatory slip |
| Lay-Up Lubricant | -lubricant applied to wire rope during manufacture |
| Pour Point | -the lowest temperature at which a liquid will flow |

# APPENDIX

## CLEANING OF WIRE ROPES

Although not included in this section of the Wire Protection Program, it is of utmost importance that a wire rope be clean prior to the application of a field dressing. Entrapped dirt, rust, and salt combined with moisture can accelerate the corrosive process in the wire rope. These unwanted materials can also increase mechanical wear by increasing friction and preventing the lubricant from penetrating and adhering properly.

The design of a cleaning apparatus to be used prior to lubrication will be carried out at a later date. Some possible ideas include using compressed air or wire brushes to clean the rope. Also, the rope should be rinsed with fresh water in order to dissolve corrosive salts.

The evidence suggests that by implementing an effective cleaning program and providing proper lubrication, wire rope life can be increased substantially. This will greatly benefit the wire rope user.

# PART 2

# TESTING OF LUBRICATION EQUIPMENT

INDEX

INDEX

(CONTINUED)

INTRODUCTION.

The importance of cleaning a wire rope prior to the application of a field dressing has been previously discussed. The removal of rust, salt, and other debris combined with good lubrication can result in a substantial increase in wire rope life.

A long length of 7/8 in. E.-M. cable exists at the Institute which, because it was in need of lubrication, was used to test a cleaning device and lubrication equipment.

The first section of this report investigates considerations for cleaning wire rope and outlines how an attempt was made to clean the cable while it was reeled from one drum to another. The second section deals with the application of a field dressing using a lubricating unit, and the observations made during this procedure.

## A.....CLEANING OF A WIRE ROPE

### 1.0. CABLE CONDITION

Inspection of the rope revealed that a substantial amount of corrosion had occured on the visible portion of the cable. The presence of iron oxide indicated that the zinc galvanizing had been removed. It was assumed that a large percentage of the cable was corroded and that an attempt should indeed be made to clean it before lubrication.

## 2.0. CLEANING METHODS

Various methods of cleaning wire rope were investigated. The cleaning of wire rope posed a unique problem in that the cleaning had to be done as the cable was reeled from one drum to another. It was decided that cleaning by hand would be ruled out,as it would be a long and tedious process requiring several laborers and slow rope speeds. Furthermore, one of the goals of the Wire Protection Program is to produce a unit which will automatically clean wire rope before lubrication.

A prototype cleaning unit was designed and assembled (see figure 1, photos 1 and 2) which consists of four wire brushes mounted perpendicular to one another on blocks of wood. The unit was designed so that each brush makes full contact with the wire to ensure good cleaning.

## 3.0. OPERATION

The cleaning attempt took place while the cable was reeled from a large metal drum to a smaller, more manageable wooden drum. The take-up reel was positioned inside the Canopy and the pay-off reel about 50 feet away on the jetty. The cleaning unit was chained to either side of the pay-off (Timberland) reeler.

The operation was carried out at a rope speed of approximately 70-80 FPM, and the take-up reel was spooled by hand. Since the cable length was not measured, it was calculated using the drum equation from the Wire Rope Industries handbook (see Appendix). It was determined that the cable was approximately 4360 feet in length. This will be verified by measuring when the cable is lubricated.

## 4.0. SUCCESS OF THE CLEANING UNIT

The cleaning unit appeared to remove a good amount of dirt and surface rust on the corroded section of the cable, which made up roughly half of the total length. During the operation large amounts of corrosive dust could be seen leaving the cleaning unit and also came off the wire when it was hammered into place during spooling. Also, by visual inspection of the cable on either side of the cleaning unit, it was obvious that surface rust was being removed.

After several hundred feet of cable had been payed out it could be seen that one of the wooden supports on the cleaning unit was being worn through. This was occuring because the unit could not be correctly supported in the vertical axis and therefore was not oriented properly with respect to the cable. To improve the situation a forkift was stationed beside the reeler and one of the chains fastened to the forks after they were raised to about 8 feet. This did help to decrease wear, but the unit was rotated 180 degrees after about half the wire was reeled in order to distribute wear evenly.

## 5.0. CONCLUSION

As stated previously, the cleaning unit did remove a substantial amount of dirt and surface rust from the cable. After it was removed from the cable the unit was hit against the floor and several ounces of rust and dirt were recovered. This amount is only a fraction of the material actually removed from the cable.

Modifications to the cleaning unit would greatly improve its effectiveness. The following ideas were suggested which might be incorporated into a final design: (1) orient the unit properly, which would reduce wear and improve coverage,(2) add a second section with brushes offset 45 degrees from the existing ones, (3) possibly rotate the unit while the cable is being passed through it, and (4) bolt the unit at one end only and fasten the wire exit end with a leaf spring.

This unit was built in 3 to 4 man hours at a materials cost of about $15, excluding the chain. Experience would reduce assembly time of additional units considerably. It is believed that a modified unit could be built for a reasonable price and that it would effectively clean surface dirt and rust off wire rope and cable.

Other means of cleaning wire rope were available which may have been more effective, but wil not be considered until later in the program, as an immediate, inexpensive cleaning unit was required for this operation.

## B.....LUBRICATION OF A WIRE ROPE

### 1.0. Introduction

As noted in the general introduction a length of 7/8" diameter electro-mechanical wire rope required cleaning and lubricating. This section will describe the actions and results of lubricating the wire with a pressure applicator, "MASTO", using two lubricants; #4 and #5. Lubricant #5, a more viscous version of #4, will be cut with 1 part No. 2 diesel to 5 parts lubricant.

This work will act as an initial evaluation of the use of such an applicator and immediately offer protection to the cable. The applicator will be tested at various operating pressures and speeds to check for characteristics such as lubricant loss and seal wear. Indications of the lubricants' adhesion qualities could be judged from its ability to stay on the cable immediately after leaving the applicator, while passing through the wire measuring device and while being wound onto the take up drum. Long term investigation would show any tendency for the lubricant to drip or weep from the cable.

## 2.0. EQUIPMENT

The equipment used for the tests can be broken down into two categories including application of the lubricant and wire handling.

The following equipment was used to apply the lubrication to the cable: MASTO lubricating unit, pumping unit, supply and return lines and a Wire Brush Rope Cleaner. The arrangement of this equipment can be seen in figure 2.

The handling of the wire rope was managed through the use of a "Dotan" supply winch, a "Timberland" cable measuring device and a "Timberland" take up winch. The configuration is sketched in figure 3.

## 3.0. PREPARATION OF THE LUBRICANT

Of the many lubricants currently under investigation by the company, only the manufacturer of #4 and #5 had evidence that their products would not harm electro-mechanical cable insulation. This evidence and references that indicate the effectiveness of these lubricants formed the basis for deciding to use them.

The preparation of lubricant #5 was a time consuming process. The actual mixing took a couple of hours and was a very messy job. The mixture, although less viscous than #5 alone, was more viscous than #4. From the viewpoint of a simple clean operation #4 would be the better of the two products.

## 4.0. TEST PROCEDURE

This test was intended to determine the operating characteristics of the MASTO lubricating unit and the behavior of the lubricants.

Initially the unit was tested with the wire rope in a static mode using lower viscosity lubricants than those specified for use with the unit. The unit would then be used to apply the lubricants to a 7/8" diameter electro-mechanical cable to determine its operating abilities and limitations. Finally long term dripping or weeping of the lubricant from the cable would be monitored for future reference.

## 4.1. TEST PROCEDURE-STATIC MODE

An initial test of the MASTO applicator was performed with the wire rope in a static mode (see photo 3). The intention was to observe the loss rate due to the low viscosity of the lubricants and to record other operating characteristics of the unit.

The unit was secured to the cable and the lubricant pressure increased from 0 to 600 PSI. At pressures greater than 500 PSI there seemed to be a high steady flow rate from the unit.

From this static cable test visual observations allowed several facts to be noted; these can be found in section 3.4., 'Results' of this report.

These facts were critical to the immediate continuation of the test. The application of the lubricants to the cable could only be commenced if the static test demonstrated that the system would actually pump the lubricant with limited loss. The system operated successfully and achieved good penetration into the cable.

## 4.2. TEST PROCEDURE-DYNAMIC MODE

With the success of the system in the static cable mode, the next step was to proceed to the actual lubrication of the 7/8" E-M cable.

The set up for the test is depicted in figure 2 and photos 1-7. Several of these show the use of the Wire Brush Rope Cleaner attached in front of the lubricating unit. The purpose of this set up was to first provide a final cleaning of the cable and secondly attempt to prevent some of the seal wear from occuring.

The cable in question was rusted for approximately half of its length while the remainder was of good quality (see figure 4). For the purposes of evaluating the separate lubricants on each type of cable the application configuration depicted in figure 4 was adopted.

The tests required knowledge of the leakage volumes and the volume initially applied to the rope; therefore various flow parameters were recorded for the test periods. The data is presented in Table 1.

From this table it can be seen that the cable was broken down into three separate sections A,B &C. The test itself was broken into nine separate test periods which were determined by testing parameters such as equipment problems,seal wear, lubricant supply and wire condition.

At the beginning of the operation the test pressure was varied to determine "visually" how good the application was. This involved looking for a good lubrication film without excess amounts that would drip or shake off. The operating pressure selected for the recomended cable speed of 75-100 FPM was 240 PSI. The remainder of the cable was lubricated at these settings and the parameters recorded (see Table 1). The items being studied over a length of cable were application volume, lost volume at the applicator, the short term loss from the cable as it was measured and as it was placed onto the take up drum.

The major recurring problem during the test was the excessive wearing of the seals. This wear was due to the lack of a centering device on the front of the unit.

Another problem was the failure of the unit's tightening lugs (see photo 7). The literature states that the nuts should be tightened securely and at no point specifies a torque limit. Several jubilee clamps were used to continue with the tests.

## 4.3. TEST PROCEDURE-LONG TERM WEEPING

The cable was checked at intervals to determine the amount of lubricant loss from the cable in the long term. The recorded values are tabulated in Table 2.

## 5.0. RESULTS

### 5.1. RESULTS-STATIC MODE

The MASTO unit operating with the cable in a static mode yielded the following visual observations:

(1) The pumping unit will pump low viscosity lubricant.
(2) The MASTO unit will not "spray" lubricant during operation but rather allow it to seep out around the end seals at a rate proportional to the operating pressure.
(3) Capillary action of the lubricant combined with the high pressure static application resulted in an extra length of cable outside the lubrication units' housing being lubricated (see photograph #1).
(4) Full penetration to the polyethylene jacket was achieved.

### 5.2. RESULTS-LUBRICATION OF WIRE ROPE

The results show that the cable speed was maintained close to the recommended value of 75 to 100 FPM. The application volume varied from 0.015 l/m (0.001 gal/ft) to 0.03 l/m (0.002 gal/ft) for the three cable sections. The drip loss at the lubrication unit was 0.47 l/min (0.103 gal/min) to 0.15 l/min (0.0330 gal/min).

The leakage under the Timberland cable measuring device was minimal and certainly could not be considered excessive, demonstrating the ability of the lubricants not to be shaken off (see photo 9).

The take up drum had approximately 1 litre of lubricant below it when the lubrication process was complete, representing a time span of 3.5 hours (see photo 10).

The rusty cable was checked for penetration by cutting through the outside armour. There appeared to be a good lubrication film on the insulating jacket and between the armour layers.

## 5.3. RESULTS-LONG TERM WEEPAGE

The long term weepage gradually decreases over a period of one month. Photos 11 and 12 show the leakage 24 hours after lubrication. Table 2 lists observations made during periodic inspections of the cable.

In general most of the dripping or weeping of the lubricant from the drum occured in the first two weeks after application. After these initial two weeks the leakage appeared to be a function of rainfall; however, these 'washed off' quantities were minute.

## 6.0. CONCLUSIONS

In conclusion the testing went well and a great deal of information was gained. As a result of the test results several points were noted.

The first conclusion drawn was that the MASTO lubrication unit could be used to apply a low viscosity lubricant providing several alterations were made:

(1) The unit would require some method of preventing the wire from wearing the seals. Perhaps a set of adjustable rollers, 'steady-head' type idea, or a sacrificial type opening could be used.

(2) The method of securing the unit around the cable will have to be modified.

(3) A drip collection device will have to be added to the system to collect lubricant leakage (see photo 5). This container will have to extend past the ends of the unit by several inches, which is necessary since the low viscosity lubricant will never be perfectly sealed against the moving cable.

(4) For continuous repumping of the lubricant lost from the MASTO, contaminants picked up from the cable should be filtered out.

The second major point concerned the lubricants tested. The products seemed to be less "messy" in general than greases would have been. Lubricant #4 appeared to leak slightly more than #5; however, neither lubricant leaked drastically with good seals in place. The "shake-off" of both the lubricants was slight, and they were easily applied using the MASTO.

Finally, it was found that the long term dripping and weeping lasted about two weeks, during which about 3/4 l of lubricant was lost. After this initial period, rainfall tended to wash minute amounts of lubricant off the cable (0-10 ml).

TABLE 1

SUMMARY OF APPLICATION

| SECTION | DRIPPAGE (GAL/FT) | APPLICATION RATE(GAL/FT) | LENGTH (FT) | CABLE SPEED (FPM) | AMOUNT APPLIED (GAL) |
|---|---|---|---|---|---|
| A | 0.01 | 0.002 | 885 | 121 | 1.82 |
| B | 0.02 | 0.001 | 1550 | 78 | 1.52 |
| C | 0.03 | 0.0015 | 1760 | 110 | 2.59 |

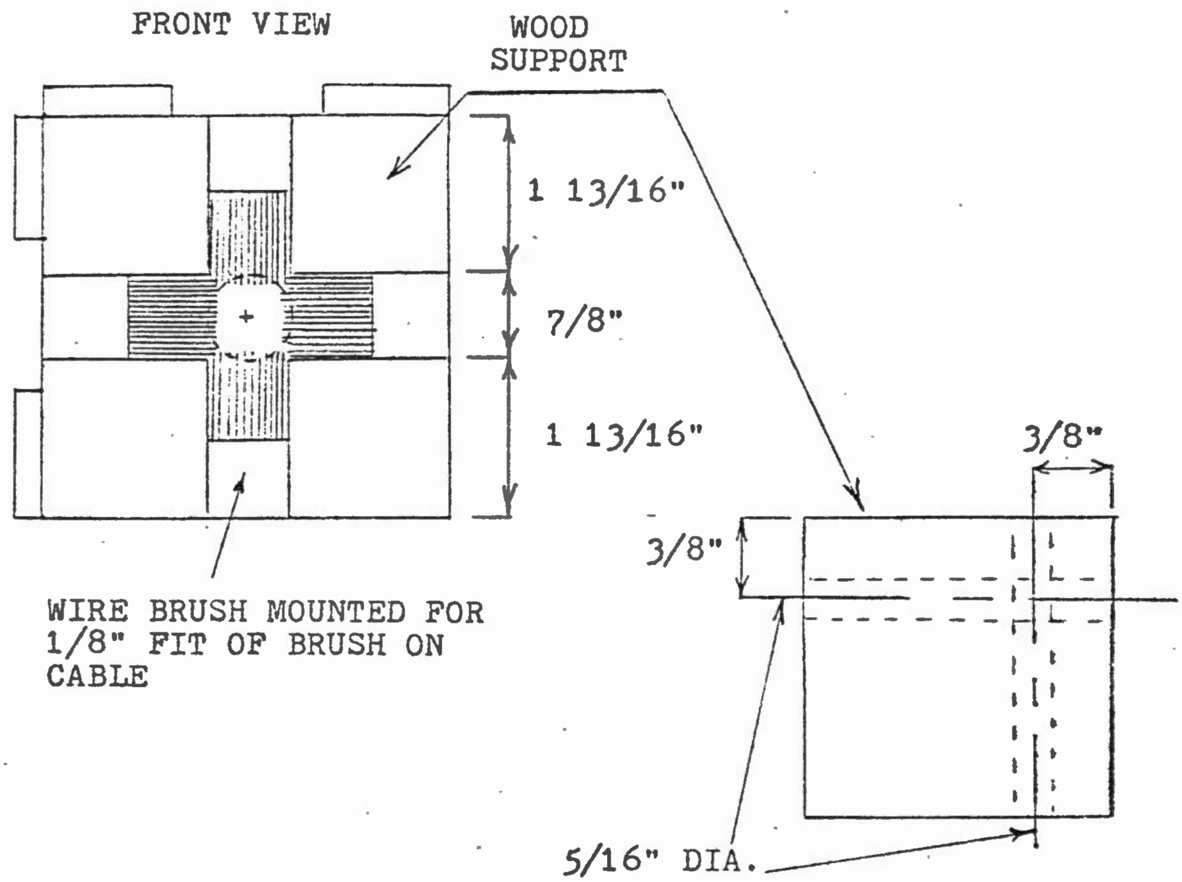
TABLE 2

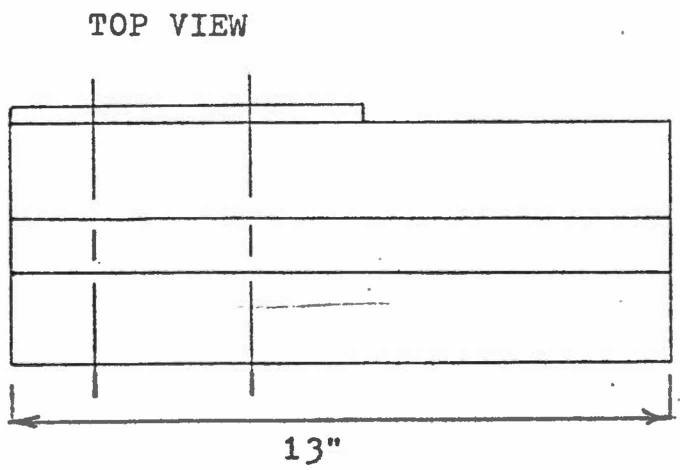
LONG TERM DRIPPING OR WEEPING OF LUBRICANT

| DATE | DRIP VOLUME (l) | COMMENTS |
|---|---|---|
| 10/15/84 | – | lubricate cable |
| 10/16/84 | 0.5 | @ 24 hrs. see photo 11&12 |
| 10/17/84 | 0.125 | drum outside |
| 10/25/84 | 0.125 | plastic sheet added |
| 10/29/84 | ~0.001 | heavy rain |
| 11/02/84 | ~0.001 | heavy rain |
| 11/05/84 | ~0.0005 | light rain |
| 11/14/84 | 0 | plastic removed no drippage |
| 11/15/84 | 0 | moderate rain |
| 11/16/84 | 0 | light rain |
| 11/19/84 | 0 | cold temps. |

total ~0.75 liters

# ROPE CLEANER




- DESIGNED FOR 7/8" CABLE
- DO NOT CUT HANDLES OFF BRUSHES
- USE FLAT WASHERS

FIGURE 1

## MASTO LUBRICATING UNIT

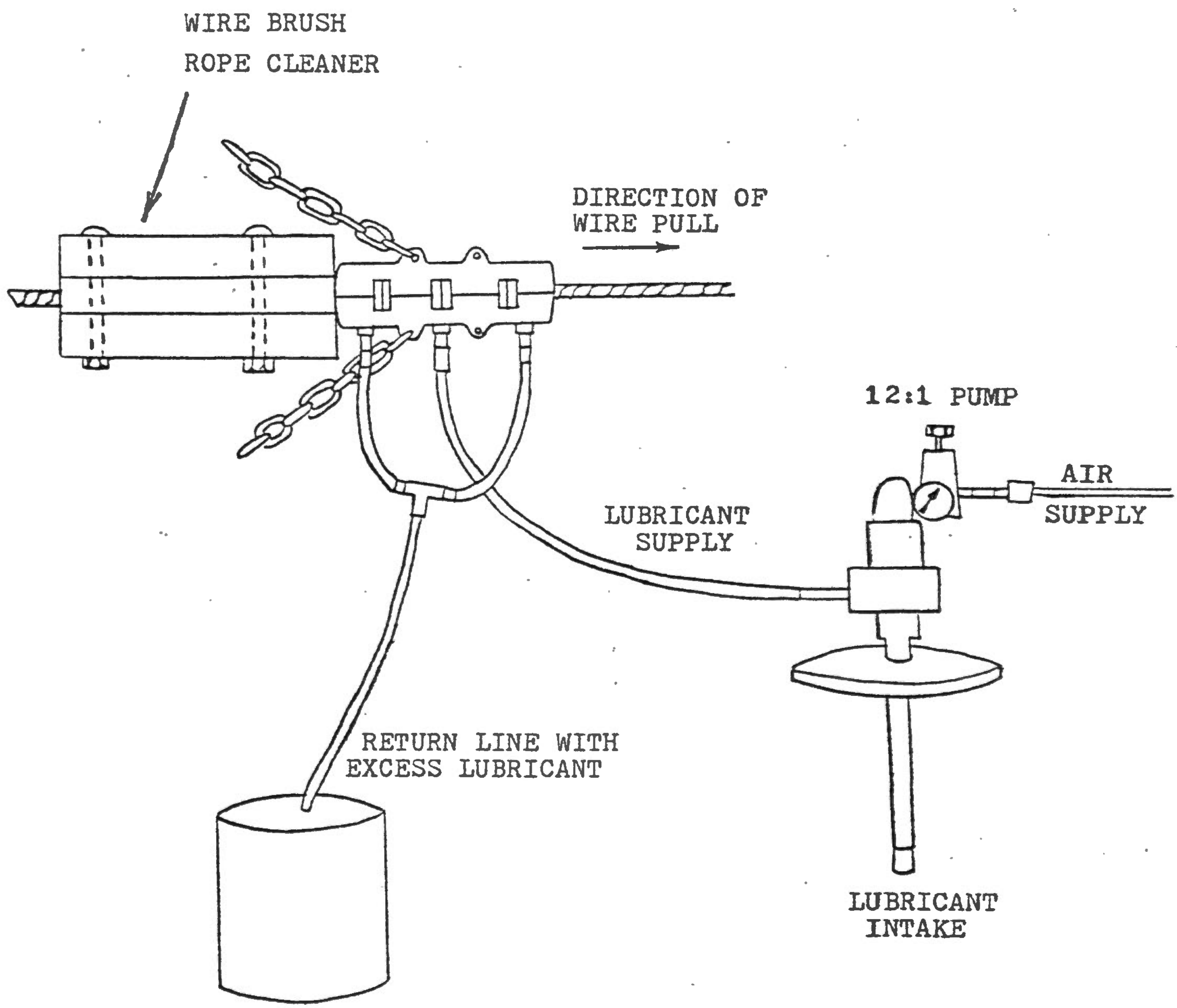



FIGURE 2

SET UP FOR CABLE LUBRICATION

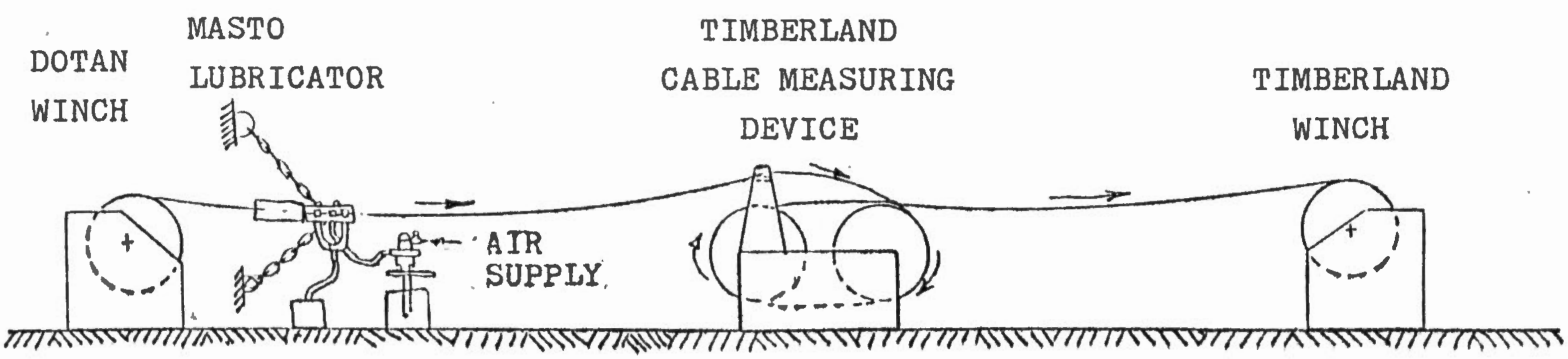



FIGURE 3

ROPE DESCRIPTION

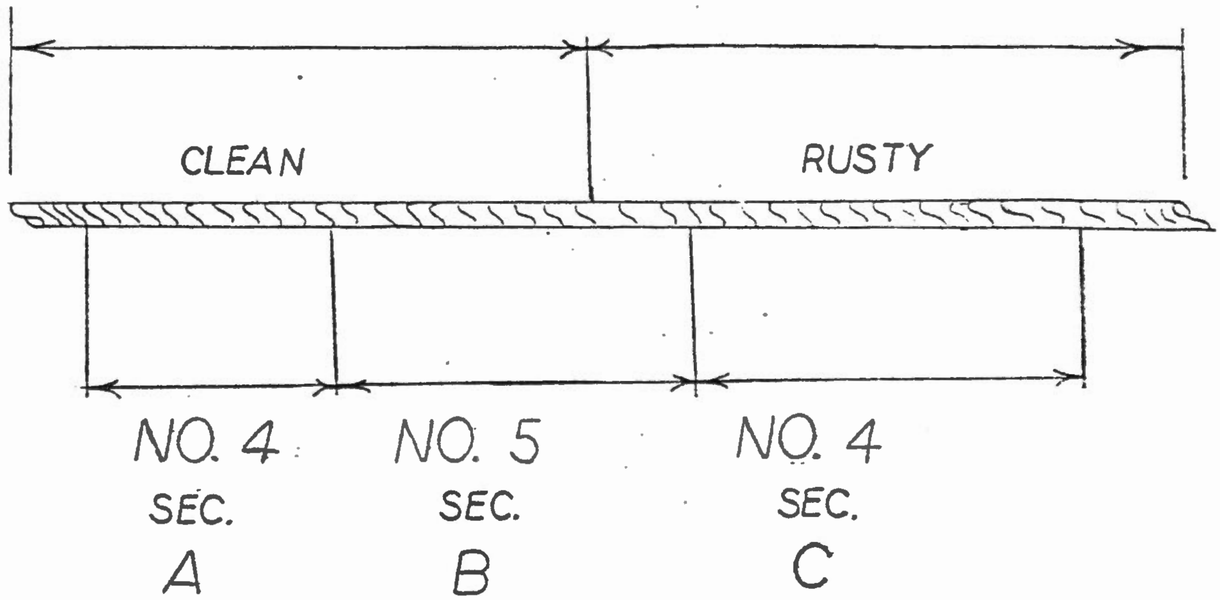
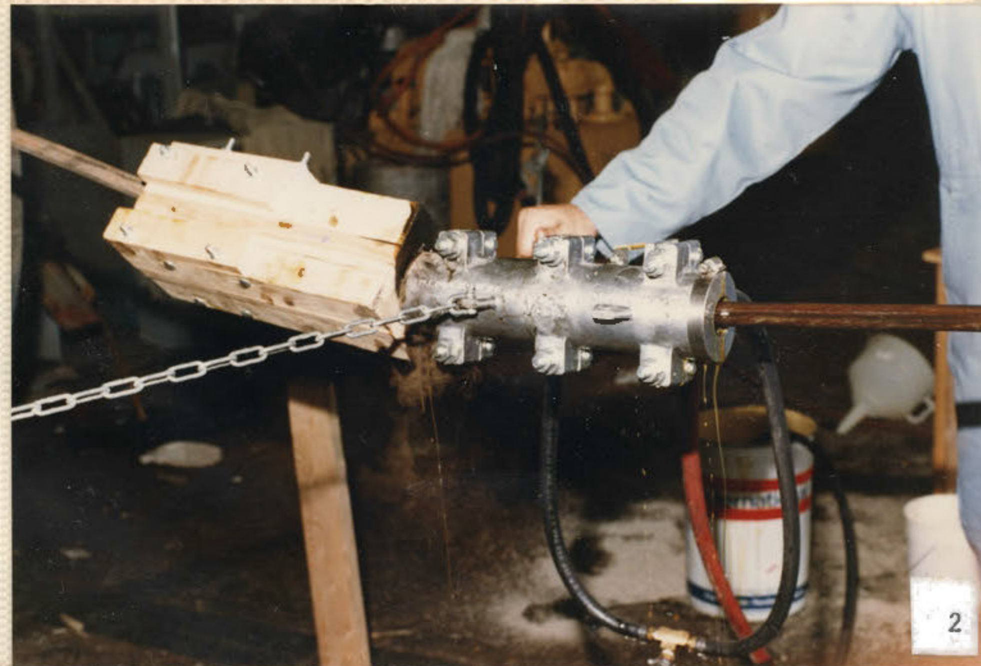



FIGURE 4

LIST OF PHOTOGRAPHS

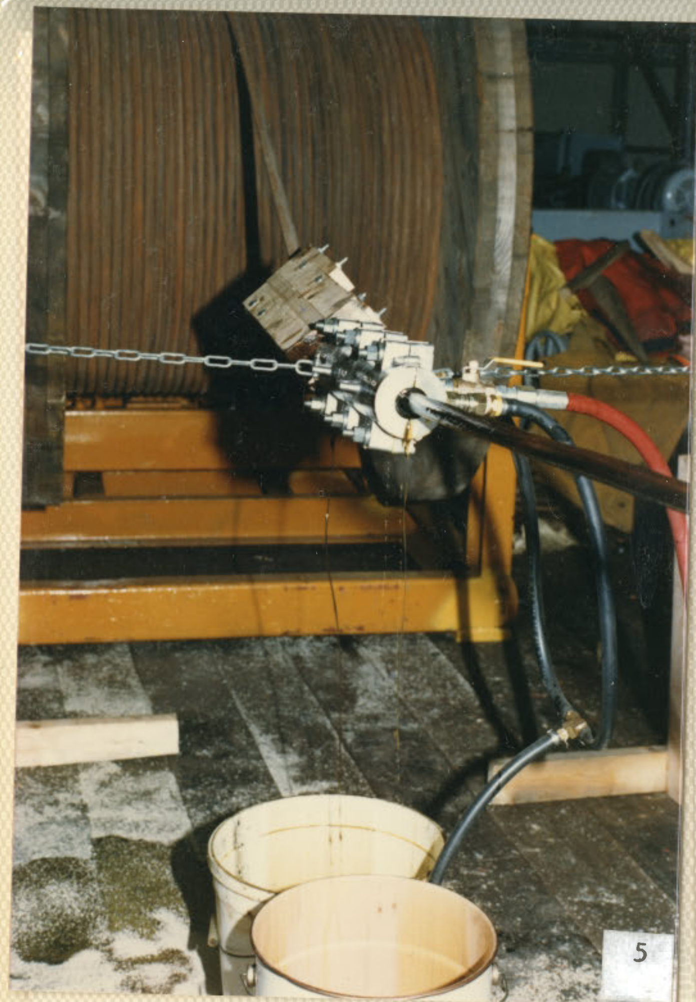
1



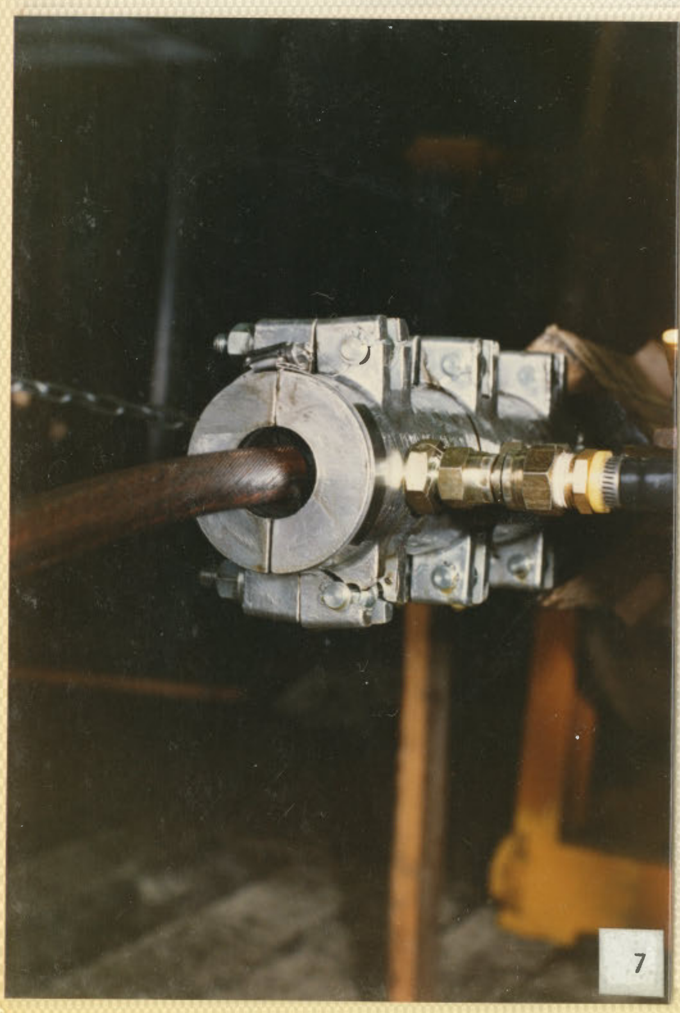
2

3

4


5

6


7

8

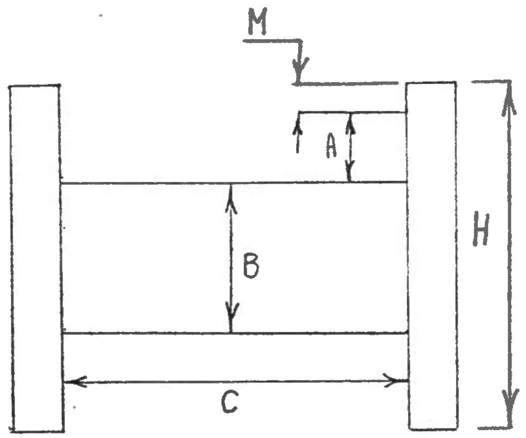

9


10


11


12

# APPENDIX




$A = 9\frac{1}{2}'' = 241$ mm

$B = 30'' = 762$ mm

$C = 34'' = 864$ mm

$D = \frac{7}{8}'' = 22.2$ mm

$K = \frac{0.003142}{22.2^2} = 6.36 \times 10^{-6}$

$H = 61'' = 1550$ mm

$M = 6''$

DRUM EQUATION $\quad L = (A+B) * A * C * K$

L = ROPE LENGTH (m)

A = DEPTH OF ROPE LAYER (mm)

B = DRUM DIAMETER (mm)

C = WIDTH BETWEEN REEL FLANGES (mm)

M = DESIRED CLEARANCE

$K = \frac{0.003142}{d^2}$

$L = (241 + 762) * 241 * 864 * 6.36 \times 10^{-6} = 1330\text{m} = 4360\text{ FT}$

L = 4360 FT

NOTE: THIS IS AN ESTIMATE

# PART 3

# LUBRICANT ANALYSIS

# INDEX

INTRODUCTION.

The following subsections outline tests carried out which will, in the estimation of Brooke Ocean Technology, indicate which lubricant(s) will offer the best protection to wire rope used in ocean work.

## 1.0. CORROSION

### 1.1. STEEL WOOL CORROSION TEST

OBJECT: to determine the corrosion resistance of lubricant samples in an artificial salt water environment.

APPARATUS: lubricant soaked steel wool balls, salt water, small styrofoam bowls.

PROCEDURE: The steel wool balls are those used in Test 2.2. These balls were placed in separate containers about half filled with salt water. The amount of time elapsed until corrosion begins and its severity will be carefully noted.

| | |
|---|---|
| Degree of Corrosion | 0- none |
| | 1- slight |
| | 2- moderate |
| | 3- heavy |
| | 4- severe |

TABLE 1 RESULTS OF STEEL WOOL CORROSION TEST

| Sample No. | Corrosion Observed | Degree of Corrosion |
|---|---|---|
| 1 | >5 hours | 1 |
| 2 | >5 hours | 1 |
| 3 | 5 hours | 3 |
| 4 | >5 hours | 1 |
| 5 | >5 hours | 2 |
| 6 | >5 hours | 0 |
| 7 | 5 hours | 3 |
| 8 | 1 hour | 3 |
| 9 | >5 hours | 2 |
| 10 | >5 hours | 1 |
| 12 | 1 hour | 3 |
| 16 | 1/2 hour | 4 |
| 17 | >5 hours | 2 |
| 18 | >5 hours | 3 |
| 19 | >5 hours | 2 |
| 20 | >5 hours | 2 |
| 21 (control) | 1/2 hour | 4 |

DISCUSSION

The results show that only one sample, #6, a black, asphaltic grease, prevented corrosion from occurring. Lubricant #4, a light liquid, also provided good protection against corrosion, as did #'s 1,2,and 10. On the other hand, #16 experienced corrosion as severe as the unlubricated control.

As expected, most of the dark, heavy lubricants protected the steel wool from corrosion to an acceptable degree. However, #4 offered the best protection with the exception of #6, and #2 was not too far behind. This is impressive because both these lubricants are light liquids, and cannot protect by their physical nature as higher viscosity lubricants do.

Because this test is meant to be comparative in nature only, one cannot conclude that the samples that fared poorly would not protect. However, the lubricants which did well in this test will be considered when a choice is made.

1.2. CABLE CORROSION TEST

OBJECT: to determine a lubricant's ability to protect wire rope against corrosion by placing lubricant coated cable lengths in various corrosive atmospheres.

APPARATUS: lubricant coated cable lengths, polypropylene rope, steel bar, 2x4's, floats, diver's cement, bonding tape, electrical tape.

PROCEDURE: Two lengths of 7/8" E-M cable were cut from a length which B.O.T. had lubricated in the fall. One of the lengths was badly corroded, while the other was relatively uncorroded.

These lengths were cut into 5' and 2.5' sections, and the ends sealed. Lubricant samples were applied with a brush. The Masto lubricator applied lubricant no.'s 1,3,4,and 6 to the center of the cable length, and the rest coated with a brush. This was done to determine a difference in corrosion, if any.

Corroded and uncorroded cables were placed at three locations: A) the splash zone region at the BIO jetty, so that the tide will vary the amount of cable immersed, B) just above the splash zone at the BIO jetty, where the cables will be exposed to wind and salt spray, and C) Tuft's Cove Power Generating Station, where the cooling water is discharged at elevated temperatures and currents. This should give accelerated results.

TABLE 2 RESULTS OF 110 DAY EXPOSURE TO SPLASH ZONE

| Lubricant No. | Degree of Corrosion | |
|---|---|---|
| | Corroded Cables | Uncorroded Cables |
| 1 | 3 | 2 |
| 2 | 3 | 3 |
| 3 | 4 | 2 |
| 4 | 3 | 1 |
| 5 | 2 | 2 |
| 6 | 2 | 1 |
| 7 | 3 | 3 |
| 8 | 2 | 2 |
| 9 | 2 | 2 |
| 16 | 3 | 2 |
| 19 | 3 | 2 |
| 20 | 3 | 1 |
| 21(control) | 4 | 1 |

TABLE 3 RESULTS OF 110 DAY EXPOSURE TO MARINE ATMOSPHERE

| Lubricant No. | Degree of Corrosion | |
|---|---|---|
| | Corroded Cables | Uncorroded Cables |
| 1 | 2 | 0 |
| 2 | 2-3 | 1 |
| 3 | 2-3 | 1 |
| 4 | 2 | 2 |
| 5 | 2 | 2 |
| 6 | 2 | 0 |
| 7 | 4 | 1 |
| 8 | 3 | 2 |
| 9 | 3 | 1 |
| 16 | 3 | 1 |
| 19 | 3 | 1 |
| 20 | 3 | - |
| 21(control) | 4 | 3 |

TABLE 4 RESULTS OF EXPOSURE TO TUFT'S COVE DISCHARGE

| Lubricant No. | Degree of Corrosion | | | |
|---|---|---|---|---|
| | Corroded Cables | | Uncorroded Cables | |
| | 44 days | 128 days | 44 days | 128 days |
| 1 | 3 | 4 | 0 | 1 |
| 2 | 4 | 4 | 0 | 4 |
| 3 | 4 | 4 | 1 | 4 |
| 4 | 2 | 3-4 | 2 | 3 |
| 5 | 3 | 4 | 1 | 3 |
| 6 | 2 | 2 | 0 | 1 |
| 7 | 2-3 | 3-4 | 1 | 3 |
| 8 | 3 | 4 | 0 | 3-4 |
| 9 | 2 | 4 | 1 | 2 |
| 10 | 4 | 4 | 0 | 0 |
| 11 | 3 | 4 | 0 | 1 |
| 16 | 3 | 3-4 | 1 | 2-3 |
| 17 | 3-4 | 4 | 1 | 1 |
| 18 | 3 | 4 | 1 | 2 |
| 19 | 3 | 4 | 0 | 2 |
| 20 | 3-4 | 4 | 1 | 2 |
| 21(control) | 4 | 4 | 1 | 1 |

DISCUSSION

It can be seen from the results shown in Tables 2, 3, and 4 that most of the samples were not particularly effective in protecting against corrosion for such long periods of time. As expected, the greases seemed to protect better than the liquids, with sample #6 performing the best of all samples. The next best corrosion inhibitor was sample #1, a liquid with excellent adhesion and water washout resistance. Two other lubricants, #4 and #9, also provided reasonable protection against corrosion.

The four samples which were applied under pressure to part of the cable were checked to see if there was a difference in corrosion between the section lubricated under pressure and that lubricated by hand. There was some evidence to indicate that lubrication under pressure offers better protection because of more complete coverage. However, it is believed that more obvious results would have been obtained if a mechanical cable was used instead of an electro-mechanical cable with only two layers of armour.

One might wonder why sample #4 was mentioned as a good corrosion inhibitor when it had poor results in protecting the uncorroded samples at Tuft's Cove (see Table 4). It is believed that excessive corrosion had occurred because the taped cable ends had deteriorated, allowing the individual wires to unwind from the cable. This could have allowed the corrosive process to occur at an accelerated rate because of a more plentiful supply of electrolyte and increased water wash-off of lubricant.

The uncorroded cable lengths immersed in the splash zone and at Tuft's Cove provided some interesting results. In both tests (Tables 2,4), the unlubricated control had only a few spots of zinc oxide and iron oxide, while most of the other samples were in advanced stages of corrosion after the full period of exposure. In the case of the corroded samples, the control specimens were among the most severely corroded with a large percentage of their surface covered with a new layer of iron oxide.

A relatively simple explanation for this occurrence may be as follows. The uncorroded samples were originally protected by a layer of zinc galvanizing while the corroded samples had none. As the duration of immersion increased, the washing action of the salt water began to remove lubricant from the cable. Simultaneously the corrosive process was consuming the zinc coating, exposing sections of steel wire. A difference in potential then existed between the bare steel, the bare zinc, the lubricant covered steel, the lubricant covered zinc, and in some cases, copper when the sealed ends of the cables began to deteriorate. The formation of this 4 or 5 way corrosion cell in the presence of salt water lead to a greatly accelerated corrosion rate.

Although the samples at Tuft's Cove and the splash zone were exposed for roughly the same period of time, corrosion was more severe at Tuft's Cove, where high (5-6 knot) currents and elevated temperatures would speed up lubricant wash-off and accelerate the chemical reactions. Zinc is particularly susceptible to corrosion in these conditions.

It can be seen that the data from this test corresponds roughly with the data from the steel wool corrosion test. It is also evident that periodic re-lubrication of wire rope is necessary to ensure that every strand and wire is protected. Otherwise, removal of lubricant by washing, fatigue and axial stresses, and hydrostatic pressures could lead to rope failure from corrosion and wear. However, for long term immersion of wire rope such as oceanographic moorings, it appears that lubrication or any other form of chemical protection should not be used because of the formation of corrosion cells.

## 2.0. DURABILITY

### 2.1. WATER WASHOUT TEST

OBJECT: to acquire a comparative measure of the water washout resistance of the lubricant samples.

APPARATUS: steel wool, Mettler scale, electric drill, beakers, salt water, hot plate, large bucket.

PROCEDURE: Pieces of steel wool were formed into small balls, weighed, soaked in lubricant, allowed to drain, and reweighed. Greases were heated until they liquefied before soaking. The balls were then placed on a drill bit, rotated at full speed in a bucket of salt water for 5 seconds, and reweighed the next day after the water had evaporated.

CALCULATIONS:

Water Washout Number= A/B *100

where A=amount of sample left on steel wool

B=amount of sample applied to steel wool

-a high number indicates good water washout resistance;maximum=100

## 2.2. ADHESION TEST

OBJECT: to acquire a comparative measure of the adhesive qualities of the lubricant samples.

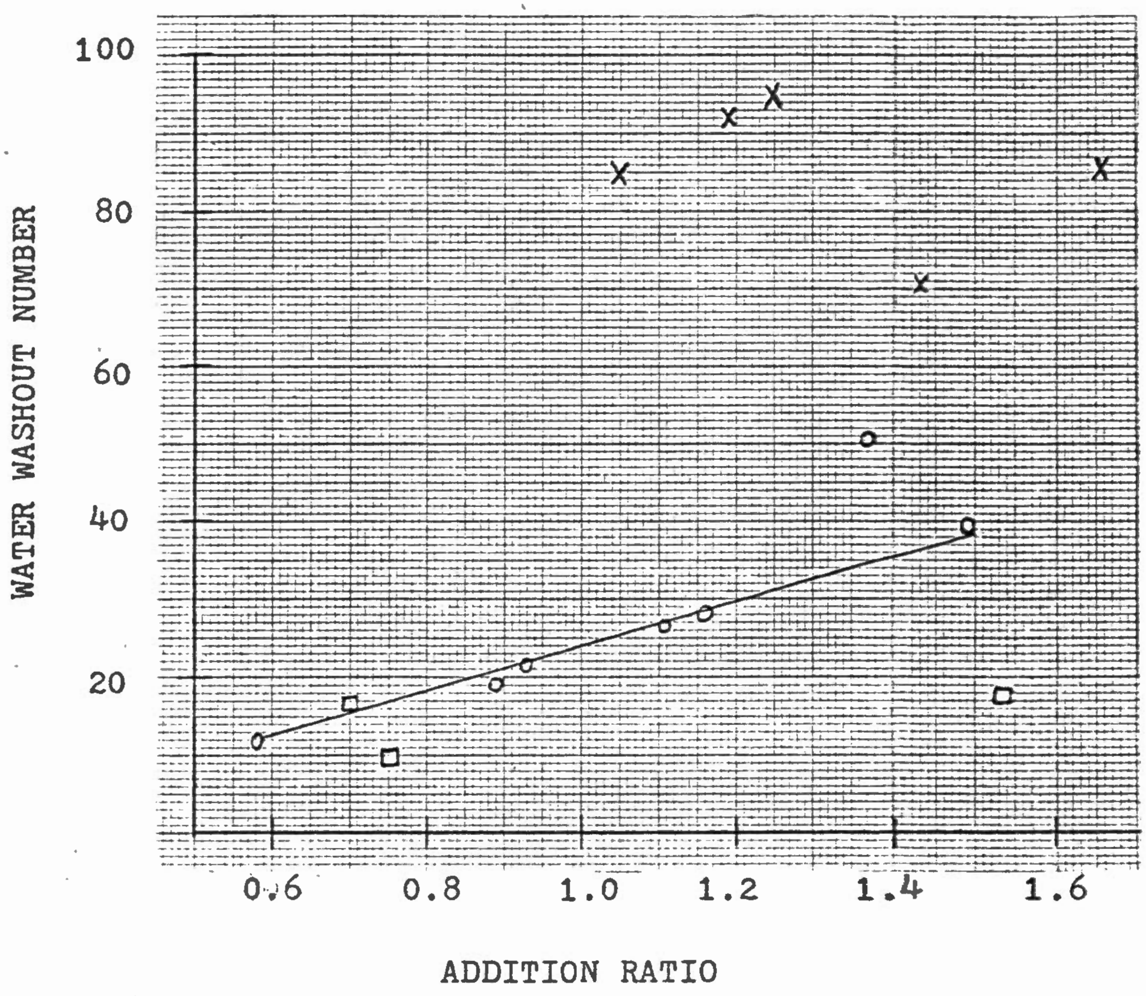
APPARATUS: steel wool, Mettler scale, electric drill, large bucket, hot plate, beakers.

PROCEDURE: same as 1.3.3.A except the steel wool balls are spun in air.

CALCULATIONS:

Adhesion Number is calculated as in 1.3.3.A

PLOT OF WATER WASHOUT NUMBER VS ADDITION RATIO




ADDITION RATIO= $\frac{\text{AMOUNT OF LUBRICANT ADDED TO STEEL WOOL}}{\text{WEIGHT OF STEEL WOOL}}$

X GREASE

O LIQUID

☐ LIQUID CUT WITH A SOLVENT

FIGURE _

TABLE 5 RESULTS OF WATER WASHOUT AND ADHESION TESTS

| NUMBER | WATER WASHOUT NUMBER | ADHESION NUMBER | ADDITION RATIO |
|---|---|---|---|
| 1 | 50.9 | 25.7 | 1.37 |
| 2 | 21.4 | 9.6 | 0.93 |
| 3 | 19.3 | 10.7 | 0.89 |
| 4 | 28.5 | 12.6 | 1.16 |
| 5* | 17.4 | 24.6 | 1.53 |
| 6 | 70.7 | 45.2 | 1.43 |
| 7* | 9.7 | 13.1 | 0.75 |
| 8 | 85.9 | 24.2 | 1.66 |
| 9 | 92.0 | 97.5 | 1.19 |
| 10 | ~95 | 74.6 | 1.25 |
| 12 | 39.6 | 15.3 | 1.49 |
| 16* | 16.4 | 14.7 | 0.70 |
| 17 | 26.3 | 13.1 | 1.06 |
| 18 | 89.7 | 97.7 | 1.05 |
| 19 | 11.8 | 15.3 | 0.58 |
| 20 | 26.6 | 12.2 | 1.06 |

* CONTAINS A SOLVENT

## DISCUSSION

As expected, the results show that a lubricant's adhesion and water washout resistance are directly related to its viscosity. The high viscosity samples, which includes 3 heavy black greases, a sticky, very viscous liquid, and vaseline, generally had superior results. The liquids, of course, had lower values.

The results also show that addition ratio varies according to viscosity. As can be seen from figure 1, a graph of water washout number vs addition ratio, most liquids follow a linear relationship. However, 3 liquids do not follow this pattern. Lubricant #1 has a higher water washout number than normal, but this sample is the most viscous of the liquids. The other 2, #5 and #7, have lower numbers than expected. Both these lubricants have been cut with a solvent, suggesting that the presence of a solvent can weaken the water washout resistance of a lubricant. Also, note that for most liquids, the water washout number is roughly twice the adhesion number. This does not hold true for the three liquids that have been cut with solvents-both numbers are about equal.

It is important to realize that these results are not indicative of actual lubricant loss from a working rope. This is a comparative test only.

## 3.0. TEMPERATURE

OBJECT: to observe any changes in lubricant consistency when the samples are exposed to low temperatures.

APPARATUS: small paper cups, freezer

PROCEDURE: The samples were placed in a freezer where the temperature was approximately -15C. These samples were periodically checked for any changes in consistency.

TABLE 6 RESULTS OF TEMPERATURE TEST

Net Changes After 30 Day Exposure

| Sample | Comments |
|---|---|
| 1(L) | hard, won't flow |
| 2(L) | slightly more viscous |
| 3(L) | soft, waxy solid |
| 4(L) | slightly more viscous |
| 5(L) | more viscous |
| 6(G) | slightly more viscous |
| 7(L) | hard, won't flow |
| 8(G) | slightly harder |
| 9(G) | harder |
| 10(G/L) | very hard, brittle |
| 11(L) | light, waxy solid |
| 12(L) | hard, waxy solid |
| 13(L) | light, waxy solid |
| 14(L) | light, waxy solid |
| 15(L/G) | light, waxy solid |
| 16(L) | more viscous |
| 17(L) | slightly more viscous |

TABLE 6

(continued)

| Sample | Comments |
|---|---|
| 18(L) | very hard |
| 19(L) | more viscous |
| 20(L) | more viscous |

DISCUSSION

Of the 20 lubricant samples tested, 10 experienced dramatic changes in consistency when exposed to -15C temperatures. Numbers 3 and 11-15 changed from liquids to light, waxy solids. Numbers 1 and 7 also liquids, were transformed into hard solids. The last two, #10 and #18, turned into very hard, brittle solids which would undoubtedly flake, crack, and fall off wire rope in use.

None of the lubricants which had major changes in consistency would be acceptable for use. They would not effectively penetrate and lubricate a wire rope in cold weather. On the other hand lubricants such as #2 and #4 had very little change in their consistency and should lose none of their effectiveness in cold weather.

## 4.0. INSULATION

OBJECT: to determine the effect of the lubricant samples on the polyethylene and polypropylene jackets commonly used to insulate conductors in electro-mechanical cable.

APPARATUS: multimeter, polyethylene (PE) and polypropylene (PP) jacketed wire, small glass containers.

PROCEDURE: Lengths of jacketed wire were immersed in the lubricant samples. The jackets were periodically inspected for any deterioration or change. Inspection was carried out (A) visually and (B) by removing the wire from the lubricant, wiping dry, bending several times to encourage cracking, and immersing in water with a current passing through it to detect a breakdown in the insulation. Small pieces of insulation with the wires removed were also immersed and inspected, as these will show any cracking or changes in hardness more readily.

Note: Part (B) was carried out in water because all of the samples are non-conductive.

TABLE 7 RESULTS OF INSULATION TEST AFTER 180 DAYS

| NUMBER | BREAKDOWN OF INSULATION | COMMENTS |
|---|---|---|
| 1 | NO | PE is noticeably softer |
| 2 | NO | -- |
| 3 | NO | PE is noticeably softer |
| 4 | NO | PE is noticeably softer |
| 5 | NO | PE is noticeably softer |
| 6 | NO | PE and PP are both softer |
| 7 | NO | PE and PP are both softer |
| 8 | NO | PE and PP are both softer |
| 9 | NO | -- |
| 10 | NO | -- |
| 12 | NO | PE and PP are both softer |
| 16 | NO | PP softer |
| 17 | NO | -- |
| 18 | NO | PE and PP are both softer |
| 19 | NO | -- |
| 20 | NO | -- |

## DISCUSSION

None of the samples experienced any breakdown of insulation. However, of the 16 samples tested, 10 had effects on one or both of the jackets. The affected jackets were somewhat softer, suggesting that some degree of lubricant penetration had occured.

These results indicate that none of the lubricants tested should affect insulating jackets in any adverse way. However, a major manufacturer of wire rope reported that a customer had used a field dressing which deteriorated the insulating jacket of an E-M cable.

## 5.0. WATER DISPLACEMENT

OBJECT: to determine the ability of a lubricant to displace water and subsequently prevent corrosion. These results will be compared to those from 1.0. to determine if there is a correlation between the two, as concluded in D.R.E.P. Materials Report 71-C, "Protective Greases For Sea Water Towing Cables."

APPARATUS: steel plate, pipette, magnifying glass

PROCEDURE: A mild steel plate was sectioned off and used for the following two tests:

A) Drop Test: A drop of salt water and a drop of lubricant were placed beside each other so that they were just touching.

B) Smear Test: A small amount of lubricant was smeared on to an area of about 1cm.x1cm., and a drop of salt water placed on top of the smear.

Important Events To Observe

-does the sample encircle and/or displace the water drop in the drop test?

-does the water drop penetrate the smear?

-when does corrosion begin?

TABLE 8 RESULTS OF DROP TEST

| SAMPLE | WATER DROP ENCIRCLED | WATER DISPLACEMENT | CORROSION 2 HRS. | CORROSION 24 HRS. | DEGREE OF RUST AFTER 20 HRS. |
|---|---|---|---|---|---|
| 1 | Y" | Y-N | N | Y | 1 |
| 2~ | Y" | Y | N | N | 0 |
| 3~ | Y" | N | N | Y | 4 |
| 4~ | Y" | Y | N | N | 0 |
| 5 | N | N | N | Y | 2 |
| 6~ | N | N | Y | Y | 2 |
| 7 | Y" | N | Y | Y | 1-2 |
| 8~ | N | N | Y | Y | 3 |
| 9 | N | N | Y | Y | 3 |
| 10 | N | N | Y | Y | 3 |
| 11~ | Y | N | Y | Y | 2 |
| 12 | N | N | Y | Y | 2 |
| 13 | N | N | Y | Y | 2 |
| 14 | Y(75%) | N | N | Y | 1 |
| 15 | N | N | N | Y | 4 |
| 16~ | Y" | N | Y | Y | 4 |
| 17 | Y" | N | Y | Y | 4 |
| 18 | N | N | N | N | 4 |

TABLE 8

(continued)

| SAMPLE | WATER DROP ENCIRCLED | WATER DISPLACEMENT | CORROSION 2 HRS. | CORROSION 24 HRS. | DEGREE OF RUST AFTER 20 HRS. |
|---|---|---|---|---|---|
| 19~ | Y" | N | N | Y | 1 |
| 20 | Y" | Y | N | N | 0 |
| 21 (CONTROL-WATER ONLY) | | | Y | Y | 3 |

~ INDICATES A SAMPLE WHICH MIGRATED CONSIDERABLY ON THE PLATE

" WATER DROP IMMEDIATELY ENCIRCLED BY SAMPLE

DEGREE OF CORROSION

0 NONE

1 BARELY DETECTABLE

2 SLIGHT

3 MODERATE (INCLUDES CONTROL)

4 HEAVY

TABLE 9 RESULTS OF SMEAR TEST

| SAMPLE | WATER PENETRATES SAMPLE? | CORROSION AFTER 20 HOURS |
|---|---|---|
| 1 | Y | N |
| 2~ | N | N |
| 3~ | ? | N |
| 4~ | ? | N |
| 5 | Y | N-Y |
| 6~ | N | N |
| 7 | Y | N |
| 8~ | N | N |
| 9 | N | N |
| 10 | N | N |
| 11~ | Y | Y |
| 12 | Y | N |
| 13 | Y | Y |
| 14 | Y | N |
| 15 | Y | Y |
| 16 | ? | N |
| 17 | N | N |
| 18 | N | N |
| 19~ | N | N |

TABLE 9 (CONTINUED)

| SAMPLE | WATER PENETRATES SAMPLE? | CORROSION AFTER 20 HOURS |
|---|---|---|
| 20 | N | N |

~ INDICATES A SAMPLE WHICH MIGRATED CONSIDERABLY

DISCUSSION

As can be seen from the results of the drop test, the samples which offered the best protection were those which displaced the salt water drop (no.'s 1,2,4,and 20). This observation also corresponds with the results of 1.1., Steel Wool Corrosion Test.

An important observation made during this test was that many of the liquid samples immediately encircled the water drop. All of these samples protected the steel plate to some degree except for #3 and #16.Sample #3, in fact, forced the drop into a small, circular bead. One might have thought that this sample would offer protection with its ability to make water bead. However, corrosion, as with #16, was more severe than the control.

The smear test did not reveal as many useful results as did the drop test. All but three samples, no.'s 11, 13, and 15, prevented corrosion of the steel plate. Only these lubricants allowed the water drop to penetrate to the plate (two others allowed partial penetration).

It is important to note that this test does not give a fair comparison between a liquid and a grease. While a grease does not have the ability to migrate and encircle a water drop that a liquid has, a liquid cannot provide the purely physical "barrier" type protection of a grease.

## 6.0. PENETRATION

OBJECT: To determine the degree of penetration achieved in a mechanical cable when lubricated A) by hand and B) under pressure.

APPARATUS: Masto lubricator, paint brush, 7/8" 6x19 fibre core galvanized cable (unlubricated).

PROCEDURE: Lubricant #5, a medium viscosity liquid, was applied to a "dry" 7/8" mechanical cable 1) with a brush, and 2) with the MASTO lubricator at 60 and 120 psi. The cable was pulled through the MASTO manually at about 1 ft./sec. After 1/2 hour, 1 strand was removed and pulled apart to inspect for penetration.

RESULTS: In all three cases, lubricant reached the fiber core. When the individual strands were pulled apart, a thin film of lubricant was found on the wires at the core of the brushed section. At 60 psi, a heavy coating of lubricant had penetrated through the first layer of wires, but the wire at the core had only a thin layer of lubricant. The section lubricated at 120 psi had good penetration through to the core.

Checking the penetration of this 7/8" cable represents the worst case that would be encountered at the Institute. The largest mechanical cable on hand is 3/4", and lubricant penetration into double armoured E-M cable will not be a problem.

As a result of this test, it is recommended that when wire rope less than 1" is lubricated with a liquid, a pressure of at least 120 psi is required in order to achieve adequate penetration at rope speeds of about 60 ft./min. If the rope speed is higher, the pressure should be increased accordingly.

## 7.0. CONCLUSION

The results obtaiined indicate that lubricant #4 should be the most suitable for oceanographic wire rope. Lubricant #1 also would have been considered were it not for the fact that it hardens at low temperatures. Preliminary recommendations prior to the completion of 1.2., Cable Corrosion Test, suggested that lubricant no.'s 2 and 20 might also be acceptable. However, sample #4 showed better results in test 1.2., so we are therefore recommending that Prelube lubricants be used as a field dressing for oceanographic wire rope.

A decision was made at the beginning of the program to use a liquid instead of a grease for reasons previously discussed. However, of the several greases tested, Ropetex EP proved to be an excellent corrosion inhibitor and would have been recommended had a grease been required.

Two of the most important properties on which selection was based were corrosion resistance and durability. However, another critical property which was not analyzed was the ability of the samples to reduce frictional wear through lubrication. Although not as important as corrosion resistance in most cases of oceanographic wire rope use, it is a property which would have been analyzed had resources allowed.

Lubricant #5, another Prelube product, was cut with #2 diesel as an experiment. Although this combination did not perform as well as Prelube 6, Prelube 14 itself is a more viscous, chemically identical version of its brother, only with more corrosion inhibitors. It would not have the penetrating ability of Prelube 6, but where it could be applied under pressure Prelube 14 could be used. This product would provide better lubrication, durability, and corrosion resistance.

Undoubtedly there are other suitable wire rope lubricants available which our product search did not reach. This, combined with new lubricants that are always coming out on the market, makes it difficult to keep abreast of these products.

The user should ensure that they are applying a suitable field dressing to their wire rope. Consulting with other users who have experience in the field, or carrying out independent testing in the lab and in the field is recommended. By using a good field dressing and following proper maintenance procedures, rope life can be increased and operating costs minimized.