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(6) DESTRUCTION OF CABLE INSULATION BY RODENTS AND OTHER BIOLOGICAL AGENTS

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(10) Harold P. Vind[redacted].

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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

DESTRUCTION OF CABLE INSULATION BY RODENTS AND OTHER BIOLOGICAL AGENTS

Technical Note N-923

Y-R005-17-01-002

by

Harold P. Vind, Ph. D.

ABSTRACT

Very few quantitative records of cable damage by any agents have been published, hence, it is difficult to ascertain the extent attributable to rodents and other biological agents. Such damage is probably of relatively minor economic consequence but it can result in the disruption of a military communication at a critical time.

Though bare insulated cable is very susceptible to damage by insects and rodents, cable protected by 5-mil steel tape or by 10-mil copper tape is relatively immune to animal attack. Numerous attempts are being made to replace the metal tapes by lighter weight polymeric sheaths to which insect and rodent repellent chemicals have been added. The rodent resistance of the chemically treated sheaths is usually somewhat limited because gnawing rodents possess two pairs of lips, an adaptation which enables them to gnaw into material without getting any of the material into their mouths. Nevertheless, statistical analysis discloses that chemical barriers do afford some protection against rodents, and the barriers retard or prevent attack by insects and microorganisms.

A well rounded research program on the protection of electrical cables from biological attack was recently initiated at the U. S. Army Electronics Command, Fort Monmouth, New Jersey. Participating laboratories are the U. S. Army Natick Laboratory, Natick, Massachusetts and the U. S. Fish and Wildlife Service Laboratory, Denver, Colorado. Research on the development of termite-proof plastics for general use, including the sheathing of electric cables, is underway at the Naval Research Laboratory, Washington, D. C. and at the Forest Insect Laboratory. The studies are sponsored by the U. S. Naval Facilities Engineering Command.

INTRODUCTION

The U. S. Naval Civil Engineering Laboratory (NCEL) has conducted a survey on the biological deterioration of insulated electric cables. The primary purpose of the survey is to ascertain the need for increased research effort on methods for protecting insulated electric cables from gophers and other gnawing animals.

NATURE AND SCOPE OF PROBLEM

Most electrical cable is jacketed or sheathed by several layers of electrical insulating materials such as lead, rubber, jute, cotton, tar asphalt, or various synthetic resins or fibers.[1] A layer of steel or copper tape is often wrapped about the insulated cable to protect it from external damage, and finally a water repellent layer or coating is added to prevent corrosion of the metal tape.

Although the deterioration of electric cables is usually caused by mechanical, electrical and chemical forces, it can also occur in consequence of biological processes.[2] One or more of the layers of protective or jacketing materials is often destroyed by microorganisms, marine invertebrates, insects, rodents, or other gnawing animals. The problem is of special concern to the communications industries and to the armed services.

It is difficult to obtain accurate information as to the extent of cable damage attributable to biological processes. Giblin and King,[3] in perhaps the only quantitative survey pertaining to biological attack on insulated cables, reported that of 1663 cable failures occurring in Switzerland over a ten year period, 110 were caused by corrosion and 71 by rodents.

Not more than a few dozen articles on the subject of biological attack on insulated electrical cables have appeared in the technical literature during the past 30 years. E. G. Linden,[4] who heads the research on cable deterioration at the U. S. Army Electronics Component Laboratory, Fort Monmouth, New Jersey, expressed the view that, although cable damage by gnawing animals may result in the failure of military communications at a critical time, such damage is generally not extensive. The Phillips Petroleum Company,[5] on the other hand, report that in their investigations at Bartlesville, Oklahoma, 50-80 percent of the cable samples buried in untreated soil, including samples of armored cable, are damaged within six months by gnawing animals. Apparently biological attack on insulated electric cable is either relatively rare or it is so common place that it is not recognized as a problem.

Biological attack on insulated electrical cable is potentially severe at military installations in Southeast Asia. Giblin and King[3] and numerous others[4,6] report that cable insulation in tropical climates can deteriorate and fail in less than a year. On at least one occasion during the current conflict, the electrical insulation of field communication systems in the rice paddies of Vietnam has been damaged by rodents.[4] Such damage could result in the interruption of battle field communications at a critical time. Fortunately, such occurrences do not appear to be numerous.

During World War II, Greathouse and Wessel[7] reviewed in some detail all phases of biodeterioration at U. S. military installations in the Southwest Pacific. They merely mentioned the possibility of biological attack on cable insulation materials.

Materials used for protecting and insulating electrical cables vary considerably in their resistance to fungus attack.[8] In the unplasticized form, synthetic organic polymers such as polyethylene or polyvinyl chloride are not readily attacked by common fungi. Cellulose derivatives, however, are slowly attacked and numerous natural materials are rapidly attacked by microorganisms. Materials in the latter category are natural rubber, asphaltic compositions, polymers plasticized with vegetable oils, and cellulosic wraps and fillers such as jute and paper. Microbial decomposition of jute wrapping often liberates products which cause the underlying lead sheath to corrode.[9]

Numerous studies have been made of the effect of moisture and fungi on the electrical resistance of cable insulation.[10,11,12] According to some workers, electrical resistance increases in the presence of fungus growth even if the insulation itself is not attacked or even before it exhibits evidence of deterioration. Other workers refute this, however, and claim that decreased electrical resistance is due entirely to moisture since the decrease occurs regularly in a moist environment even if mold growth is prevented by fumigation.

Electrical cable potting compound for the connectors of cable assemblies must be replaced every three months at the Panama Canal Zone.[4] The potting compound, an ether type polyurethane polymer, undergoes hydrolysis via a reaction believed to be bacterial, though this has not been proven.

Snoke and Richards[13] reported on the destruction of lead sheathed submarine telephone cable by a marine mollusk, probably a member of the family Pholadidae. It has also been reported[3] that Teredo navalis can burrow into the woody fibers of a jute overwrap and then into the lead sheath.

Insect larvae frequently burrow into the insulation of above ground cables and leave the cable sheaths pocketed and pitted with neatly bored holes and depressions.[3] The guilty insects usually belong to one of numerous species of beetles. Some moths also attack cable insulation removing small pellets of lead from the cable sheathing which they incorporate into their cocoons. Subterranean termites, particularly in tropical soils, can cause damage to cables at depths of up to ten feet. Damage is attributed to the saw tooth jaws of the worker termites and to the acidic secretions of the soldier termites. Composition of the secretion is apparently unknown.

Virtually any cable accessible to mammals and birds is subject to external damage.[14] Aerial, surface and underground cables and wires have all been damaged by rodents and other small animals. Electrical insulation of the electric wiring systems in buildings and vehicles have been similarly damaged. Animals responsible for the damage include gophers, mice, rabbits, squirrels, rats and numerous other rodents. On occasions coyotes, foxes, cattle, bears and birds have been similarly indicted.

Most of the western half of the United States is infested with pocket gophers.[15] Since World War II, the major telephone companies of the U. S. have buried most of their cross-country cables. Initially they employed bare insulation on the cables and were forced to expend considerable sums in replacing cable damaged by pocket gophers. The gopher problem was largely overcome by wrapping the cables with a protective armor of steel or copper tape.

Some of the rodents which attack insulated electric cables are quite large. In Louisiana, the rodent called "nutria" or "coypu," which weighs around 25 pounds, has been blamed for the destruction of cable protected by sheathing of high density polyethylene.[14]

In New Mexico, cable insulation is frequently damaged by wood rats, which are also called pack rats. They have the habit of clearing the paths between resting sites and food sources by removing any object they can.[14]

In summary, biological attack of insulated electrical cables and wires takes many forms. Various types of insulation and armor and a great variety of organisms are involved. Only one or two reports are usually available to substantiate the attack of a given insulation or sheathing material by a given animal or microorganism. Hence, it is difficult to ascertain whether biological attack on insulated cables occurs quite generally or is confined to isolated events.

EFFORTS UNDERWAY TO SOLVE PROBLEM

Research effort to eliminate biological attack on insulated electric cables has been sporadic and not very extensive. Published reports of research performed by utility firms and by manufacturers of electric cable and equipment have been especially scarce. The latter institutions must have expended considerable (unpublished) effort on the development of improved cables. Such effort probably did not include investigations of rodent repellents and fungicides per se, but may have included field tests of experimental cable and hence observations of cable resistance to biological attack.

Shortly after World War II, the Bell Telephone Company briefly investigated ways to protect the West Coast coaxial cable system from pocket gophers.[15]

They found that an armor of 5-mil steel tape or 10-mil copper tape provided adequate protection. Bell Telephone Company scientists apparently have terminated these investigations of rodent repellency, though they have since reported on the resistance of organic materials and cable structures to marine biological attack.[16]

Chemical companies have patented numerous chemicals as agents for repelling rodents.[17,18,19,20] The agents are proposed for use in protecting objects, cables and packaging material from rodents and insects, and for treating all soil surrounding pipes and cables, thereby rendering the soils rodent and insect proof. Though the companies made many claims for the chemicals, they performed very few experiments to vindicate those claims.

The U. S. Fish and Wildlife Service in 1946 conducted one of the earliest government sponsored investigations[14] on methods for rodent-proofing communication wire. Though the investigation was terminated a year later, numerous related studies on rodent repellents and rodenticides continued. Studies were made of repellents for the control of mammal damage to plants,[21] of rat-proofing agents for cardboard boxes and paper bags,[22] and of rodent and termite-proofing agents for soils.[14] Recently the Fish and Wildlife Service commenced a new series of investigations on methods for rodent-proofing insulated electrical cable. The investigations are limited by the availability of personnel and funds.

In 1966, a research program on rodent resistant cable materials was undertaken jointly by the U. S. Army Electronic Command, Fort Monmouth, New Jersey, and the U. S. Army Natick Laboratories, Natick, Massachusetts.[4,23a,23b] The latest progress report for the joint undertaking also lists the U. S. Fish and Wildlife Service Laboratory, Denver, Colorado, as a participant. Mr. Erick Linden heads the phase of the research that is performed at Fort Monmouth; Dr. John Pratt, that performed at Natick; and Mr. James Tigner, that performed at Denver. The program is well rounded and hopefully will be sustained as a continuing effort.

Research on the development of termite-proof plastics for general use, including the sheathing of electric cables, is underway at the Naval Research Laboratory, Washington, D. C. and at the Forest Insect Laboratory, Gulfport, Mississippi. The studies are sponsored by the U. S. Naval Facilities Engineering Command.[24]

TEST METHODS

Numerous test methods have been employed to evaluate the effectiveness of agents for preventing biological attack on cable materials. A few of them are briefly described below.

In tests performed by the Bell Telephone Laboratories,[15] gophers were placed in a corrugated metal ash can partly filled with dirt. The only escape route from the can was via a six inch square opening cut in the bottom of the cans. The holes were partly blocked by segments of the test cable. Once a week the gophers were transferred to other cans and the cable samples were examined for evidence of rodent damage.

In a test of rodent repellency performed at the U. S. Army Natick Laboratories,[23b] small burlap bags were impregnated with various formulations of a group of compounds known to be repellent to rodents. The bags were filled with wheat and each of ten bags of each treatment were placed in cages with house mice. Refusal to eat the wheat in a given bag was an indication that the rodent repellent applied to the bag was effective. The U. S. Fish and Wildlife Service conducts a very similar test of rat-repellency using chemically treated cardboard containers filled with rat feed.[22]

At the Central Laboratory T.N.O., Delft, Netherlands, tests were made of the resistance of polymeric materials to gnawing animals.[25] Both mice and rats were employed in the tests. Well fed males and females were separated by a barrier or fence made of the test cable. The fence was rotated through several cages with different pairs to compensate for individual variation. Results were registered photographically and by weight-loss determinations of the specimens.

Resistance of cable insulation to microbiological attack is frequently measured by ability of the microorganisms to grow with no other carbon source.[10] Measurements of the electrical resistance of the cable insulation are employed as indices of deterioration.[11]

The most commonly employed tests of the resistance of cables to biological deterioration are field tests. Samples of the test cables are simply buried for given periods of time and then removed for examination.

POTENTIAL SOLUTIONS

Applied and experimental methods for preventing biological attack of insulated cables are briefly as follows:

Armors and Protective Sheaths. One of the oldest and most successful methods for protecting insulated cables from attack by rodents and other gnawing or burrowing animals is to wrap them with steel or copper tape.[15] Five-mil steel tape provides adequate protection against most of the animals which might damage insulated cables. The protection provided by this tape is perhaps more adequate than that provided by any other known measure, though unfortunately, steel tape is readily damaged by corrosion. It is also somewhat susceptible to lightning damage. Five-mil copper tape fails to prevent gophers from gnawing into telephone cable insulation, but 10-mil copper tape provides fairly good protection against the gophers and is less apt to be damaged by corrosion and lightning.

For many applications, cables wrapped with 5-mil steel tape or with 10-mil copper tape are too heavy and too bulky.[5] Many attempts are being made to substitute tough polymeric sheaths for the metal tapes. In some instances a measure of protection is obtained with high density polyethylene or with polyvinyl chloride. The degree of protection of the polymeric sheath depends upon the hardness of the polymer and the diameter of the cable.[26] Rodents prefer to gnaw on cables or pipes of small enough diameter to fit inside their jaws and they seldom attack material of more than about half the hardness of their own teeth. Insects do not usually burrow into the unplasticized polymeric sheathing but do burrow into polymers plasticized with vegetable oils or other natural products.[6] Unfortunately, the unplasticized polymer lacks the flexibility required of cable sheathing.

Toxic and Repellent Chemicals. Another possible way to reduce the bulk and weight of insulated electric cables is to replace the heavy metal armors with chemical barriers that repel or kill rodents, insects, and microorganisms. The chemicals might be incorporated into the electrical insulation itself or into light weight protective sheaths, they might be applied as thin films adhering to the surfaces of the cables, or they might be applied to the soil surrounding the cables.

The effectiveness of tributyltin chloride as a rodent-proofing agent for insulated cable is being evaluated at the U. S. Fish and Wildlife Service Laboratory. It is being evaluated both as an agent for direct application to electric cables and for treating the surrounding soil. Although the tests have not been completed, they do indicate that a least some degree of protection is afforded by tributyltin chloride.

The Phillips Petroleum Company has evaluated tertiary-butylsulfenyldimethyldithiocarbamate as an agent for protecting buried cable from rodents. These tests indicate that the agent provides considerable protection to cables when liberally applied to the soil surrounding the cables and less protection when incorporated into a sheath covering the cable.

In cooperation with the U. S. Army Electronics Laboratory, the Natick Laboratories have investigated methods for coating, impregnating, or otherwise compounding electrical cable sheathing material with known rodent repellents. They have developed several film-forming formulations containing organotin compounds. One of their most promising formulations is a mixture of tributyltin chloride in chlorinated rubber. Evaluation of the formulation is not yet complete, but the data obtained thus far indicates that the formulation affords some, though not complete, rodent protection to insulated electrical cables.

The Naval Research Laboratory, Washington, D. C., is attempting to develop insect-proof jacketing material for cables.[24] Dieldrin and other insecticides, in strengths of from 1 to 15 percent, have been incorporated into polyethylene, polyvinyl chloride, and other plastic materials. The various combinations are being exposed to termite attack under controlled conditions. To date, the results have been somewhat inconclusive, occasionally with greater variation between lots of the same combinations than between different combinations. While there have been failures with plastics containing persistent insecticides, there have also been instances in which incorporation of the insecticides has successfully protected the plastic from termite attack.

At some U. S. naval facilities, somewhat different results were obtained with dieldrin. "During a visit to the Philippine Islands, 10 to 14 April 1967, Dr. W. S. Haynes of the U. S. Naval Civil Engineering Laboratory talked to Mr. Y. L. Ching, Materials Branch, Construction Division, OICC Southwest Pacific. Mr. Ching said that because of earlier problems with termite attacks on direct burial rubber cable in the Battle Monument area at Fort McKinley and on lead covered cable at Clark Air Base, a local firm had worked with him in developing a polyethylene insulated and jacketed cable containing one-half percent dieldrin in the plastic, with good results. Direct burial electrical cable of this type was installed five years ago at Clark Air Base and is still providing good service. Mr. Ching said that previously termites had bored right through lead coverings--he theorized that during the rainly season when the ground gets soaked the termites may like the bit of heat emitted by the lead cable--that they perhaps bored into it for extra warmth and to hatch their young."[27]

The rodent resistance of protective chemical barriers for insulated electrical cable is, in general, somewhat limited because gophers and other gnawing rodents possess two pairs of lips; an adaptation which enables them to gnaw into material without getting any of the material into their mouths. Nevertheless, statistical analysis of test results discloses that chemical barriers do afford some protection against rodents, and the barriers retard or prevent attack by insects and microorganisms.

Physical Methods. Other proposed methods are to employ pulsating electric currents, noise makers, and numerous other scaring devices.[14] None of the devices tested thus far have been successful.

Tigner[14] at the U. S. Fish and Wildlife Service Laboratory suggested that manipulating and compacting the soil in the trenches surrounding buried electric cables might tend to protect them from burrowing animals; or that materials such as crushed rock might be added to the trenches. Apparently he did not engage in experimental studies to explore these ideas, however.

CONCLUSIONS

Service records are prerequisite for a reliable decision as to the need for research on the biological deterioration of insulated electric wires and cables. Records are needed which will show how much cable is employed, how long it lasts, and why it fails.

From the limited information now available it appears that biological deterioration of insulated electric cables is a relatively minor problem at most U. S. naval facilities, but can result in the disruption of military communication at a critical time.

RECOMMENDATIONS

A well rounded research program on the biological deterioration of electric cables is already underway at other government laboratories. Additional laboratory effort at the U. S. Naval Civil Engineering Laboratory is not recommended at this time; but it is recommended that naval facilities institute a record keeping system that will provide the data required for an accurate assessment of the cause, extent and prevention of cable deterioration.

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Though bare insulated cable is very susceptible to damage by insects and rodents, cable protected by 5-mil steel tape or by 10-mil copper tape is relatively immune to animal attack. Numerous attempts are being made to replace the metal tapes by lighter weight polymeric sheaths to which insect and rodent repellent chemicals have been added. The rodent resistance of the chemically treated sheaths is usually somewhat limited because gnawing rodents possess two paits of lips, an adaptation which enables them to gnaw into material without getting any of the material into their mouths. Nevertheless, statistical analysis discloses that chemical barriers do afford some protection against rodents, and the barriers retard or prevent attack by insects and microorganisms.

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