

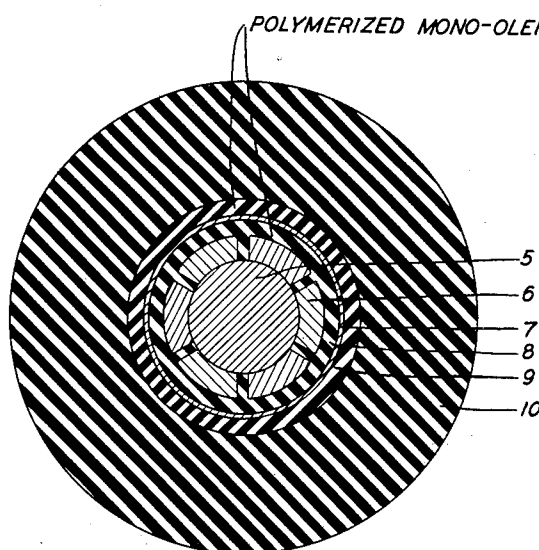
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INSULATED CABLE

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INSULATED CABLE

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This invention relates to improved deep-sea communication cables of the type insulated with rubber, gutta-percha and substitutes for these materials, and more particularly to an improved impregnating substance especially adaptable for use as a pressure equalizing substance for continuously loaded cables.

The purpose of continuous loading is to increase the inductance of a cable conductor or circuit and one method of doing this, commonly employed, is to wrap the copper conductor with a fine tape or wire of highly permeable magnetic material applied in a spiral throughout the entire length of the conductor or throughout relatively long portions thereof. The plastic insulation proper consisting of gutta-percha, compositions known as paragutta consisting of gutta-percha and balata with specially treated rubber, waxes, or vulcanized rubber, etc., is then applied over the tape. Early in the use of such cable it was discovered that the plastic insulation caused stresses or strains to occur in the magnetic material, which greatly reduced the permeability thereof before, during or after laying the cable and generally had a detrimental effect which impaired the usefulness of the loading material. To overcome this difficulty use has been made of so-called pressure equalizing substances. Generally speaking, these consist of materials of good insulating properties which remain semiliquid for at least a considerable time after the cable is manufactured and preferably for an indefinite time. Among the substances so employed as the pressure equalizing substance have been fluid bitumen and also depolymerized rubber prepared according to various special processes known to those skilled in the art. The latter is sometimes referred to by the rather unscientific expression "melted rubber."

Some of the properties of an entirely satisfactory pressure equalizing material are that it must not chemically attack the copper conductor, that it must not attack the magnetic loading material or react therewith, that it must not contain any foreign substances or impurities which might attack the copper or the loading material, that it must not be too quickly or readily absorbed into the insulating material proper, and if so absorbed, it must not impair the physical or electrical properties of the insulating material.

The electrical properties of the pressure equalizing material itself are of great importance. For reasons known to those skilled in the art a high leakage or a high specific inductive capacity in

the pressure equalizing substance may under certain conditions have a considerable effect in increasing the attenuation of cable and thereby decreasing its usefulness as a transmission conductor. For this reason a decrease in the dielectric constant K , a decrease in the leakage of the pressure equalizing substance and a reduction in the quantity G/C (leakance divided by capacitance) of the pressure equalizing substance will result in an improved cable. If these desirable characteristics can be obtained without the sacrifice of any other desirable or necessary properties the result is a valuable contribution to the art of cable manufacture.

Furthermore, in the manufacture of unloaded conductors for deep-sea communication cables, it is customary to make the conductor of several strands having the interstices filled with a semiliquid filling material, a small portion of which often lies between the conductor and the insulation proper in the completed cable core. For analogous reasons it is desirable that this filling material have a low leakage and a low dielectric constant. In so far as the filling material lies within the conductor interstices it has but small effect electrically and one of its functions is to act as a seal against the flow of water along the cable.

In accordance with this invention a primary constituent of pressure equalizing material or filling material for plastically insulated cable conductors consists of pure polymerized mono-olefin, a product having the consistency of a heavy oil or syrup both at ordinary temperatures and at the temperature of the ocean bottom, namely, 3.3°C . This polymerized mono-olefin substance may be prepared in accordance with methods known to those skilled in the chemical art.

In the preferred embodiment of this invention the pressure equalizing material made as described herein is applied to a continuously loaded submarine cable of the general structure shown in the attached drawing.

In accordance with this drawing, which is a sectional view of the cable and in which no attempt has been made to indicate dimensions of the parts to scale, the central conducting core, preferably of high grade copper built up of a central strand 5 and a plurality of segmental strands 6 which are shaped to conform to the central strand and to present a smooth outer surface.

The magnetic loading 7 is in the form of a thin, narrow ribbon which is wound helically with close abutting turns about the conducting

core in such a manner that a small angular space is provided between it and the outer surface of the strands 6.

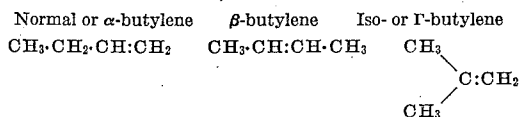
The loading material may be a nickel-iron alloy specially heat treated after being placed on the conductor so it will have a permeability greatly in excess of that of iron. Alloys of this kind have been described in Patent 1,586,884 granted to G. W. Elmen on June 1, 1926. As is well known, the magnetic properties of certain of these alloys and of other magnetic materials suitable for loading purposes are deleteriously affected by strains in the material. Thus when an alloy of this type is used for loading the submarine cable and has been treated to have a high permeability, the effect thereupon of the extremely high hydrostatic pressure existing at deep sea bottom results in a greatly diminished inductance of the cable as compared with the inductance measured under atmospheric conditions unless precautions such as here described have been taken to prevent unequal distribution of the pressure within the cable, thereby eliminating the strains in the loading material.

The interstices within the loading are preferably filled to the exclusion of all the air with the pressure equalizing compound in accordance with this invention.

In the drawing, the pressure equalizing material which surrounds the magnetic loading tape is indicated by the numerals 8 and 9 and the principal insulation 10 of the cable core is conventionally illustrated.

A typical pressure equalizing material is prepared by treating mono-olefins (in a typical and preferred case of four carbon atoms) separately or in mixtures under pressure with inorganic halide catalysts such as anhydrous aluminum chloride, stannic chloride, boron fluoride, titanium chloride, etc. The practice generally is to polymerize these mono-olefins singly or together while they are dissolved in butane. Following the polymerization reaction conducted for various periods of time at temperatures generally below $-10^{\circ}\text{C}.$, the catalyst is removed by filtration and washing and the butane distilled from the polymer.

Generally, branch chain mono-olefins polymerize more rapidly than straight chain mono-olefins. The general formula for these mono-olefins is C_nH_{2n} . Ethylene is the lowest member of the series and each of the olefin members has one double bond which upon polymerization becomes mutually saturated by joining with a second molecule of itself. As one goes up in the series to the butylenes, for example, the number of isomers increase rapidly. Three isomeric butylenes, for example, are known.



When isobutylene, for example, polymerizes it appears to form a straight chain compound with a great many of the iso-butylene molecules linked together with the elimination of most of the double bonds in each through mutual saturation.

The next member in the homologous series above butylene is amylene or pentene, five isomeric members of which are known, and so on up the series.

A typical product suitable for present purposes which we will call No. 1 has a molecular weight of about 1200 and has been found by us to have the following electrical properties;

Electrical properties measured at 2000 cycles, $0^{\circ}\text{C}.$ —

Dielectric constant..... 2.25
G/C..... 5

Per cent power factor..... 0.04

Electrical properties measured at 2000 cycles, $27^{\circ}\text{C}.$ —

Dielectric constant..... 2.25

G/C..... 2

Power factor, per cent..... 0.016

Polymerization products of mono-olefins having a lower limit of four carbon atoms up to an upper limit of approximately eight carbon atoms will be satisfactory for the present purpose. A certain proportion of those having as few as three carbon atoms might be admissible but, in general, these are considered less satisfactory. The various butylenes or butenes are typical substances whose polymers are useful for the present purpose. Isobutylene is the preferred raw material because of its relative cheapness and ease and controllability of polymerization.

As variant forms of the invention to produce better pressure equalizing substances polymerized mono-olefins may be mixed with small portions of other substances. By small portions we refer generally to such proportions as 2 to 20 per cent without however closely de-limiting the range which may be employed as this depends greatly upon the material added. Among these other substances which may be dissolved in or mixed with the polymerized mono-olefins by milling or other suitable methods are purified rubber, paraffins, or petroleum hydrocarbons, gutta-percha, balata and similar substances. One method which may be used to combine these substances with the polymerized mono-olefins consists in dissolving the materials in suitable solvents such as carbon tetrachloride, gasolene or naphtha and distilling off the solvent.

The degree of polymerization can be controlled so that the products vary from sticky substances of fluid nature to tough elastic rubber-like materials. The range of useful molecular weights extends from 1000 to about 15,000 as determined by the Staudinger viscosity method, the softest material, of course, having the lowest molecular weight.

In preparing pressure equalizing materials having the desired properties two different procedures can be followed. In one case it is possible to arrive at the desired result by mixing two or more separately polymerized mono-olefin products and in another case an equivalent result can be obtained by polymerizing isobutylene, for example, to the proper degree. An example of the first case is given in the mixture of a polymerized mono-olefin having a molecular weight of approximately 1200 described as No. 1 material and a polymerized mono-olefin having a molecular weight of approximately 15,000, described as No. 2 material. The consistencies of such mixtures are shown in the following table as compared with melted rubber. As a specific example of preparing a suitable pressure equalizing material by controlling the polymerization, isobutylene is polymerized with boron fluoride as a catalyst at a temperature below room temperature to a molecular weight in one case of 1000 to 5000, for example, and in another case where a more viscous pressure equalizing material is desired to a molecular weight of 5000 to 10,000. Materials and mixtures of materials having other ranges in molecular weight may also be desirable.

It is desirable in the general case to provide a material with a range of molecular weights as narrow as possible since materials of too low molecular weight are more readily absorbed by the insulation.

Compositions	Penetration in degrees—1°=0.1 millimeter—using 100 grams load for 5 seconds	
	24° C.	0° C.
A No. 1.....	420	63
B No. 1+2 percent No. 2 of molecular weight 15,000.....	309	50
C No. 1+4 percent No. 2 (molecular weight 15,000).....	238	39
D No. 1+6 percent No. 2 (molecular weight 15,000).....	179	27
E Melted rubber (for comparison).....	163	19

The penetration as here measured refers to the penetration of a plunger with a flat face 1 3/4 inches in diameter.

The superiority of polymerized mono-olefins over melted rubber from the physical point of view is seen in that they can be made softer and so that they will flow more readily at 0° C. than will rubber. Their viscosity or fluidity is readily subject to closer control over a wide range than is melted rubber. Tests also show that the polymerized mono-olefins do not stiffen with time as rapidly as the melted rubber. Another important feature of superiority of these mixtures over melted rubber lies in their electrical characteristics. Comparative electrical characteristics at 2 kc. and 24° C. which are typical are as follows:

	Polymerized mono-olefines	Melted rubber	Asphalt flux
G at 0° C.....	5	135	294
G at 24° C.....	2.6	146	532
Dielectric constant (K) at 0° C.....	2.25	2.53	2.60
K at 24° C.....	2.26	2.54	2.84

We prefer, in general, to use the materials of lower molecular weights since they are cheaper and easier to utilize to prepare the mixtures. In the case of non-loaded paragutta insulated cables, for example, we have employed melted rubber and also asphalt flux to fill the interstices of the stranded conductors and as a very thin coating over the conductors separating the insulation from the copper. This layer must necessarily be kept very thin when using these materials since their electrical characteristics, particularly their G/C values, are considerably poorer than paragutta, being in the neighborhood of about 100 as compared with 10 to 12 of paragutta measured at 25° C. and 2 kc. Since the G/C value of the polymerized mono-olefin products is only 2 to 3, it is readily seen that it will be a distinct advantage to use not only a thin but a heavy layer of this type of material between the conductor and the insulation. This advantage is still more evident in dealing with ordinary gutta-percha insulation instead of paragutta because the electrical losses of gutta-percha at sea bottom conditions are about 30 times higher than those occurring with paragutta. Its electrical effect within the conductor, of course, is negligible and it is placed here to seal against the entrance of sea water along the cable conductor if a break should occur.

In order to improve the dielectric properties

of the gutta-percha or a paragutta core, for example, this can be accomplished by using a layer of polymerized mono-olefin of appreciable thickness, said 5 to 40 mills, between the conductor and insulation. For this purpose it will be desirable to employ a much stiffer mixture than the one containing 6 per cent of type 2 material since there is no pressure equalization effect involved and since a stiffer material will not allow the conductor to be displaced so readily.

Chemically, the polymerized mono-olefins are among the most stable highly polymeric organic materials known. They are pure hydrocarbons and free from any corroding or conducting substances. They have an extremely low water absorption, in fact, almost negligible, and they have an extreme resistance to oxidation being, of course, vastly superior to rubber, gutta-percha, or paragutta in this respect. This oxidation resistance is due primarily to the saturated nature of the polymerized mono-olefin molecules.

The electrical superiority of polymerized mono-olefin per se pressure equalizing substances over melted rubber is indicated by the table hereinbefore given.

In addition to possessing improved electrical properties as shown by the table the polymerized mono-olefin pressure equalizing substances are otherwise technically advantageous in that their other properties are suitable and, furthermore, they are readily obtained in highly pure and uniform condition with respect to the absence of minute portions of foreign substances which might be deleterious. Furthermore, they do away with the necessity for practicing much of the special technique which renders the production of satisfactory partially polymerized rubber difficult.

What is claimed is:

1. An insulated submarine cable conductor consisting of a highly conductive metal surrounded by a highly magnetic metal including as a pressure equalizing material surrounding said magnetic metal a viscous or semiliquid substance consisting principally and as an essential constituent of polymerized mono-olefin hydrocarbons, and thermoplastic insulation surrounding said substance.

2. An insulated cable conductor consisting of a conductor surrounded with magnetic metal including as a filling or pressure equalizing material for the magnetic metal a semiliquid substance consisting of polymerized mono-olefin hydrocarbons of the type produced by polymerizing mono-olefin hydrocarbons having around 4 to 8 carbon atoms per molecule before polymerization with inorganic halide catalysts to a degree of polymerization such that a viscous product results.

3. In a submarine cable, a conductor surrounded with magnetic metal, a principal insulation for said conductor, and a coating around said metal and between said metal and said insulation consisting of polymerized mono-olefin hydrocarbons of from 4 to 8 carbon atoms and having a molecular weight of around 1000 admixed with from 2 to 20 per cent of mono-olefins so polymerized as to have a molecular weight of from 1000 to 15,000.

4. A magnetically loaded cable conductor having the magnetic loading material surrounded with viscous polymerized mono-olefins and thermoplastic insulation surrounding the conductor.

5. A submarine cable of the plastically insulated type having magnetic material therearound including as a pressure equalizing or filling ma-

terial for said inductance increasing material a semiliquid viscous material composed chiefly of polymerized mono-olefin hydrocarbons admixed with minor proportions of hydrocarbon substance of the class including natural or artificial rubber or gutta-percha.

6. A submarine cable having a central conductor consisting of a composite structure made up of a number of metallic strands having interstices between and under them, a principal thermoplastic insulation therearound and a layer of polymerized mono-olefins between the conductor and the principal insulation and thoroughly filling said interstices.

7. A submarine cable conductor having a con-

ducting core, a covering of magnetic material therearound for increasing the inductance and viscous polymerized mono-olefins serving as a strain relieving substance filling the interstices within and around the magnetic material.

8. A submarine cable conductor having a conducting core, a covering of magnetic material therearound for increasing the inductance, and a strain relieving substance filling the interstices within and around the magnetic material, said substance composed chiefly of polymerized mono-olefins mixed with not over 20% of paraffin hydrocarbons.

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