Paragutta, A New Insulating Material for Submarine Cables *

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Gutta percha and balata have proven eminently suitable for the insulation of long deep sea telegraph cables, but their dielectric losses are too high to meet the requirements of submarine telephone cables designed to operate over long distances or of shorter cables employing carrier currents.

This paper describes a new material called paragutta which has been developed to meet the present needs. It consists essentially of the purified hydrocarbons of balata (or gutta percha) and of rubber together with minor quantities of waxes to modify the mechanical characteristics. The purification of rubber particularly with respect to nitrogenous constituents is necessary to effect electrical stability in water. A commercially usable method of purifying rubber is described.

Evidence is furnished that paragutta has all of the desirable thermoplastic and mechanical properties of gutta percha while possessing such superior insulation characteristics as to make it suitable for use on long cables designed for transoceanic telephony. Its use is also advantageous on shorter deep sea cables designed for carrier telephony as well as for ocean telegraphs.

FORMERLY deep sea cables were used exclusively for telegraph purposes but in recent years there has been an increasing use of this type of cable for telephone service. Telephonic communication requires cables of very much superior transmission quality to that needed for telegraph. At the higher frequencies of voice transmission the energy losses in the insulating material become a serious factor and a radical improvement in submarine insulation is called for.

The longest existing deep sea cables operating at voice frequency only slightly exceed 100 miles and the construction of a transoceanic telephone cable with standard materials has been regarded as beyond the practical limits of feasibility.

The installation and rapid expansion of transatlantic radio telephony during the past few years have created a need for a deep sea telephone cable to supplement this service, particularly during periods of atmospheric disturbances. In addition the development of carrier telephony offers possibilities for increasing the traffic over shorter submarine cables. For the shorter cable, the still higher frequencies of carrier telephony make demands upon the insulating material similar to those of long cables operating at voice frequency.

In view of these circumstances an extended study was undertaken of the causes of losses and other electrical weaknesses of submarine insulation and a search has been made for better materials. As a

* *Jour. Franklin Institute*, Jan., 1931.

result of this investigation an insulation called paragutta has been developed which, as the name suggests, is derived essentially from rubber and gutta percha. It is the purpose of this paper to describe this material and give an account of the tests to which it has been subjected to determine its suitability for the purpose.

By virtue of its superior electrical properties, the use of paragutta in place of gutta percha for the insulation of telephone and telegraph cables offers advantages either from the standpoint of improved transmission or the economies in materials of construction which can be made as a result of modified design.

Gutta percha and balata have been the standard materials for the insulation of deep sea cables since the inception of the submarine cable industry some seventy-five years ago. Although these substances are inadequate for modern telephone needs as regards their electrical characteristics, their mechanical properties are peculiarly adapted to submarine insulation. This is so much the case that gutta percha can fairly be taken as a model which must be closely imitated in respect to mechanical characteristics by any successful substitute. This is fortunate since the use of any substitute which differs radically from gutta percha would mean discarding large existing investments in special technique, equipment and trained personnel, and would involve serious risks as to the integrity of cables made with the new material. It may be remarked in passing that no manufacturing process requires a higher degree of insurance against occasional defects than does the submarine insulation art, a fact that has engendered a strong conservatism in the industry.

Because of its almost ideal mechanical properties, the requirements for submarine cable insulation may conveniently be described by reference to gutta percha. Gutta percha insulation, which often includes more or less balata in its composition, is made of raw materials carefully selected for quality, which are thoroughly washed and extremely uniformly blended. The thermoplasticity of the material is of great service in these operations and further permits it to be readily extruded onto a conductor in multiple layers in a continuous sheath with great exactness and freedom from mechanical defects. After being forced around the conductor the material quickly sets to a hard, tough covering when drawn through cold water. Its firmness and toughness are essential to resist subsequent handling operations in the factory, as well as those involved in laying, picking up and repairing. The warm, soft material adheres readily to the conductor and is well adapted to the making of joints in the insulation between core lengths both in the factory and on the cable ship.

In addition to those excellent and unique mechanical properties, gutta percha possesses electrical characteristics peculiarly adapted to submarine cable construction. Its outstanding electrical merit consists in the fact that its electrical characteristics are stable under sea bottom conditions over a great many years.

Gutta percha is obtained from the latex of a large number of species of trees growing wild in the forests of the Malay Peninsula and the East Indian Islands. The products of the various species of trees are by no means of equal value, varying as they do in the content of hydrocarbon, resins, moisture and other substances. Since the material is gathered and worked up upon the spot by primitive people a great deal of carelessness as well as deliberate adulteration is practiced and the material comes upon the market in a dirty condition and in a bewildering variety of forms which almost prohibit effective inspection, standardization and grading.

The essential constituent of gutta percha is an unsaturated hydrocarbon of colloidal nature which is similar in its chemistry to rubber. It is this constituent which makes gutta percha plastic when warm and tough when cold, and which contributes most conspicuously to its electrical excellence as an insulator. The usual gutta percha insulation is the result of blending and washing various grades of crude gutta percha to remove dirt and water soluble components. The hydrocarbon, resin, dirt and moisture contents as determined by analysis of the crude material together with the electrical and mechanical properties after washing are the principal characteristics used to determine whether or not a particular grade of crude gutta percha is suitable for use as submarine cable insulation. The hydrocarbon content of gutta percha insulation when applied to the conductor is usually about 60 per cent, the remainder being mostly the natural resins together with small amounts of very finely divided dirt (humus) and residual moisture. The proteins or albumens in crude gutta percha and balata are almost completely removed by simple washing.

Balata comes from two species of trees of the same general botanical family as gutta percha, but is native to the forest regions of upper South America and is unknown in the gutta percha producing area of the Far East. The latex of the balata tree is more fluid than that of gutta percha, which permits the trees to be tapped and the fluid to be collected at a central point in the forest, where the product from various trees is mixed for recovery of the gum. Because of the small number of species involved and the transportability of the fluid latex, balata is produced in a much more limited number of grades and is cleaner and more dependable as to uniformity of quality. Its essential constituent is the same hydrocarbon which gutta percha contains. In addition to the hydrocarbon, there is present in balata some 40 per cent of resins and amounts of dirt, moisture and other impurities which usually total about 15 per cent. The resins of balata are softer than those of gutta percha and make the product in its raw state a little less desirable than the better grades of gutta percha from the mechanical standpoint. Balata, however, contains a smaller amount of finely divided dirt or humus than gutta percha, which is reflected in its superior electrical characteristics and lower water absorption.

The resins of both gums have been usually included with the hydrocarbon in making submarine insulation. Sometimes, however, a portion of the resins are removed, partly to increase the toughness and partly to improve the electrical characteristics.

There are several methods which may be used for preparing gutta hydrocarbon nearly free from resinous substances. One of these methods involves dissolving the balata or gutta percha in warm petroleum naphtha, filtering the solution from dirt and precipitating the gutta hydrocarbon from solution by refrigeration, leaving most of the resins in solution. A simpler and less expensive method, however, is that of leaching out the resins by simply soaking the sheeted or finely cut material in a suitable grade of petroleum naphtha at ordinary temperature, followed by draining off the solution of resins and finally evaporating the residual solvent from the extracted material.

The completely deresinated hydrocarbon from either source is not suitable for use alone as submarine cable insulation because insufficiently plastic at safe working temperatures, as well as prohibitively expensive. Otherwise the complete deresination of these products would be highly advantageous as, for example, is indicated by the superior electrical characteristics of deresinated balata shown in Table I. A substantial amount of experimentation upon the methods of refining balata has been necessary to secure the excellent electrical characteristics therein indicated but no revolutionary innovation has been necessary.

TABLE I

EFFECT OF RESIN CONTENT ON THE ELECTRICAL CHARACTERISTICS OF BALATA

Material	Electrical Characteristics 0° C., 1 Atm., 2000 Cycles: Dielectric Constant	Specific Conductance Unit = 10^{-12} mho. cm.
Balata	3.1	66
Deresinated Balata	2.6	3
Balata Resins	3.3	52

In attempting to develop a new insulating material for deep sea cables it seemed best to begin with gutta hydrocarbon as a basis, since its mechanical properties are so unique, rather than to attempt to synthesize a new chemical compound which would imitate it. In order to overcome the excessive stiffness of the pure gutta hydrocarbon, as well as its prohibitive cost, it was determined to attempt to blend large quantities of rubber with it, since rubber is the nearest kindred material and is commercially available at low cost. There resulted thermoplastic products of fairly good mechanical characteristics which, however, proved to be insufficiently stable electrically.

Meanwhile, a thorough study was being made of the electrical and physical characteristics of rubber and particularly of the causes of its electrical instability upon prolonged immersion in water. Our hope that such a study would not only reveal the nature of the defects of rubber but also suggest means for remedying them has been realized to a gratifying degree.

Rubber, as is well known, is also derived from the latex of certain trees, chiefly *Hevea Brasiliensis*. This tree has been cultivated in large areas on the plantations in the Far East and the product is obtainable commercially in excellently standardized grades. Its principal constituent is a hydrocarbon scarcely distinguishable from that of gutta percha by chemical means, but radically different from it in physical properties, notably in that it has but a slight degree of thermoplasticity and is far more distensible in the cold state. Aside from the hydrocarbon, rubber also contains small amounts of resins, proteins and other impurities, but the aggregate non-hydro-carbon constituents in the better grades are usually less than 10 per cent in contrast to 50 per cent or thereabouts for gutta percha and balata.

Rubber is used almost exclusively in industry in a vulcanized form, that is, in combination with a small percentage of sulphur. In this form rubber has also been used to a limited extent for submarine cable insulation, but has long been recognized as lacking sufficient electrical stability for deep sea cables designed to carry a heavy traffic. It is still used to a considerable extent with a fair degree of success for insulation on short cables where the electrical requirements are not severe. In tropical waters it has the advantage over gutta percha of greater resistance to teredo attack and to damage by high temperature.

Some years ago an extended study [1] was made of the causes of the electrical instability of vulcanized rubber, which led to the conclusion that the water soluble impurities are largely responsible. These impurities can be removed comparatively readily and satisfactorily in the process of manufacture, and a submarine insulation of a fair degree of stability is thereby attained.

[1] Williams and Kemp, *Jour. Franklin Inst.*, **230**, 35 (1927).

Even so, vulcanized rubber is very inferior to gutta percha for submarine insulation as the necessary manufacturing operations are more difficult and likely to lead to defects. The removal of mechanical impurities is by no means simple because the raw stock is not plastic enough for thorough straining. The lack of plasticity also interferes with multiple covering of conductors, and the process of heating to bring about vulcanization is liable to result in deformation of the insulating layers. The joining and repairing of core lengths insulated with rubber is also more of a problem than with gutta percha, which can be so readily remolded in case imperfections appear in the course of the process.

The methods of electrical stabilization of vulcanizable rubber compositions are only partially effective in the absence of vulcanization and it was therefore necessary to extend the study in an effort to secure the desired electrical properties in rubber in the raw state. It might be supposed that mere admixture of raw rubber with gutta hydrocarbon would produce the necessary stability. This is true only to a limited extent. When the proportions of rubber are high enough to meet the mechanical and economic requirements, the electrical stability is impaired.

Effect of Proteins on Electrical Stability of Crude Rubber Immersed in Water

It has been previously shown that crude rubber contains considerable water soluble impurities and that their removal results in a large reduction in water absorption.[1, 2] Rubber so prepared absorbs no more water than good cable gutta percha but in a raw state when immersed in water, it fails sooner or later as an insulator, often suddenly and completely.

To determine the reason for this electrical instability of crude rubber in water, samples of very pure rubber hydrocarbon completely freed from proteins, resins and other impurities were prepared and tested. It was found that this material not only absorbed very little water but showed practically no change in electrical characteristics as a result of prolonged immersion in water. The impurities natural to rubber therefore seem to be responsible for its instability.

It has been known for many years that crude rubber contains proteins, ordinary plantation rubber containing about 3 per cent. Previous investigators have postulated and shown considerable indirect evidence to the effect that the rubber globules in rubber latex have an adsorbed film of protein around them and that this condition

[2] Lowry and Kohman, *Jour. Phys. Chem.*, **31**, 23 (1927).

also exists in crude rubber. It is also known that latex serum contains a substantial quantity of protein in solution. The preparation of crude rubber from latex by addition of acid or by processes of evaporation of the water by heat undoubtedly results in the precipitation of considerable quantities of this protein which becomes entrapped between the globules as they coalesce. It is easy then to visualize that in crude rubber there exists a continuous phase of protein or a protein network which, acting like most protein matter, absorbs large quantities of water, resulting in paths through which electrical conduction occurs.

Removal of Nitrogen Containing Bodies from Rubber

The problem of developing a suitable commercial method for preparing rubber free from nitrogenous matter offered many apparent difficulties. The proteins are colloidal in nature and in the presence of water form gelatinous masses rather than true solutions. On this account they often cannot be removed by simple washing as can be done in the case of gutta percha and balata. It has been known for some time that proteins can be broken down to water soluble products by boiling with dilute hydrochloric or sulphuric acids. This treatment did not produce satisfactory results in the case of rubber. As a result of many experiments involving a variety of methods, it was found that heating rubber in an autoclave at an elevated temperature in the presence of water alone fairly rapidly brought about the desired hydrolysis of the rubber proteins, converting them to water soluble materials. As a result of subsequent washing, it was found that the nitrogenous bodies had been almost completely eliminated without deleterious effect on the rubber hydrocarbon.

Rubber either in the form of sheets immersed in water or as an aqueous rubber dispersion such as latex can be employed in the process. The treatment of latex, however, results in a more rapid hydrolysis of the proteins. Considerable latitude exists in the choice of conditions, but the following example will suffice to describe one method of carrying out the process: ammonia preserved latex is diluted 1 to 5 with pure water. The latex is then heated in an autoclave for approximately ten hours at 150° C. After cooling it is coagulated with acetic acid and thoroughly washed. As a result of this treatment the nitrogen content of the rubber is found to be less than 0.10 per cent, which is about one fourth that of ordinary plantation crude rubber. Figures 1, 2, 3 and 4 illustrate the relative water absorption and electrical stability of deproteinized rubber as compared with the ordinary crude product. Vulcanized deproteinized rubber was also found to be somewhat superior to ordinary vulcanized crude rubber as regards its electrical stability in water.

In addition to the superior electrical stability of deproteinized rubber, it was found to be more readily plasticized and mixed with gutta

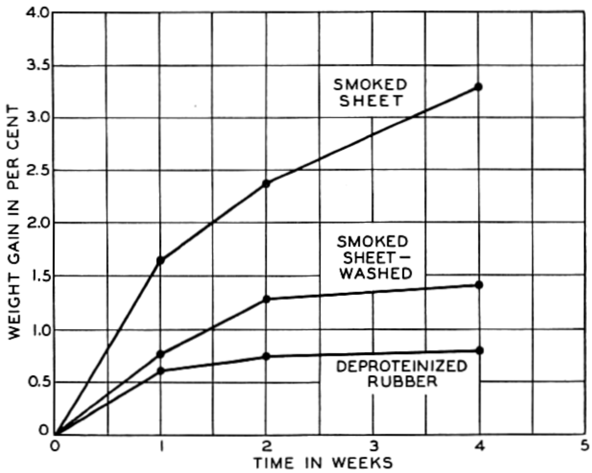

Fig. 1—Effect of washing and removal of protein on the water absorption of crude rubber when immersed in 3.5 per cent NaCl solution at room temperature.

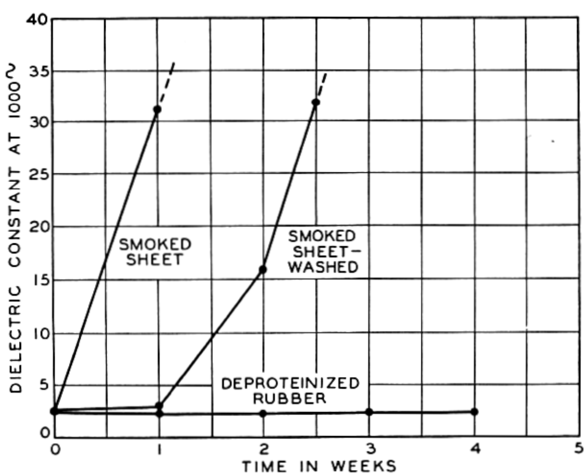

Fig. 2—Effect of washing and removal of protein on the dielectric constant of crude rubber when immersed in 3.5 per cent NaCl solution at room temperature.

than is the case with crude rubber, thereby yielding a product with better thermoplastic properties.

Preparation of Paragutta

As previously stated, the principal constituents of paragutta are deproteinized rubber and purified gutta hydrocarbon. Specially treated hydrocarbon or montan waxes may also be added as a third constituent to modify mechanical properties and reduce cost. The proportions of these constituents may be varied over a wide range to achieve the desired characteristics, but in general rubber and gutta

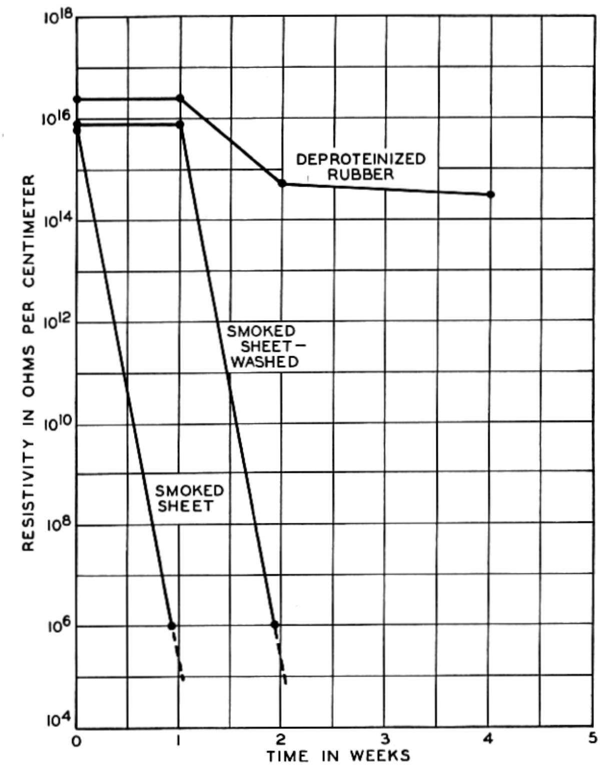

Fig. 3—Effect of washing and removal of proteins on resistivity of crude rubber, when immersed in 3.5 per cent NaCl solution at room temperature.

are used in about equal proportions and purified montan wax may be added up to about 40 per cent. Superior electrical properties, however, result from the use of hydrocarbon waxes, which may be added in amounts up to about 20 per cent. By the proper blending of these materials, a thermoplastic insulation is obtained which closely approximates gutta percha in mechanical properties and is fully its equal as to electrical stability in water. Its specific electrical characteristics represent a substantial improvement over those of the classical insulation compounds and its cost is lower.

The final steps in processing paragutta are very similar to those used for gutta percha and involve blending and washing the deproteinized rubber and deresinated balata or gutta together, masticating to remove excessive water and at the same time incorporating such waxes as are found necessary. The material is then strained through fine sieves under hydraulic pressure to remove adventitious impurities, kneaded to remove air and finally placed on the covering machine rolls to be forced around the conductor. The machinery in use for pro-

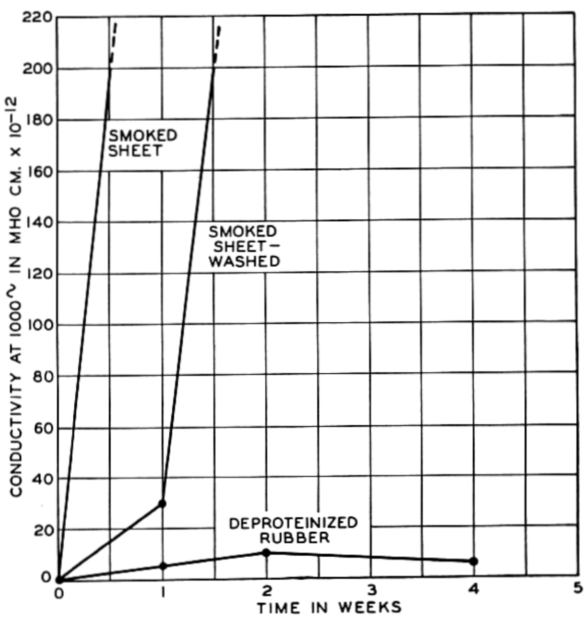

Fig. 4—Effect of washing and removal of proteins on conductivity of crude rubber when immersed in 3.5 per cent NaCl solution at room temperature.

cessing gutta percha is suitable for handling paragutta in these operations.

Comparative Properties of Paragutta and Gutta Percha

Tensile Properties: Although submarine insulation is not subjected to tensile deformation in practice, tensile properties indicate to some degree the relative mechanical suitability of a given material for the purpose. Figure 5 shows the stress-strain characteristics of paragutta and gutta percha submarine cable insulation. These results show that paragutta has tensile properties equal to cable gutta percha although its gutta content is substantially lower.

Compression Properties: The insulated submarine cable conductor commonly known as the core is frequently subjected to uneven compression stresses during manufacture, laying and repairing. The insulation must therefore be capable of withstanding these stresses without appreciable deformation. To determine the relative merits of paragutta and gutta percha in this respect their comparative stress-strain characteristics under compression have been measured, using a special compression machine,[3] and are shown in Fig. 6. In this test

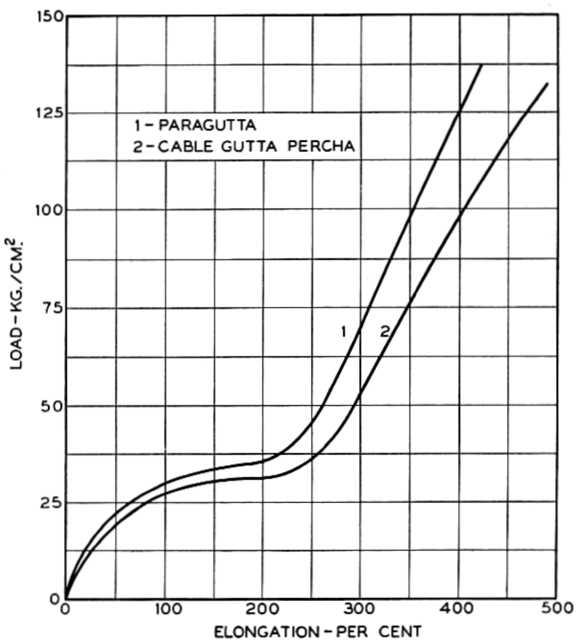

Fig. 5—Comparative tensile properties of paragutta and gutta percha at 25° C.

a steel rod 1.6 cm. in diameter was forced endwise into a sheet of the material .375 cm. in thickness at a rate of about 4 cm. per minute while simultaneously recording the deformation and load. These results show that very little difference exists between these materials in this test, and factory handling of cores confirms the general conclusion.

Flexibility: The flexibility of submarine cable insulation is important because the core is subjected to considerable flexing during manu-

[3] Hippensteel, *Bell Laboratories Record*, **5**, 153 (1928).

facture, laying and repairing and possibly at times during use, especially where tidal currents may cause movement in the cable. Paragutta and gutta percha cores have been subjected to slow and continuous flexing at 0° and 25° C. for long periods and it was found that both materials will withstand millions of repeated flexures at small amplitudes without failure. When the amplitude of flexure was increased to strain the conductor slightly beyond its elastic limit, the conductor always failed in advance of the insulation.

Plasticity Tests: Laboratory tests were made to determine the relative plasticity of paragutta and gutta percha, using both the Williams [4]

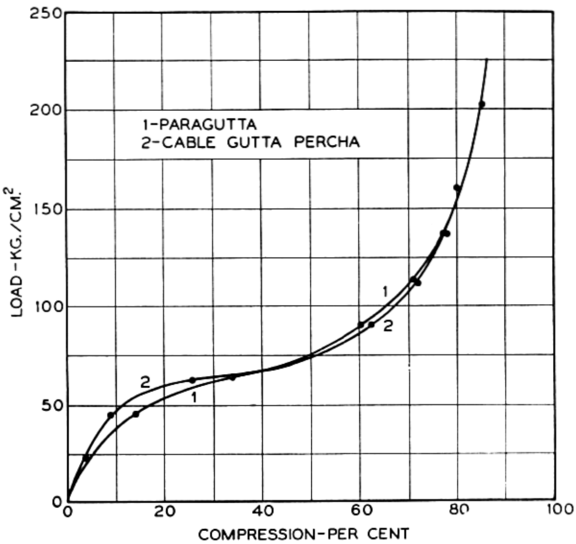

Fig. 6—Comparative compression properties of paragutta and gutta percha at 25° C.

and the Marzetti [5] type of plastometers. These tests are valuable guides but the final judgment of a material as regards thermoplasticity was made by determining its workability on commercial gutta percha insulating machines. Paragutta is somewhat more resistant to flow than gutta percha at temperatures ranging from about 40° to 70° C. When applied to the conductor, however, its greater resistance to flow at elevated temperatures can be taken as an advantage as it lessens the danger of faults occurring if the core should be accidentally exposed to elevated temperatures or to conditions which might exist in connection with cable used in the tropics.

[4] Williams, *Jour. Ind. & Engg. Chem.*, **16**, 262 (1924).
[5] Marzetti, *Giorn. Chim. Ind. Applicata*, **5**, 342 (1923).

Figure 7 shows the relative plasticities of cable gutta percha and paragutta at several temperatures as determined by the Williams [4] method, which can be taken to indicate the relative plasticities of these materials at working temperatures.

Brittle Temperature: It is extremely important that the temperature at which submarine cable insulation becomes brittle should be far below the range of sea bottom temperatures to be encountered in use. This is one of the properties in which rubber and gutta percha greatly excel any other available insulating material. Kohman and Peek [6]

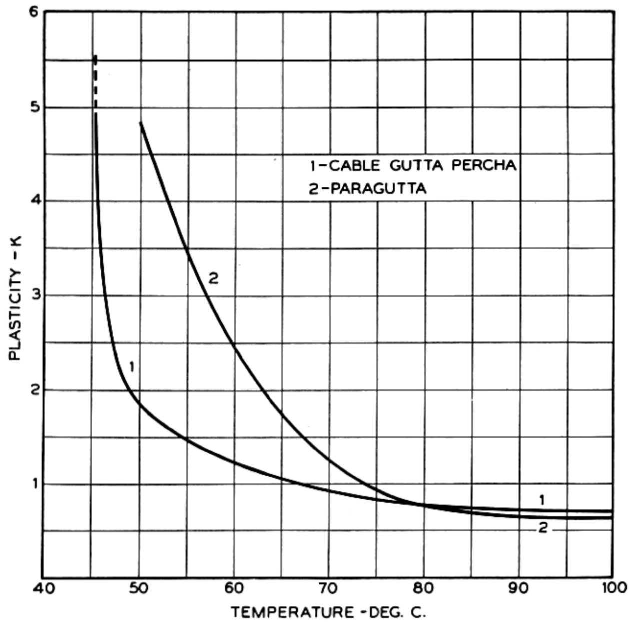

Fig. 7—Effect of temperature on the plasticity of cable gutta percha and paragutta.

have described an apparatus for accurately determining this temperature. The brittle temperature of paragutta is somewhat lower than cable gutta percha, as can be seen from the results in Table II, which give the range of brittle temperature values found for different samples of several materials.

Water Absorption—Electrical Stability

The amount of water absorbed by rubber and gutta percha when immersed in water is the result of a complicated mechanism. The quantity and nature of water soluble or water absorbing impurities

[6] Kohman and Peek, *Jour. Ind. & Engg. Chem.*, **20**, 8 (1928).

TABLE II

Brittle Temperature of Paragutta and Other Insulating Materials

Material	Brittle Temperature °C.
Gutta Percha (Cable Insulation)	−23 to −36
Paragutta	−45 to −61
Balata (Washed)	−44 to −52
Balata (Washed and Deresinated)	−62 to −67
Crude Rubber	−57 to −58
Vulcanized Rubber (Soft)	−53 to −58

in the rubber or gutta percha and the salt concentration of the water in which the samples are immersed are controlling factors. The enormous increase in the quantity of water absorbed by ordinary rubber when immersed in distilled water as compared with its absorption in salt solutions has been explained on the basis of osmotic theory.[1] In accordance with this theory rubber acts as a semi-permeable membrane. Water soluble crystalloids or hydrophillic colloids (proteins) attract the water which enters the rubber by diffusion. When immersed in distilled water these impurities tend to reach infinite dilution with water, being opposed in this by the resistance of the rubber itself to swelling. In salt solutions the amount of water absorbed is finite and depends on the equalization of osmotic pressures of the internal and external solutions. The change in water absorption of pure rubber hydrocarbon with the salt concentration of the external solution is small over the whole range, which indicates that the water enters by a process of solution. This has also been found to be the case for gutta hydrocarbon and is more or less true for paragutta and gutta percha. The water absorption in distilled water can therefore be taken as a measure of the freedom from water soluble or water absorbing impurities. Figure 8 shows the effect of NaCl concentration in the immersion solution on the quantity of water absorbed by samples of rubber, paragutta and gutta percha at room temperature. Samples of rubber containing water soluble matter or proteins do not readily reach an equilibrium water content in distilled water. Crude rubber has been found to absorb more than 100 per cent water in distilled water at ordinary temperature without reaching equilibrium.[1] Gutta percha, paragutta and pure rubber hydrocarbon on the other hand reach a definite and lower equilibrium water content in distilled water, which shows their greater freedom from water soluble or water absorbing matter.

As the electrical stability of paragutta in sea water is of paramount importance an exhaustive study has been made on a large number of specimens as regards their changes in electrical values over long periods of immersion in 3.5 per cent salt solution. Gutta percha insulation contains about one per cent water when at equilibrium with sea water whereas paragutta contains somewhat less than this amount. These values have been determined by testing samples made up with various water contents below and above equilibrium values and determining the water content after prolonged immersion in 3.5 per cent NaCl solution, as seen in Figure 9. The equilibrium value is practically the same when equilibrium is approached from either direction.

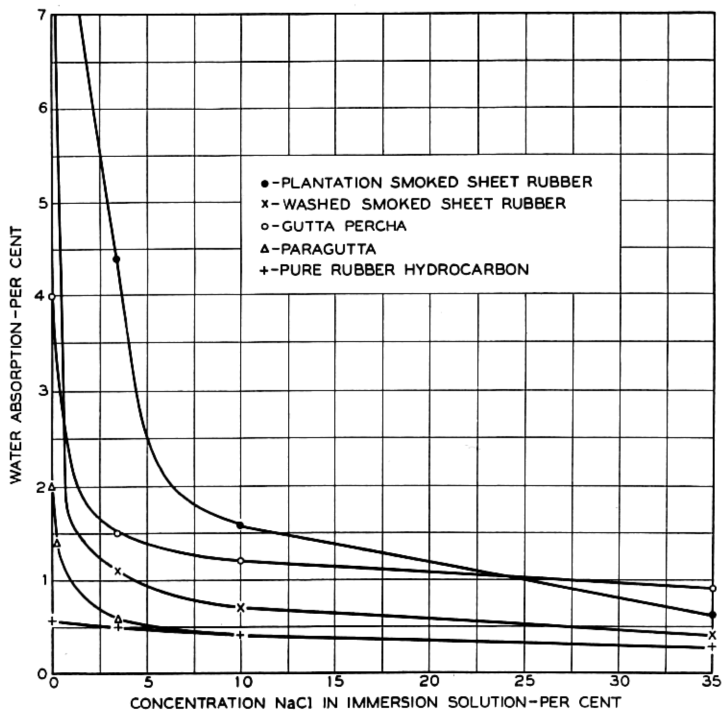

Fig. 8—Relation of water absorption to salt concentration in immersion solution.

The overall quantity of water absorbed, however, cannot be used as a final criterion by which to judge insulation for it has been previously shown (Figs. 1 to 4) that washed crude rubber completely fails as an insulator after absorbing less than one per cent water. The mode of distribution of water absorbing impurities in an insulating material has been found to be of utmost importance as regards the magnitude of the effect of moisture in various insulating materials. Examples where large effects on insulating properties are caused as a result of moisture absorption by localized impurities are found in the above case of proteins in crude rubber, water soluble salts associated with fillers in vulcanized rubber [1] and hygroscopic salts on the surfaces of textile fibers.[7]

On the other hand, the electrical properties of paragutta or gutta percha are not impaired when several times their equilibrium water content is incorporated with them. Gutta percha, however, does show an increase in capacitance of about 10 per cent as a result of water absorbed by a completely dried specimen, but as it is always the practice to apply it to the conductor in a wet condition this

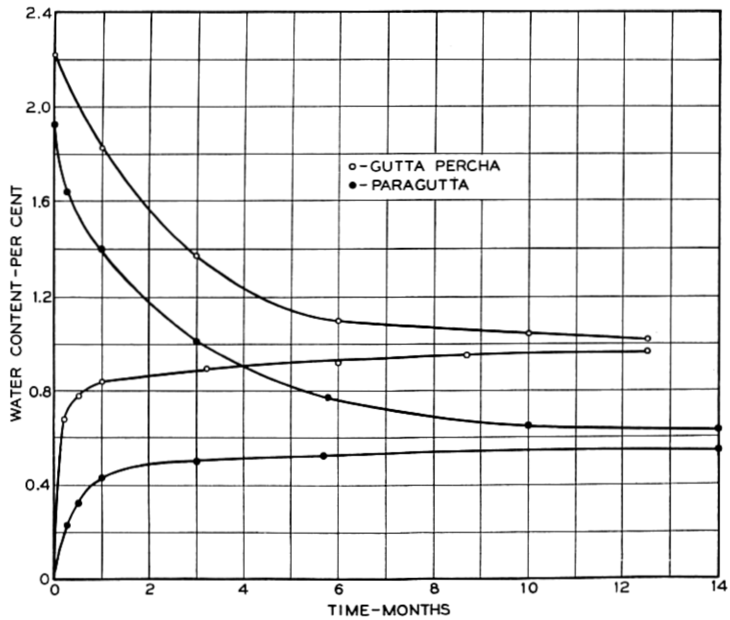

Fig. 9—Changes in water content of 50 mil wet and dry paragutta and gutta percha sheets when immersed in 3.5 per cent NaCl at room temperature.

change is not of practical significance. The electrical properties of paragutta on the other hand show practically no changes as a result of moisture absorption by a dry sample. These facts are taken to be the best evidence of the electrical stability of paragutta in contact with water.

Hundreds of specimens of paragutta and gutta percha have been studied as regards changes taking place in electrical characteristics after long periods of continuous immersion in 3.5 per cent salt solution. These tests, some of which have been for periods of three to five years, show that paragutta is fully equal to gutta percha as regards its

[7] Williams and Murphy, *Bell Sys. Tech. Jour.*, **8**, 225 (1929).

stability. When properly prepared both of these materials show practically negligible changes in electrical properties as a result of prolonged submergence in water. Sea bottom conditions are even less likely to affect these materials than those existing in the laboratory. This is because of the absence of light, limited oxygen supply and low temperature, all of which reduce the tendency of materials such as paragutta or gutta percha to oxidize or otherwise deteriorate. It has also been shown [2] that the low temperature and high pressure existing at sea bottom reduce the rate of water absorption but do not materially affect the amount absorbed.

Electrical Characteristics: The electrical properties of paragutta depend upon the particular composition chosen, the quality of the raw materials and the care exercised in processing them. For long telephone cable insulation, it is necessary to exercise the utmost care to obtain a material having dielectric constant and specific conductance values sufficiently low to reduce to the minimum its effect on the attenuation. On the other hand, for ordinary telegraph cables these values are less critical and it may be advantageous to modify the practice for purposes of economy. Representative values for the electrical properties of a superior grade of paragutta and typical cable gutta percha under sea bottom conditions are given in Table III. It will be seen in this table that paragutta has a 20 per cent lower dielectric constant and a specific conductance one-thirtieth that of ordinary cable gutta percha under sea bottom conditions. The insulation resistance and dielectric strength of the two materials are practically the same.

TABLE III

Comparative Electrical Properties of Paragutta and Cable Gutta Percha at Sea Bottom Conditions

	Specific Inductive Capacity 2° C., 400 Atm., 2000 Cycles	Effective A-C Conductivity 2° C., 400 Atm., 2000 Cycles Unit = 10^{-12} mho. cm.
Cable Gutta Percha	3.3	90
Paragutta	2.6	3

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