

April 16, 1940.

H. M. HOBART

2,197,639

HIGH TENSION CABLE SYSTEM

Filed April 29, 1939

Fig. 1.

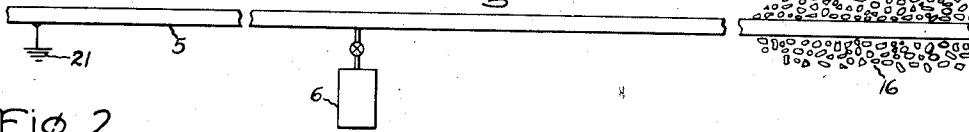


Fig. 2.

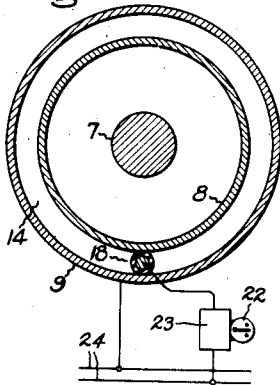


Fig. 3.

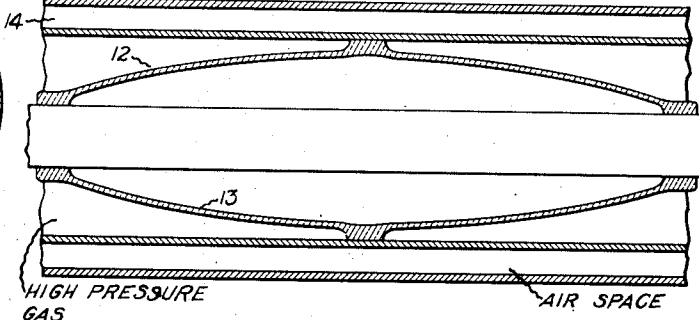


Fig. 5.

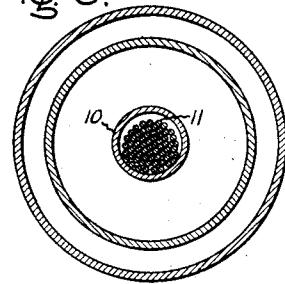


Fig. 4.

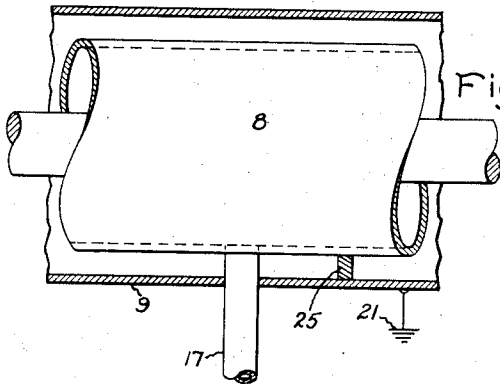
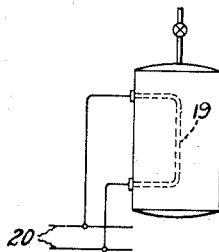


Fig. 6.



Inventor:
Henry M. Hobart,
by *Harry E. Dunham*
His Attorney.

UNITED STATES PATENT OFFICE

2,197,639

HIGH TENSION CABLE SYSTEM

Henry M. Hobart, Schenectady, N. Y., assignor to
General Electric Company, a corporation of
New York

Application April 29, 1939, Serial No. 270,807

8 Claims. (Cl. 174-14)

The present invention relates to cable systems for transmitting large amounts of electric power at high potentials.

5 The object of my invention is the provision of an improved cable system for transmitting large amounts of power over relatively large distances in a reliable and economical manner. My invention, while more especially directed to the transmission of large amounts of direct constant
10 current by underground means, is not necessarily limited thereto.

For a consideration of what I believe to be novel and my invention, attention is directed to the accompanying description and the claims
15 appended thereto.

In the accompanying drawing which is illustrative of my invention, Fig. 1 is a plan view of a length or section of a cable; Fig. 2 is a cross-section of the cable; Fig. 3 is a detail sectional
20 view of one of the insulators for supporting the conductor; Fig. 4 is a detail view of a means for introducing gas into the inner tube or pipe; Fig. 5 is a sectional view of a slight modification, and Fig. 6 is a detail view of a heater for
25 the tank supplying gas to the cable.

In cable systems of the prior art as ordinarily constructed, one of the important things is to convey the heat necessarily generated by the current flowing through the conductor away from
30 the cable as freely as possible to thereby prevent injury to the insulation, usually paper impregnated with a suitable compound. This is commonly done by enclosing the insulated conductor in a lead sheath after which the sheathed cable is pulled into concrete ducts located under
35 ground, or the cable may be buried directly in the ground. My invention differs from the prior art cables in the important and fundamental particular that it depends for its successful operation on conserving the heat generated by the
40 flowing current within its enclosure as fully as practicable to the end that the high pressure gas employed to insulate the conductor is maintained at a temperature which is above that at which
45 the gas becomes liquid wholly or in part. In other words, the unavoidable I^2R losses in the conductors which are so objectionable in cable systems of the prior art are in my improved cable made use of in a way to improve the operation of the cable and specifically to improve or
50 to maintain the quality of the gas which insulates the conductor.

In Fig. 1 of the drawing, 5 indicates a length or section of cable, 6 a tank or equivalent means for supplying insulating gas under high pressure

to the interior of the cable structure. The number of gas supplying tanks will depend upon the length of the cable serviced thereby. In any event, they need not be very numerous.

In Fig. 2 is illustrated a cross-section of the cable wherein 7 indicates a conductor made of suitable conducting material of which copper is an example. In the particular embodiment or illustration of my invention, the conductor is designed to convey direct constant current of the order of 1000 amperes at a voltage of the order of one million volts. These figures are given as illustrations and not as limitations of my invention. It is to be noted that in a constant current system, it is the voltage not the
15 current which varies depending upon the load or amount of energy supplied by the cable to the connected consumption devices. As far as possible, it is desirable to avoid tapping the cable between its end terminals, as such taps and the apparatus supplied thereby are expensive but they may be made where they are economically justified. The conductor 7 is bare or at least is not provided with insulation designed to withstand the high voltages contemplated. As an illustration, it may have a diameter of one inch. Enclosing the conductor is a pipe 8 also made of good conducting material, of which copper and aluminum are examples. With a one inch diameter conductor, the copper pipe 8 may have an
30 inside diameter of $3\frac{1}{2}$ inches and an outside diameter of $3\frac{3}{4}$ inches. Surrounding the pipe 8 is a second pipe 9 made of steel or other conducting material in spaced relation to the first. The steel pipe may have an internal diameter $4\frac{3}{8}$ inches and a wall thickness of $\frac{1}{4}$ of an inch. The inner and outer pipes are maintained in concentric relation by spacing devices of any known or suitable construction. The conductor 7 is shown as a solid rod but the construction may be that of Fig. 5 where a thin metal tube
40 10 is provided, and 11 a stranded conductor substantially filling the tube which is pulled into the aligned tubes after some or all of the pipe lengths have been welded or otherwise united
45 electrically as well as mechanically. This arrangement has the advantage of decreasing the number of joints in the high tension conductor. The pipes 8 and 9 form the other or low tension side of the circuit. Desirably both of these pipes operate at ground potential, a ground connection 21 being provided for the purpose. Pipe 8 is grounded through the metal blocks or spacers
50 25 which also serve to hold the pipes in spaced relation.

In order to insulate the high tension conductor from the pipe 8, it is supported and held in spaced relation within the pipe by insulators 12, Fig. 3, made of porcelain, glass or other suitable material. Because solid insulators do not have nearly as high dielectric strength as the gas per unit of thickness, a long length of solid material, as indicated at 13, should be provided between the areas of contact of the supporting insulator with the conductor and the inner wall of the pipe respectively.

As previously indicated, the inner pipe 8 is maintained filled with an insulating gas under high pressure which as an example may be of the order of 500 pounds per square inch. The gas should be of such character that it does not adversely affect the metals with which it contacts. One suitable gas for the purpose which is reasonable in cost is sulphur dioxide, SO_2 , having a vaporizing temperature of 109°C . at 500 pounds. As a general proposition, it may be stated that the dielectric strength of gases increases as their pressure is increased, hence the reason for using pressures of the order mentioned. With different gases, the pressures utilized and the amount of heat that is imparted thereto by the I^2R losses in the conductors will differ somewhat depending upon the characteristics of the gas employed. In the case of some gases and particularly SO_2 , it should be meticulously dehumidified before being admitted to the inner pipe 8. The foregoing reference to SO_2 gas is to be taken as an example and not as a limitation of my invention thereto for no attempt is being made to exhaust the subject but merely to indicate one gas which has the necessary and desirable qualities. In order that the gas shall throughout the length of the cable or throughout each section, if there be more than one section, be maintained in a gaseous form and free of any mist or other indication of particles in liquid form, its temperature should be maintained above the liquefying temperature of the gas. In the case of SO_2 , it is desirable to maintain a temperature of the order of 130°C . when the pressure of the gas is 500 pounds per square inch. The necessary heat is obtained from the losses in the high tension center conductor 7 and in the surrounding low tension conductors 8 and 9. The two conductors are so designed and proportioned that the I^2R losses are or may be sufficient for the purpose. Of the total amount of heat required, the greater portion is due to the losses in the high tension conductor 7. These losses will generally be somewhat greater than in other ordinary types of cable. In brief, it may be stated that the gas is superheated to a limited extent, for instance in the example given, the superheat may be of the order of 21°C . With the relatively high temperatures mentioned, the heat would tend freely to flow radially outward. This tendency is restricted and reduced to a suitably small value by reason of the free air space or chamber 14 between the inner and outer pipes. It is to be noted that what are objectionable losses in the former prior art types of cable are, in the present system, of benefit in keeping the gas at the desired temperature.

Mention has been made of the use of tanks 6 to supply gas to the inner pipe. These tanks contain liquid SO_2 maintained at the desired temperature. For the case used for example, in which a gas pressure of 500 pounds per square inch is to be maintained in the system, consisting of pipe 8 and tanks 6, the temperature which should be maintained in the liquid in the tanks

by thermostatic control is 109°C ., namely the vaporization temperature of SO_2 at a pressure of 500 pounds per square inch. But in order to ensure that throughout the pipe 8 there shall be no trace of SO_2 in liquid form, such as suspended mist, it is necessary to have a materially higher average temperature throughout the interior of pipe 8. For the purposes of an explanatory example, 21°C . of superheat is assumed, which corresponds to an average temperature of 130°C . throughout the interior of the pipe 8. Some portions will inevitably have a temperature several degrees higher than 130°C . because it is too impractical and expensive to provide a great number of thermostats, and other portions will have a temperature several degrees lower than 130°C . But it will be practicable to keep the variation sufficiently small to ensure that at no places within the pipe 8, and at no times, shall the temperature fall to a value so near 109°C . as to permit of condensation of the SO_2 . Any such condensation would impair the dielectric strength since SO_2 in the liquid form has far lower dielectric strength than gaseous SO_2 at the chosen pressure of 500 pounds per square inch. Thus reliable working conditions are ensured by providing for an average temperature of 130°C . within the pipe 8. Then the inevitable local and time variations from that average temperature will not be deleterious. In other words, only rough control of the temperature in pipe 8 need be provided, whereas, a higher degree of exactness of the temperature control in the tanks 6 is very desirable and is easily and economically practicable. Use is made of the I^2R loss in a conductor 18, or some equivalent means, for the rough maintenance of an average temperature of some 130°C . throughout the interior of the pipe 8. Any tendency to a deficiency of temperature in pipe 8 will be corrected thermostatically by an increase in the current in 18 or other suitably located heating conductor. The thermostats employed may be of ordinary or suitable construction. The pressure in the pipe 8 and in the tanks 6 will always remain at the constant value of 500 pounds per square inch so long as the temperature of the liquid in the tanks 6 is held at 109°C . and will so remain independently of the above mentioned inevitable variations in the local temperature in the pipe 8 above or below the average value of 130°C . But any decrease in the temperature in the tanks 6 would be accompanied by decrease in the pressure, both in the tanks 6 and in the pipe 8, until automatically corrected thermostatically to restore the required condition of temperature, and consequently also of pressure. The conditions as to temperature of the liquid SO_2 in the tanks and the pressure of the gas which evaporates from its surface may be maintained in any suitable or well known manner as by the use of electric heaters and thermostatic control.

When the cable is buried, as distinguished from being located in ducts made of concrete or other material, it will be advantageous to surround the outer steel tube with some cheap thermal insulating material of which broken glass, brick, fragments of scoriaceous material, clinkers and blast furnace slag are examples. Such an enclosure for the outer pipe is indicated at 16 at one end of the cable illustrated in Fig. 1.

In Fig. 4 is illustrated one way of admitting gas from a tank or other source of high pressure supply to the inner pipe. Before or after conductors and pipes are assembled or laid in a trench and suitably united, the inner and outer

pipes are drilled and the inner pipe tapped, the outer pipe having a hole of the same or larger diameter than the one in the inner pipe. A tube 17 is then inserted in the hole in the inner pipe. The tube may be threaded or not and afterwards electrically welded in place, the tube in such operation serving as one electrode and the inner pipe 8 as the other. The inner and outer pipes are conveniently made in relatively short lengths, say 40 feet, for convenience in handling and shipping.

In installing the cable, the adjacent ends of the conductors and pipes are united by welding. Desirably the pipes are so united as to prevent water from entering the chamber 14. Where the high potential conductor is made as illustrated in Fig. 5, it will be unnecessary to make joints in the conductor except at widely spaced intervals, say 500 feet, for example.

Reference has been made to the I^2R losses which are to maintain the desired temperature of the gas. Under the conditions previously mentioned, the loss may be of the order of 30 watts per foot of length of the pipe line which, considering the large amount of power transmitted, is not excessive. Very little applicable data is at present available for estimating the heat transfer to the surrounding soil under the conditions of such a system and any quantitative statement can be of only a general nature. The value of 30 watts per foot of length given above is to be regarded as simply illustrative and not as a limitation of my invention.

The heating effect of the current due to the particular load from time to time may be subject to variations and moreover it is not convenient to employ it for the final control of the desired average temperature in the pipe 8. Furthermore, it may not be sufficiently great to conveniently maintain the gas at the desired elevated temperature. This will be so in many installations. Consequently the supply of heat may be augmented or rendered conveniently adjustable or both by locating a heating conductor 18 of suitably high resistance in the air chamber or space 14 between the inner and outer pipes as shown in Fig. 2, subject to suitable thermostatic or other control. In this Figure 22 indicates a thermostat, and 23 a means responsive thereto for varying the amount of electric energy flowing through the heating conductor 18. Current for the conductor is supplied by the circuit wires 24 from any suitable source. In order further to conserve the heat, it may in some cases be desirable to polish the inner walls of the pipes, particularly that of the inner copper pipe. Instead of a copper pipe, an aluminum pipe may be used, the nature of whose polished surface will impede the heat flow more effectively than will be the case with a copper pipe.

In order to heat the tanks and their respective contents, each tank may be provided with an immersion heater such as is indicated at 19 in Fig. 6, current being supplied by line wires 20 subject to the control of suitable means such as a thermostat.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A cable comprising a conductor carrying high tension current and forming one side of a circuit, a metal pipe enclosing the conductor and forming the low tension side of the circuit, insulating means supporting the conductor in spaced relation to the inner wall of the pipe, a filling of insulating gas for the pipe under such

high pressure that it tends to liquefy at such pressure, the conductor and pipe being so proportioned that the heating thereof due to the passage of current therethrough tends to maintain the temperature of the gas at a value above its liquefying temperature, a second metal pipe surrounding the first in spaced relation thereto, and heat insulation between the inner and outer pipes.

2. A cable comprising a conductor carrying high tension current and forming one side of a circuit, a metal pipe enclosing the conductor and forming the low tension side of the circuit, insulating means supporting the conductor in spaced relation to the inner wall of the pipe, a filling of insulating gas for the pipe under such high pressure that it tends to liquefy at such pressure, the conductor and pipe being so proportioned that the heating thereof due to the passage of current therethrough maintains an elevated temperature for the gas, a second metal pipe surrounding the first in spaced relation thereto, and an air chamber in the space between the pipes to restrict the outward passage of heat from the conductor and inner pipe to the second pipe.

3. A cable comprising a conductor carrying high tension current and forming one side of the circuit, a metal pipe enclosing the conductor, insulating means supporting the conductor in spaced relation to the inner wall of the pipe, a filling of insulating gas for the pipe, means for maintaining the gas under predetermined elevated pressure within the pipe, a second pipe enclosing the first in spaced relation thereto, the two pipes being electrically connected and forming the other side of the circuit, and heating means located in the space between the pipes for reducing the outward escape of heat from the center conductor and inner pipe to the enclosing pipe.

4. A cable comprising a conductor carrying high tension current, a metal pipe enclosing the conductor, solid insulators for supporting the conductor in spaced relation to the inner wall of the pipe, a filling of insulating gas for the pipe having a higher dielectric strength than the solid insulators, tanks for supplying gas to the pipe under sufficiently high pressure to insulate the conductor, the tanks being arranged to drain any liquefied gas from the pipe, heating means for the tanks, and means surrounding the pipe acting to prevent the free passage of heat radially outwardly from the conductor to the surrounding atmosphere.

5. A cable comprising a conductor carrying high tension current, a metal pipe enclosing the conductor, solid type insulators supporting the conductor inside of the pipe in spaced relation to the inner wall thereof, a second metal pipe enclosing the first in spaced relation thereto to define a chamber, means for supplying high pressure insulating gas to the inner pipe to insulate the conductor which tends to liquefy at that pressure, the current flowing in the conductor imparting a substantial amount of heat to the gas, means for restricting the outward passage of heat from the inner pipe, and a conductor located in the chamber having sufficient resistance to the passage of current therethrough to add heat to the high pressure gas within the inner pipe to assist in preventing it from liquefying.

6. A cable comprising a conductor carrying high tension current and forming one side of a circuit, a metal pipe enclosing the conductor

and forming the low tension side of the circuit, insulators arranged in endwise spaced relation for supporting the conductor out of contact with the inner wall of the pipe, a filling of high pressure gas for the pipe, a second pipe enclosing the first defining an air chamber between them to prevent free escape of heat, the pipe operating at ground potential, and a heating means located in the space between the pipes, the heat thereof and that due to the passage of current through the conductor superheating the gas to such a value as to prevent it from liquefying at the pressure thereof.

7. A cable system comprising a conductor carrying high tension electric current, a metal enclosure for the conductor, spaced elongated insulating means supporting the conductor within the enclosure and out of contact therewith, a filling of insulating gas for the enclosure under such high pressure that it tends to liquefy, and a heating conductor located adjacent the outer surface of the metal enclosure and extending longitudinally thereof for adding sufficient heat through the wall of the enclosure to heat the gas and prevent it from liquefying during normal operation of the cable.

8. A cable comprising a bare conductor carrying constant current at high voltage, the voltage

varying with the load, the conductor being substantially heated by the current flowing there-through, a metallic pipe capable of withstanding high internal pressure in which the conductor is located, axially spaced solid insulators located within the pipe for supporting the conductor, the areas of contact between each insulator and the pipe and conductor being widely spaced to provide long creepage surfaces for the current, a filling of gas for the pipe under such high pressure that it tends to liquefy when its temperature is decreased below a predetermined value, means for conserving the heat generated by the current passing through the conductor comprising a second pipe surrounding the first and separated therefrom by an annular space, the second pipe being subjected to a cooling atmosphere so that heat from the conductor and first pipe tend to flow thereto and be dissipated, the inner pipe also forming a part of the electrical circuit, a resistance heating unit located in the space between the pipes and extending longitudinally thereof, and a source of current independent of that flowing in the bare conductor for supplying current to the unit for heating it and the material in the space.

HENRY M. HOBART.