

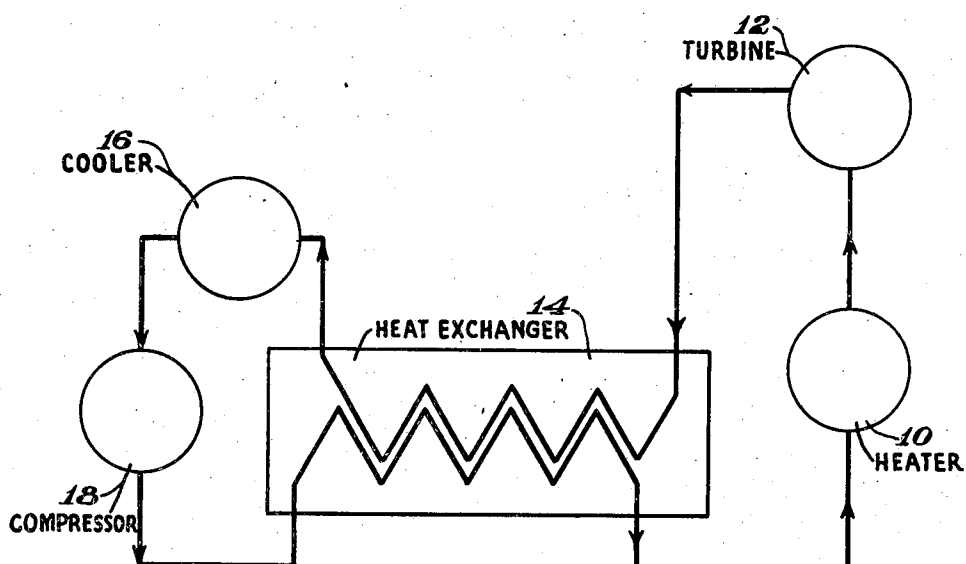
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PROCESS AND APPARATUS FOR TRANSMITTING ENERGY

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PROCESS AND APPARATUS FOR
TRANSMITTING ENERGY

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This invention relates to processes and apparatus for transmitting energy and particularly to such processes and apparatus employing octafluorocyclobutane as the energy transmitting medium.

Water, particularly in the form of steam, has been most widely used as the medium for transmitting energy and especially for operating turbines and the like. However, it has properties which limit its use and the efficiency of the apparatus in which it is used. Its boiling point is rather high for best results in many applications. It has a high critical pressure, over 3000 pounds per square inch, which is impractical to attain commercially due to limitations in the strengths of materials and difficulties in design. Steam has a low density, which limits the power obtainable, and requires large and bulky apparatus. Steam is also deficient in entropy relationships along the saturation line, showing a decreasing entropy with increasing temperature. Consequently, steam turbines must be operated within narrow temperature limits fixed by the entropy at which the expansion is effected or the steam must be resuperheated between stages to prevent crossing the liquid line.

Mercury has also been proposed as a medium for transmitting energy. However, it is highly toxic and high in cost which greatly limits its practical utilization. It has a high boiling point which limits its use in turbines and which makes the actual operating vapor density and pressure quite low. Also, like steam, the entropy changes along the saturation line are unfavorable leading to liquid formation upon unrestricted adiabatic expansion.

It has been proposed to employ organic compounds for transmitting energy. Usually, however, such compounds are quite unstable at desirable temperatures of operation of the apparatus. Diphenyl and diphenyl ether have been proposed and appear to be quite stable at temperatures somewhat in excess of 300° C. However, due to their high boiling points of 255° C. to 270° C., their utility is quite limited.

It is an object of our invention to provide a process and apparatus for transmitting energy employing a novel energy transmitting medium. A further object is to provide a process and apparatus whereby octafluorocyclobutane can be successfully employed for transmitting energy at high temperatures. A particular object is to provide a process and apparatus for operating turbines and the like with octafluorocyclobutane as the power fluid. Other objects are to advance the

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art. Still other objects will appear hereinafter.

The above and other objects may be accomplished in accordance with our invention which comprises apparatus and the process of operating the same for transmitting energy wherein octafluorocyclobutane is employed at temperatures above 200° C. and not substantially in excess of 400° C., in which the parts of the apparatus in contact with the octafluorocyclobutane at the temperatures aforesaid are made of a metal of the group of nickel and "Inconel." We have found that octafluorocyclobutane can be successfully employed under such circumstances with many advantages.

In copending application Serial No. 535,208, filed May 11, 1944, now Patent No. 2,384,821, Downing, Benning and McHarness disclose and claim octafluorocyclobutane as a new chemical compound and its preparation by pyrolysis of CHClF_2 . We have found that octafluorocyclobutane has many desirable properties which particularly adapt it for utilization as an energy transmitting medium. It is non-corrosive, non-toxic and non-inflammable. It has a boiling point of -4.7° C. and a freezing point of -40.7° C. It has critical constants which are practically ideal for transmitting energy. These constants are:

$t_c = 115.3^\circ \text{C.}$

$p_c = 393 \text{ pounds per square inch absolute}$

$d_c = 0.612 \text{ g./cc.}$

It is readily feasible to heat this fluid above the critical pressure, eliminating ebullition completely with a resulting smooth temperature gradient between power fluid and heat source. Its molecular weight, 200, is over 10 times that of steam and its high vapor pressure permits its utilization at high vapor densities. Its entropy variation along the saturation line is ideal, permitting unrestricted adiabatic expansion under almost any condition within the superheat range without danger of crossing the saturation line.

We have found, however, that, when octafluorocyclobutane is heated at temperatures substantially above 200° C. and particularly at temperatures of about 250° C. and higher in the presence of ordinary steel, stainless steel and bronze, it decomposes to a very material extent with the deposition of gums, carbon and other decomposition products on the surfaces in contact therewith. On the other hand, we have found that, if the octafluorocyclobutane is maintained in contact with only a metal of the group of nickel and "Inconel" while at temperatures substantially

above 200° C. and not substantially in excess of 400° C., the octafluorocyclobutane will not decompose to a material extent, but will be extremely stable. Therefore, the octafluorocyclobutane can be successfully employed for transmitting energy involving temperatures of from about 250° C. to about 400° C., if those parts of the apparatus in contact with the octafluorocyclobutane at such temperatures is made of a metal of the group of nickel and "Inconel." "Inconel" is an alloy whose typical composition is nickel 79.5%, chromium 13%, copper 0.2%, iron 6.5%, silicon 0.25%, manganese 0.25% and carbon 0.08%.

The effect of metals, on the decomposition of octafluorocyclobutane at high temperatures, are shown by a series of tests, wherein a bomb, constructed of the metal to be tested, was charged with a known weight of the octafluorocyclobutane. The ratio of metal surface to weight of octafluorocyclobutane was substantially as follows:

Volume/surface of bomb=0.31 cc./sq. cm.
Surface/weight of charge=10 sq. cm./g.
Density of gas in charged bomb=0.32 g./cc.

The bomb was then sealed and heated at the test temperature for periods of from 100 to 500 hours. From the amount and nature of the organic material recovered and from the amount of carbon or other solid matter found in the bomb after the test, the amount of decomposition of the octafluorocyclobutane was determined and the per cent of decomposition to be expected in a year's constant operation was calculated. The calculated per cent decomposition per year is shown in the following table:

Table

Temperature, °C.....	250	300	350	400	500-530
Steel.....	7	23	33	40	2,400
Nickel.....				<5	2,400
"Inconel".....				<5	2,400

The steel employed in the above table was an S. A. E. 1340 steel whose composition is given in the 1944 S. A. E. handbook as follows: Carbon 0.38-0.43%; manganese 1.60-1.90%; phosphorus maximum 0.040%; sulfur maximum 0.040%; silicon 0.20-0.35% and balance iron.

Attempts were made to carry out the same tests in bombs made of 18-8 stainless and in bronze. The 18-8 stainless steel was an S. A. E. 30915) A. I. S. I. type 302) steel, the specifications for which are: Carbon 0.08-0.15%; manganese maximum 2.00%; silicon 0.75%; phosphorus maximum 0.03%; sulfur maximum 0.03%; chromium 17.00-20.00%; nickel 7.00-10.00% and the balance iron. It was found impossible to complete the tests because of the rapid decomposition of the octafluorocyclobutane which caused the safety discs in the bombs to blow in substantially less than 100 hours. For example, in the 18-8 stainless steel bomb at 350° C., the discs blew during the first 29 hours and an analysis of the residue left in the bomb indicated a decomposition of at least 3 times that in an ordinary steel bomb after 100 hours. The results in the bronze bomb were similar.

The apparatus embodying our invention may be any apparatus suited to transmitting energy and wherein a gaseous fluid at temperatures of from about 250° C. to about 400° C. is advantageously employed. The apparatus may take the form of a heat exchanger wherein the octafluorocyclobutane is employed as a cooling medium

or a heating medium at the indicated high temperatures. Our invention is particularly adapted, however, to the operation of an engine involving a prime mover of the character of a turbine. A representative form of apparatus is indicated somewhat diagrammatically in Fig. 1 of the drawings accompanying this application.

In the drawings, the apparatus is shown as comprising a heater 10, a turbine 12, a heat exchanger 14, a cooler 16 and a compressor 18, all connected by suitable conduits. As illustrative of a possible operation of such apparatus, in accordance with our invention, the octafluorocyclobutane may be heated in the heater 10 to about 600° F. and under a pressure of about 700 pounds per square inch. The octafluorocyclobutane under such temperature and pressure may then be introduced into the turbine and expanded to drive the turbine, during which the temperature will be reduced to about 460° F. and the pressure will be reduced to about 50 pounds per square inch. The exhaust from the turbine may then be passed through the heat exchanger 14 where it is brought into indirect heat exchange relationship with octafluorocyclobutane passing to the heater. In this heat exchanger, the exhaust gases may be cooled to a temperature of about 390° F. at a pressure of about 50 pounds per square inch. The exhaust gases from the heat exchanger may then be passed to the cooler 16 wherein the temperature is further reduced to about 235° F. The cooled fluid from the cooler will then be passed to the compressor 18 where it will be compressed to about 700 pounds per square inch and then returned to the heater through the heat exchanger. In the heat exchanger, the compressed octafluorocyclobutane will be heated to about 440° F. For successful operation without material decomposition of the octafluorocyclobutane, it will be essential that the surfaces of the heater, the turbine and the conduits connecting them be made of nickel or "Inconel." This is illustrative of an operation employing a non-condensing cycle.

If it is desired to operate with a condensing cycle, this may be done by substituting a condenser for the cooler 16. The octafluorocyclobutane may be heated to about 750° F. at about 1000 pounds per square inch. It will then be conducted to the turbine and expanded to drive the turbine, whereby the temperature may be reduced to about 580° F. and the pressure may be reduced to about 75 pounds per square inch. The exhaust gases from the turbine will then be passed through the heat exchanger in indirect heat relation to the octafluorocyclobutane passing to the heater. In the heat exchanger, the exhaust gases will be cooled to about 110° F. and converted to a mixture of liquid and vapor. When this mixture of liquid and vapor is passed to the condenser 16, it will be converted to a liquid at about 100° F. and 75 pounds per square inch. The liquid from the condenser will then be passed to the pump wherein it will be subjected to a pressure of about 1000 pounds per square inch and forced through the heat exchanger to the heater. While passing through the heat exchanger, the octafluorocyclobutane will be heated to about 540° F. and converted to a vapor which passes to the heater for further heating. Under these conditions, also, the surfaces of the heater, turbine and conduits connecting the same, which surfaces are in contact with the octafluorocyclobutane, will be made of a metal of the group of nickel and

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"Inconel" in order to avoid objectionable decomposition of the octafluorocyclobutane. Also, under these conditions, the surfaces of the heat exchanger, in contact with the octafluorocyclobutane, are preferably made of nickel or "Inconel," although this is not absolutely necessary since the rate of decomposition in steel is not particularly high at the maximum temperature (238° C.) attained therein. In both cycles, the cooler or condenser, the compressor or pump and the conduits connecting them with each other and with the heat exchanger may be made of ordinary or stainless steel without inducing objectionable decomposition of the octafluorocyclobutane.

From all of the above, it will be apparent that, by our invention, we have provided a process and apparatus which makes it possible to employ octafluorocyclobutane as an energy transmitting medium and obtain the advantages of the desirable properties of the octafluorocyclobutane and without obtaining objectionable decomposition of the octafluorocyclobutane. It will be readily apparent to those skilled in the art that many variations may be made in the construction and type of the apparatus and its mode of operation without departing from the spirit or scope of our invention. Accordingly, our invention is not to be limited to the specific embodiments disclosed, but we intend to cover our invention broadly as in the appended claims.

We claim:

1. The process of protectively conducting octafluorocyclobutane at temperatures of from about 250° C. to about 400° C. which comprises enclosing the octafluorocyclobutane in a conductor in which at least the surfaces in contact with the octafluorocyclobutane are made of a metal of the group consisting of nickel and an alloy whose composition is essentially nickel 79.5%, chromium 13%, copper 0.2%, iron 6.5%, silicon 0.25%, manganese 0.25% and carbon 0.08%.

2. The process of protectively conducting octafluorocyclobutane at temperatures of from about 250° C. to about 400° C. which comprises enclosing the octafluorocyclobutane in a conductor in which at least the surfaces in contact with the octafluorocyclobutane are made of an alloy whose composition is essentially nickel 79.5%, chromium 13%, copper 0.2%, iron 6.5%, silicon 0.25%, manganese 0.25% and carbon 0.08%.

3. The process of transferring heat which comprises heating octafluorocyclobutane to tempera-

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tures of from about 250° C. to about 400° C. and then passing it in indirect heat transfer relation with a body of material to be heated, and maintaining the octafluorocyclobutane, while at temperatures between about 250° C. and about 400° C., in direct contact with only an alloy whose composition is essentially nickel 79.5%, chromium 13%, copper 0.2%, iron 6.5%, silicon 0.25%, manganese 0.25% and carbon 0.08%.

4. The method of operating an engine which comprises heating octafluorocyclobutane under superatmospheric pressures to a temperature between about 250° C. and about 400° C., expanding the heated octafluorocyclobutane through a turbine, cooling the octafluorocyclobutane exhausted from the turbine and then condensing the cooled octafluorocyclobutane, maintaining the octafluorocyclobutane while at temperatures between about 250° C. and about 40° C. in direct contact with only an alloy whose composition is essentially nickel 79.5%, chromium 13%, copper 0.2%, iron 6.5%, silicon 0.25%, manganese 0.25% and carbon 0.08%.

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