Nov. 2, 1948. G. J. LEHMANN 2,452,581

TURBO-GENERATOR

Filed June 7, 1944 2 Sheets-Sheet 1

Fig. 1.

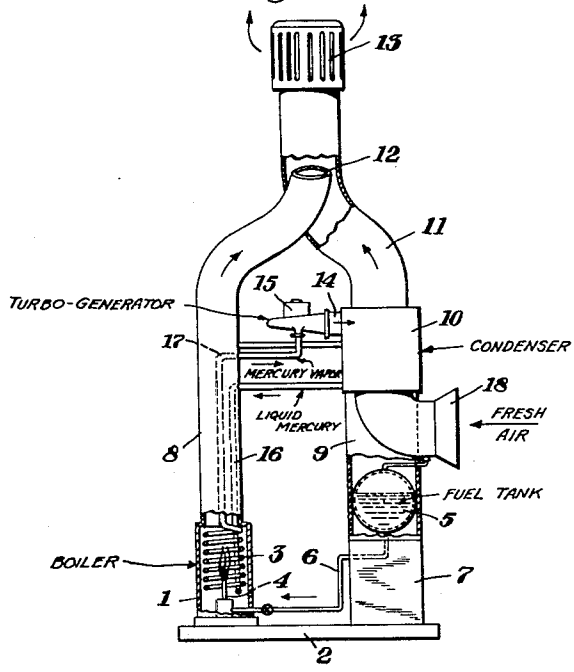
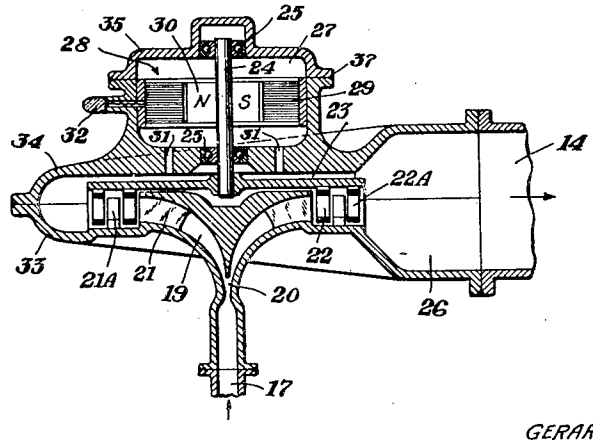


Fig. 2.



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Fig. 3.

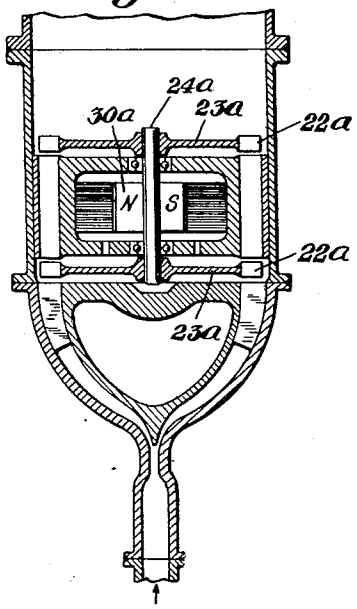
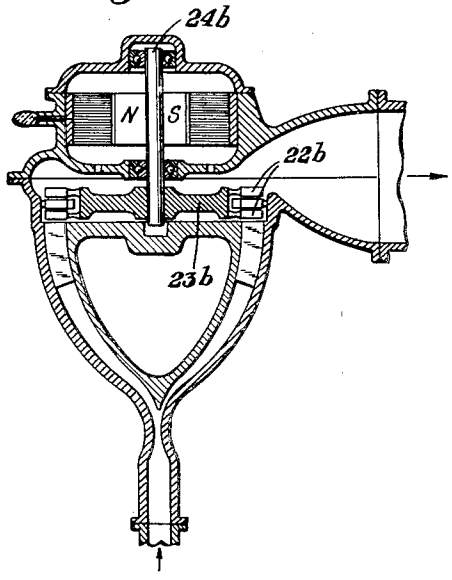


Fig. 4.



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TURBOGENERATOR

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14 Claims. (Cl. 290—2)

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The present invention relates to low-power electrical generating systems, and more particularly to turbo generators of low power.

One object of my invention is to provide a compact, self-contained electrical generating system having low fuel consumption and giving long periods of service without maintenance.

A further object of my invention is to provide a small, low-power mercury vapor turbine operating at low vapor pressure and good efficiencies.

A still further object of my invention is to provide a turbo generator sealed as a unit within a completely closed housing of relatively small size.

An additional object of my invention is to provide a mercury vapor turbo generator in which no vapor seal between the turbine and generator is necessary.

It is highly desirable to feed small turbines with a low-pressure fluid. This is due to the fact that the influence of the ambient vapor on the friction losses of the wheel in a low-power turbine is great. These losses, caused by the viscosity of the vapor, are greatly reduced if the turbine rotates in a low-pressure atmosphere. Furthermore, the use of conventional pressures gives to the area of any section crossed by the vapor a value so small that mechanical construction is impracticable. By reducing the pressure, the specific volume of the vapor increases, and the dimensions of all elements (nozzles and blades) become large enough to be mechanically feasible.

The available energy in one gram of mercury vapor is about one-ninth the available energy in one gram of water vapor. When this available energy is transformed into kinetic energy in a nozzle, the result is a velocity for the mercury vapor of about one-third that of steam. Thus the use of mercury makes simultaneously possible the low pressures needed by the mechanical structure and the high temperatures needed for thermodynamic efficiency. With water it is impossible to have simultaneously a low pressure, a low speed of the expanded vapor, and a high thermodynamic efficiency.

The complete system of the present invention utilizes the following units:

1. A boiler, a burner, and a fuel tank.
2. The turbo-generator.
3. A condenser.

The burner is utilized to heat the liquid mercury coming from the condenser, to vaporize the liquid, and to superheat the vapor. After total expansion in a single nozzle, the mercury vapor jet rotates a double impulse wheel the blades of

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which have a linear velocity in a predetermined ratio to the vapor velocity. The turbine wheel and the alternator rotor are mounted on the same shaft. The vapor thereafter goes to the condenser and is cooled by a free circulation of air. The condensed mercury due to its very high density returns to the boiler by gravity, thus eliminating any feeding pump.

Since the turbine is rotated by an entirely expanded vapor, it operates at a temperature low enough so that the bearings and the alternator can be enclosed within the turbine body itself. Therefore, no mercury vapor seal is required along the rotating shaft. Also, since the mercury and its vapor flow in a closed cycle inside a sealed system, the end result is a stability of operation over a considerable period of time without maintenance.

The above features make the present invention particularly suited for use in cases where relatively low power is needed for the supply of radio equipment, such, for example, as in repeater stations located in areas where infrequent servicing is desired. However, the disclosed system may obviously be utilized in many other instances where electrical energy is required.

Other objects and advantages of the invention will be apparent from the following description of preferred forms of the invention and from the drawings, in which:

Fig. 1 is a schematic view partly in section of a preferred form of electric generating system in accordance with the present invention;

Fig. 2 is a sectional view of the turbo-generator utilized in the system of Fig. 1; and

Figs. 3 and 4 are sectional views of modifications of the turbo-generator of Fig. 2.

In the electrical generating system of Fig. 1 is shown a boiler 1 positioned on a base 2. Within boiler 1 is a heating coil 3 encircling a burner 4. A tank 5 supplies fuel to burner 4 through a pipe 6. Tank 5 is positioned on base 2 by means of a support 7.

Extending vertically above boiler 1 is a flue 8. A hollow member 9 positioned on base 2 encloses fuel tank 5 and its support 7. Carried by member 9 is a condenser 10, while a second flue 11 extends upwardly from the condenser. The upper portions of flues 8 and 11 are curved toward each other and intersect at 12 so as to provide a common outlet 13.

Secured to a horizontal extension 14 of condenser 10 is a mercury-vapor turbo-generator 15. A conduit 16 partly enclosed within flue 8 returns the liquid mercury by gravity feed from condenser

10 to the lower portion of heating coil 3. A second conduit 17, also partly enclosed within flue 8, carries the mercury vapor from the upper end of heating coil 3 to the turbo-generator 15. Cooling air for the condenser 10 is provided by an intake 18 associated with the condenser and supported by hollow member 9. Since the condenser 10 may be of any suitable type known in the art, the details thereof are not shown.

Burner 4 is provided with fuel from tank 5 through pipe 6. Liquid mercuy from condenser 10 flows through conduit 16 and is conducted by gravity to the lower end of coil 3. After being heated and vaporized in the coil, the mercury vapor is carried by conduit 17 to the turbo-generator 15.

Following its expansion in the turbine, the exhaust mercury vapor is liquified in condenser 10 by the action of fresh cooling air entering intake 18 and being drawn up the flue 11 by heat liberated from the mercury vapor. A draft is also caused in flue 8 by the heated air and smoke resulting from the action of burner 4. The heated air in both flues 8 and 11 escapes through outlet, 13, at least the upper portion of flue 8 being of smaller diameter than flue 11 to provide an annular opening between members 8 and 11. It should be noted that a draft is established in flue 8 as soon as burner 4 is in operation. Due to their common outlet 13, a draft is consequently established at the same time in flue 11 even though no heat is being liberated in condenser 10. Thus a cooling flow of fresh air through the condenser is provided immediately upon operation of burner 4.

Fig. 2 shows the constructional details of the turbo-generator 15. One preferable design of the assembly would be on a scale approximately twice that shown in the drawings. The mercury vapor conducted by conduit 17 from coil 3 enters the turbine, nozzle 19 through throat 20. Past the throat, the surface of the nozzle 19 increases and changes from a circular to an annular substantially conic section. Adjacent the aperture of the nozzle is mounted the first of two sets of stationary blades 21, 21A which deflects the mercury vapor jet and directs the vapor onto the first of two sets of rotating blades 22, 22A. Thus there is produced an annular series of jets of vapor from a single throat, this vapor "ring" being directed at any instant against each of the first set of rotating blades 22. After passing blades 22 the vapor is directed by the second set of stationary blades 21A to the second set of rotating blades 22A. Since the mercury vapor reaches substantially its full expansion upon passing from nozzle 19, the second set of blades have substantially the same area as the first set.

Both sets of blades 22, 22A are carried by a wheel 23 which is securely mounted on a shaft 24. A pair of bearings 25 position shaft 24 within the turbine body. An outlet 26 passes the expanded mercury vapor from the turbine chamber to extension 14 of condenser 10.

The turbo-generator assembly 15 is provided with a chamber containing an alternator 28. This alternator comprises a stator winding 29 and a permanent magnet rotor 30 mounted on shaft 24. For optimum operation a three phase winding is preferable. The magnetic field in the rotor is constant, which eliminates all losses due to flux variation in the rotating magnet. In order to overcome any insulation difficulty resulting from the low pressure mercury vapor atmosphere, the voltage is preferably made low.

Openings 31 between the turbine chamber and the alternator chamber 27 permit free access of the mercury vapor to the portion of the chamber housing the alternator mechanism. Due to this method of construction, no packing members or other seals are required along shaft 24 between the turbine and generator. A glass seal 32 is provided at each point where the alternator electrical connections enter the turbine body.

For convenience of assembly the turbine body is preferably made in three sections 33, 34 and 35, these sections being secured together at 36 and 37 by any desired means that, with glass seals 32, will result in a gas-tight assembly. This securing means for example may comprise welding of the sections. Similar securing means such as welding is employed to produce gas-tight connections between the turbine body on one hand and conduit 17 and extension 14 of condenser 10 on the other.

In a preferred form of electrical generating system constructed in accordance with the present invention, in which the electrical power given by the alternator is 100 watts, the working temperatures may range from 357° C. for the saturated vapor to 120° C. for the expanded vapor. This results in the boiler being at nearly atmospheric pressure while the pressure in the condenser is equivalent to approximately .8 millimeter of mercury. The thermo-dynamic efficiency of the system under these conditions is close to 36.4%. However, it should be clearly understood that the above figures are given solely by way of example, and that any or all of such figures may be modified to meet particular conditions.

It will be noted that in the preferred example given the temperature of the expanded vapor is 120° C. This is sufficiently low to permit the vapor to dissipate a percentage of the heat generated in the bearings 25 and in the winding 29 of alternator 28.

In Fig. 3 is shown a modified form of turbo-generator operating on the same principle as that shown in Fig. 2. The two sets of rotating blades 22*a* are carried by separate rotor wheels 23*a* on opposite ends of shaft 24*a*. The alternator assembly is positioned between the turbine wheels so that the rotating magnet 30*a* is balanced between the power-receiving extremities of shaft 24*a*. In this type of construction the inlet and outlet for the mercury vapor are positioned in linear relation to one another.

In Fig. 4 is shown another modification of the turbo-generator of Fig. 2 in which the mercury vapor jet is applied longitudinally of shaft 24*b* as in Fig. 3 instead of radially as in Fig. 2. In contrast to the form shown in Fig. 3, however, both sets of rotating blades 22*b* are mounted on a single rotor wheel 23*b* on one end of shaft 24*b*. The inlet and outlet for the mercury vapor are substantially at right angles to one another in the manner of Fig. 2, rather than in the linear relation existing in Fig. 3.

Many other structural modifications of a turbo-generator in accordance with my invention will readily occur to those skilled in the art. While I have described above the principles of my invention in connection with specific apparatus, and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of my invention as set forth in the objects of my invention and the accompanying claims.

I claim:

1. A mercury-vapor turbo-generator comprising a mercury-vapor turbine, a generator operated by said turbine, a gas-tight housing enclosing both said turbine and said generator, and gas tight supply means for supplying said mercury vapor to said turbine means for permitting passage of said mercury vapor between said turbine and said generator.

2. A mercury-vapor turbo-generator comprising a mercury-vapor turbine, a generator operated by said turbine, a source of mercury vapor means for cooling said vapor, a gas-tight housing enclosing both said turbine and said generator, and conduit means secured between said housing, said source and said cooling means in gas-tight relation to conduct mercury vapor from said source to and from said turbine back to said cooling means in a closed cycle.

3. A turbo-generator according to claim 2, further comprising means associated with said conduit means for heating said mercury vapor and a condenser for cooling said vapor, said heating means and said condenser being provided with separate flues having a common outlet.

4. In a compact turbo-generator assembly of the mercury-vapor type, the combination of a substantially gas-tight body, partitioning means forming separate compartments within said body for the generator and the turbine portions of said assembly, and a power shaft within the generator compartment and extending through said partitioning means into the turbine compartment of said assembly, said partitioning means having an opening therein for permitting free passage of mercury vapor between the turbine portion of said assembly and said generator compartment.

5. A turbo-generator assembly according to claim 4, further comprising a turbine wheel carried by said power shaft within the turbine portion of said assembly, a plurality of blades around the periphery of said wheel, and a substantially annular stationary nozzle having a single throat and a plurality of deflecting means, whereby the mercury vapor passing through said throat will be shaped by said nozzle into an annular series of jets directed against the blades of said wheel.

6. In a compact turbo-generator of the mercury-vapor type, the combination of a body formed in a plurality of sections, one of said body sections being formed with a circular throat, a nozzle for shaping the mercury vapor passing through said circular throat into a substantially annular series of jets of vapor, a second of said body sections designed to form with said first body section a turbine compartment, a rotatable power shaft passing through and supported in part by said second body section, a turbine wheel on said shaft within said turbine compartment, a plurality of blades around the periphery of said wheel and in the path of said annular series of jets of vapor, a third body section designed to form with said second body section a generator compartment, said power shaft extending into said generator compartment and being in part supported by said third body section, and a generator rotor on said shaft within said generator compartment.

7. A turbo-generator according to claim 6, in which said second body section is formed with a plurality of openings therein so as to permit free passage of mercury vapor between said turbine compartment and said generator compartment.

8. A turbo-generator according to claim 6, further comprising gas-tight connections between said three body sections.

9. A turbo-generator according to claim 6, further comprising a stator coil within said generator compartment and encircling said rotor, said rotor comprising a permanent magnet, one or more electrical connections to said coil passing through said body, and means for rendering gas-tight the points at which said electrical connections pass through said body.

10. In a low-power generating system, a mercury-vapor turbo-generator, a source of liquid mercury, heating means to vaporize said liquid mercury, means for conducting the vaporized mercury to said turbo-generator, a condenser receiving the vapor output from said turbo-generator, a flue for said heating means, and a flue for the heat liberated in said condenser, both said flues having a common outlet so that the heated air rising in said first-mentioned flue will create a draft in said last-mentioned flue regardless of whether heat is being liberated in said condenser.

11. In a low-power generating system, a source of fuel, a burner receiving fuel from said source, a flue for said burner, a mercury-vapor turbo-generator, a source of liquid mercury, means receiving heat from said burner to vaporize said liquid mercury, means for conducting the vaporized mercury to said turbo-generator, a condenser receiving the vapor output from said turbo-generator, means returning the liquid mercury from said condenser to said heat receiving means, and a flue for the heat liberated in said condenser, both said flues having a common outlet so that heated air rising in said first-mentioned flue as a result of the operation of said burner will create a draft in said last-mentioned flue regardless of whether heat is being liberated in said condenser.

12. A low-power generating system according to claim 11 in which the means returning the liquid mercury from said condenser to said heat receiving means comprises a gravity feed.

13. A low-power generating system according to claim 11 in which said flues are vertically positioned side-by-side, and in which the mount of said turbo-generator extends horizontally between said first-mentioned flue and said condenser.

14. A low-power generating system according to claim 11, further comprising a base for said burner, and a hollow condenser support on said base, said source of fuel being enclosed within said support.

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