

May 29, 1945.

J. LOUMIET ET LAVIGNE

2,377,254

BOILER FEED REGULATING APPARATUS

Filed Feb. 28, 1941

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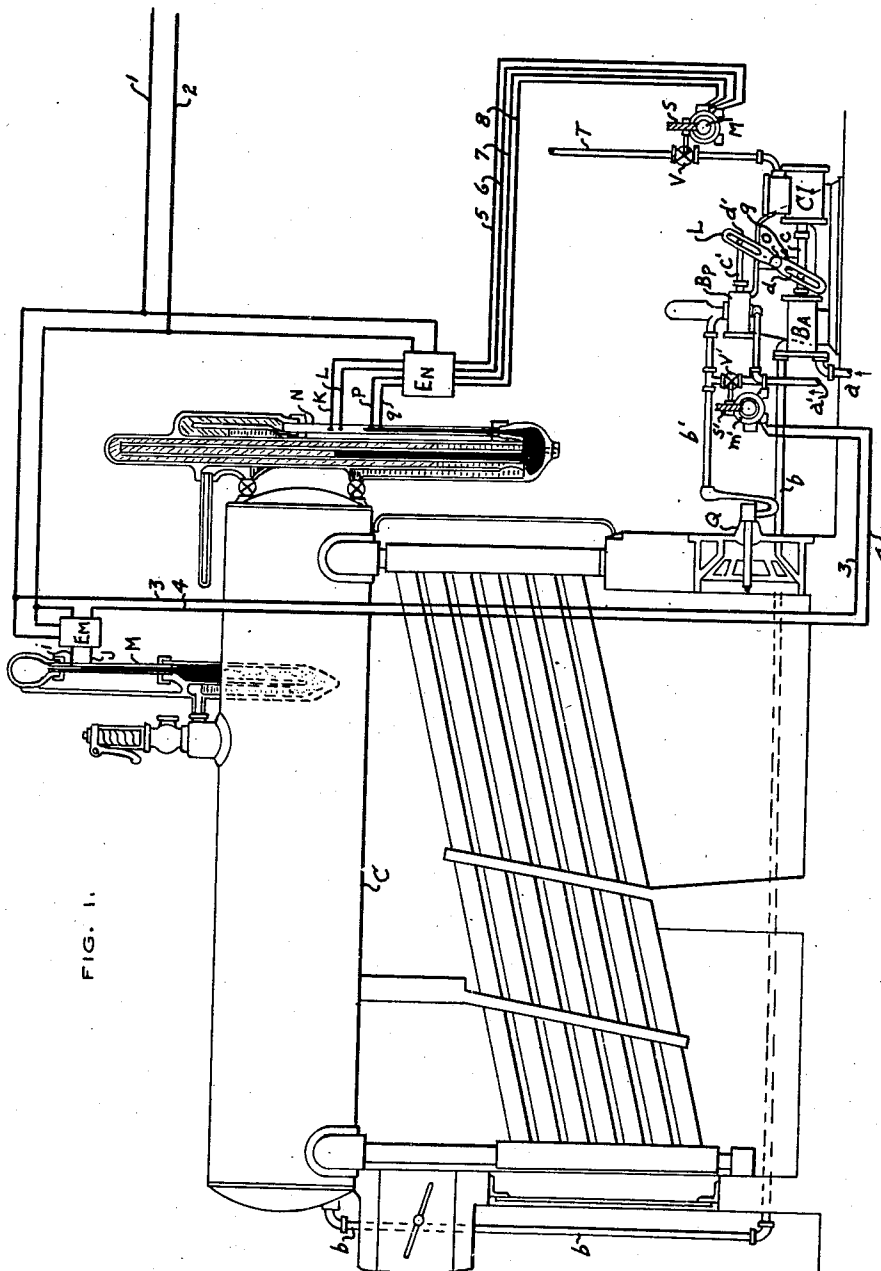


Fig. 1.

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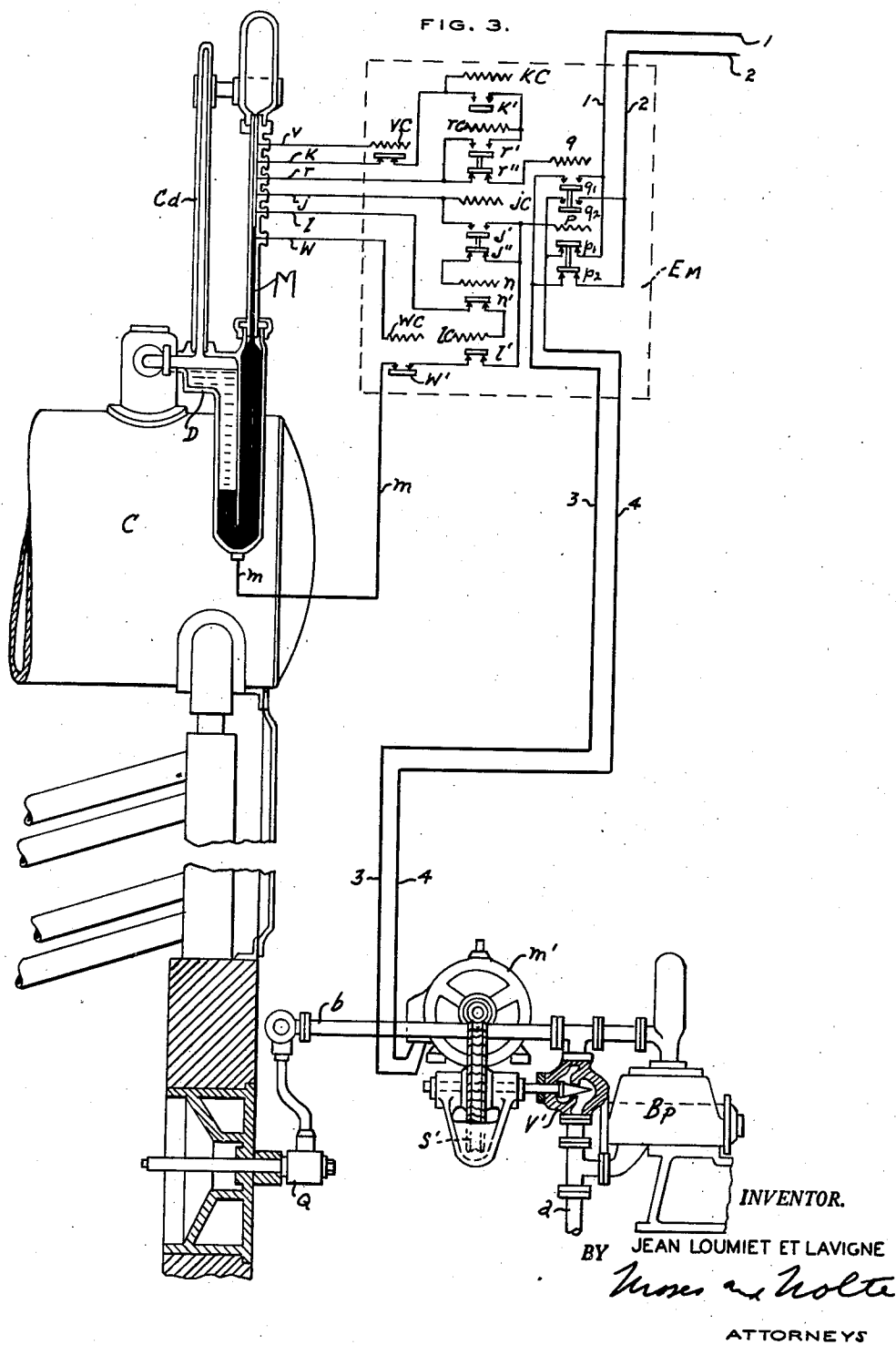
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Filed Feb. 28, 1941

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May 29, 1945.

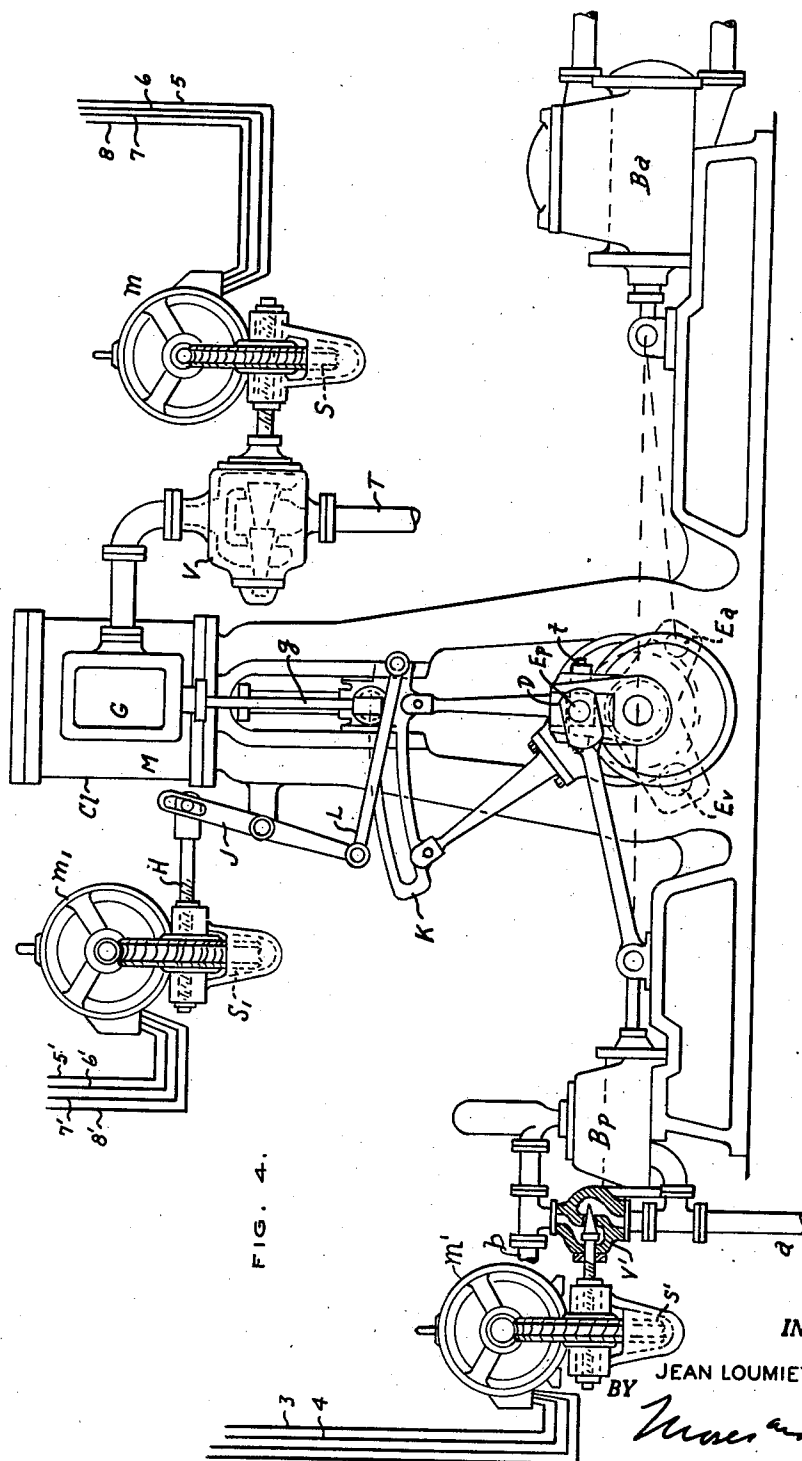
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2,377,254

BOILER FEED REGULATING APPARATUS

Filed Feb. 28, 1941

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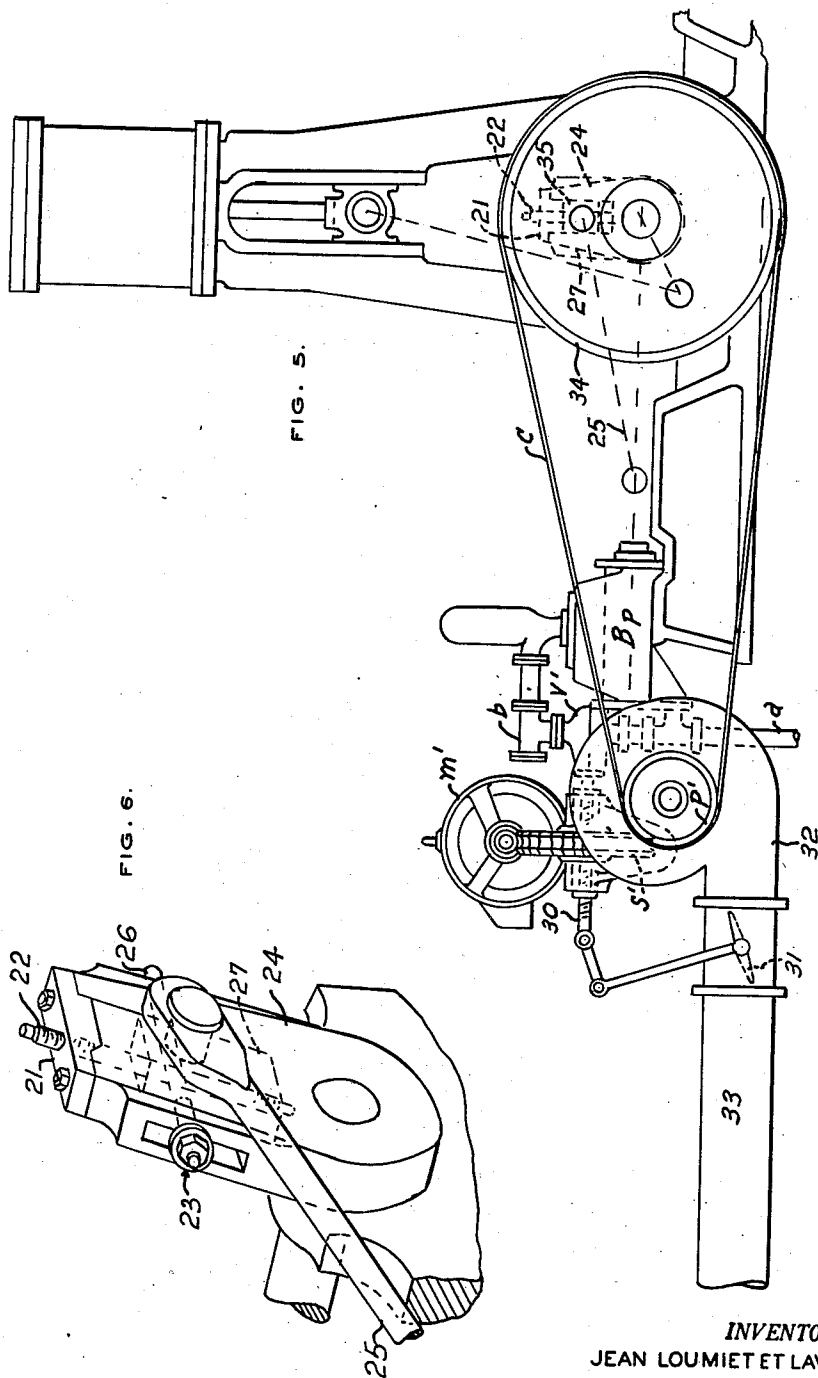
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2,377,254

BOILER FEED REGULATING APPARATUS

Filed Feb. 28, 1941

5 Sheets-Sheet 5



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2,377,254

BOILER FEED REGULATING APPARATUS

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Itabo, CubaApplication February 28, 1941, Serial No. 380,987
In Cuba, March 9, 1940

9 Claims. (Cl. 122-448)

The regulation of steam generators has heretofore been accomplished by various systems.

The systems include establishing the regulation of the feed water of the generator in the way described in the first application in such a manner that the water introduced in the boiler at a given moment exactly compensates the extraction of steam from that boiler, creating a principal feeding of fuel proportional at every moment to the supply of such a stream of feed water so as to constitute a feed supply of fuel approximating the real needs of the boiler, rectifying the quantity of said feed supply of fuel in order to adapt it at every moment to the real needs of the boiler so as to maintain the pressure of that boiler constant, and lastly reducing the important oscillations that might be produced in such regulating operations by the employment of the system of my third application. At the same time, the air injected or aspired is regulated so as to proportion its volume at any moment to the volume of fuel brought to the boiler at the same moment.

However, its solution must comply with the following requirements: (1) The water supplied must at every moment compensate for the consumption of steam taking place. (2) Fuel and air constitute means of heat production and must be supplied in relation to the steam consumption or to the water injected in a proportion exactly corresponding at every moment to the operating efficiency of the boiler.

That efficiency is variable, according as the production of steam from the boiler varies. Within the conditions of industrial operation it decreases slightly as the production increases. The decrease of efficiency becomes more rapidly accelerated than the increase in the steam production, and that acceleration is also variable, increasing as said steam production increases.

In order to solve the problem brought up in that way, the present invention does not pretend to depart from the basic principles of my anterior inventions which consists in establishing, as a first approximation of the regulation, proportional feed supplies of water, fuel and air, in accordance with one of the limiting requirements (maximum or minimum) of efficiency of the generator within the frame of the operations that it must accomplish, and to impart, in a complementary regulation, the final touch to that original regulation, so as to adapt it at every moment to the exact needs of the boiler. That conception constitutes always the basis of my processes of regulation and I also maintain the same means of operation; that is, that the imperfection of the

functioning of the boiler is evinced, on one part, as to the supply of water, by the variations of the water level in the boiler, and as to the supply of heat production means (fuel and air), by the variations of steam pressure. Those variations are utilized to automatically produce the compensating regulations that will rectify the deficiency observed. The invention does not substantially modify the apparatus for indicating the variations of the water level in the boiler and the variations of steam pressure, that respectively, govern the regulating apparatus by means of those variations. This new process is intended only to modify the general mode of application of the principles of my anterior invention.

A first purpose of my system of regulation being to obtain original stocks of water and fuel supplies in a given proportion corresponding to the maximum or minimum of efficiency of the boiler, such feeding may be obtained by means of one motor and of apparatus of constant volumetric yield, proportional to the velocity of the motor. The first regulation of the boiler feeds would be obtained in that way by means of the single regulation of said motor. A feeding apparatus of that class would then comprise a motor (steam engine or electric motor) which would at the same time drive the water feed pump, the petroleum feed pump and the air blower.

One solution of the application of that general process would consist in causing the motor of said feed system to be governed by the water level regulator of my first Cuban application No. 68,434, in order to obtain a stock of water at every moment adequate to the steam consumption of the boiler. The quantity of petroleum and of air supplied at each moment would slightly depart from the true needs of the boiler and should, in consequence, be the object of regulation in one of the ways described in my Cuban patent application No. 68,796. That manner of regulation answers to the original conception that guided my previous inventions; that is, it constitutes in the first place a feed supply of water at every moment adequate to the needs of the generator and establishes the supply of the heating medium to the generator on the basis that the heating medium supply corresponds to that required by the injection of water. The general process of regulation in that form has the feed supply of water as its principal basis.

When the regulation is carried out by regulating the motor apparatus by means of the water level so as to establish the definite stock of feed water from the first regulation, the proportion of

fuel and air can be determined, as described in my Cuban patent application No. 68,796, and adapting the quantity of the supplies of heat production means either to the minimum or to the maximum needs of the generator, that is, in accordance with its maximum or minimum efficiency within the frame of the industrial operations that it may be called upon to accomplish.

Such supplies of fuel and air will be complemented by other supplies susceptible of regulation, and the apparatus effecting the second supplies will be preferably actuated by the same motor which actuates the main supplies. The method of obtaining such regulation has been described in my Cuban patent application No. 68,796. When the principal supplies of fuel and air are fed in accordance with the minimum efficiency of the boiler, the excess of both stocks must be withdrawn before reaching the boiler. That subtraction represents the second regulation and is operated by means of the variation of boiler pressure. Several arrangements for this purpose have been described in my Cuban patent application No. 68,796. When the regulation of the motion motor is effected by means of the variations of pressure, the stock of petroleum and of air can be directly adjusted to the needs of the boiler; and as regards the water, its pumping can be effected by a centrifugal pump regulated by a valve, the regulation of that valve being effected in the manner described in my Cuban patent application No. 68,434.

Instead of employing a water pump of fixed volumetric discharge and a petroleum pump of volumetric discharge capable of being changed, the inverse arrangement might be used, possibly with more logic, because the petroleum and the air must be supplied in equal proportions and it is therefore convenient to keep the proportion of the volumetric discharge of the apparatus invariable. When operating with solid fuel this last arrangement will preferably be adopted. The described processes can be described as of the direct action type, because in their application the regulation of the water feed is obtained by means of the variations in the water level in the generator, and the regulation of the means of combustion is obtained by means of the pressure variations in the generator.

The apparatus for the supply of water, fuel and air, the type of motor actuating it, the apparatus for regulating that motor when operating by means of the variations of the water level or operating by means of the variations of the steam pressure, and the apparatus effecting the complementary regulations, be it by means of the variations of the steam pressure or by means of the variations of the water level, are all subject to variation. The description that will be given hereafter must be considered as only representing examples of the application of the general processes previously described; it being possible to carry such processes into practice in many other different forms.

Other objects and advantages of the invention will appear from the following description considered in connection with the accompanying drawings in which:

Figure 1 represents in schematic form the complete regulation of a boiler utilizing liquid fuel, assuming that the feed apparatus is moved by a steam engine, that the regulation of the motion of that steam engine is governed by variations of the water level, and that complementary regulation of the supplies of liquid fuel and of air is

governed by means of variations of the boiler pressure.

Figure 2 represents in schematic form details of the regulation of the steam engine which moves the feed apparatus by means of variations of the water level of the boiler;

Figure 3 represents in schematic form details of the complementary regulations of the supply of liquid fuel by means of variations of the boiler pressure;

Figure 4 represents in schematic form a feed group for a steam generator utilizing liquid fuel, made up of a water pump and a petroleum pump, both moved by the same steam engine, the motion of that steam engine being regulated by means of the variations of the water level of the generator, the supply of the petroleum feed stream being subject to a complementary regulation based on variations of pressure of the boiler. The volumetric yield of the petroleum pump can be changed in order to adapt it to the conditions of minimum efficiency of the generator within the limits of its operation;

Figure 5 represents in schematic form the supply of air and its regulation in the case of a steam generator utilizing liquid fuel, the blower supplying that air being moved by the same steam engine as the water pump and the petroleum pump, such steam engine being regulated by means of the variation of the water level of the generator, the stream of water generated in that way being sent directly to the boiler without any other regulation, while the supplies of petroleum and of air are the object of a complementary regulation;

Figure 6 represents an arrangement which permits varying the volumetric capacity of the petroleum pump or of the water pump so as to adapt that capacity to the conditions of minimum efficiency of the steam generating installation, thus permitting one same standard equipment to be indiscriminately used for the feeding of generators of substantially equal power and of different efficiencies.

Figure 1 represents a combination of regulation means effected in a similar manner to that of Figure 4, with the difference that the proportion of the water and petroleum pumped is differently controlled in the two figures.

In Figure 1 the water pump BA is directly moved by the steam engine C/ and transmits the motion on a scale susceptible of variation to the petroleum pump B_p by a lever arm L of variable proportion. Said water pump is of fixed volumetric capacity for each stroke of the pump while the capacity of the petroleum pump can be varied by means of the modification of the stroke of the piston.

Referring to Figure 4, this figure relates to a steam generator utilizing liquid fuel, such as petroleum, when the drive of the water feeding pump and of the petroleum pump is effected by a steam engine. The steam engine M represented in a vertical engine which moves the water pump B_a and the petroleum pump B_p, both being piston type horizontal pumps.

In this combination the regulations are carried out as follows. The water regulation is obtained through the variation of speed of the steam engine, in accordance with my Cuban patent application No. 68,434. That regulation, the details of which I shall bring up again later on, can operate either solely upon the steam admission valve V of the engine, as represented at the right side of the drawing, or solely upon the motion of the mirror, that is, upon the expansion

of the steam, in the classic way of the Stephenson link, for example; this construction being represented at the left of the figure; or simultaneously in both ways. The proportion of both petroleum and water pumped corresponding to the consumption of the generator working under its worst efficiency conditions within the limits of its operation, is obtained through the previous regulation of the stroke of the piston of the petroleum pump. To that end, the connecting bar transmitting the motion to that piston can be more or less offset in relation to the center of the shaft that moves it. Such an arrangement is represented in Figure 6.

There is obtained in that way the first regulation, namely the production of a supply of water corresponding at every moment to the needs of the generator, and of a supply of petroleum which would exactly represent the supply required by the generator if operating at that moment under the worst efficiency conditions within its operating limits. Since, in real practice, the efficiency of the generator varies, it is necessary to adjust continuously the supply of petroleum obtained in that way, and this constitutes one first approximation of the exact needs of the generator, which is obtained by returning to the suction of the pump the amount of petroleum pumped in excess. Such adjustment is effected through the regulation of the valve V' which controls such return. The stream of petroleum issuing from tube b is thus adjusted at all times to the needs of the generator, by reason of the partial subtraction from the original supply pumped.

The principal regulation that acts upon the steam engine is effected through the variations of the water level by means of the application of the gauge described in my first Cuban application No. 68,434. The arrangements employed are represented in Figure 2. It is noted that said gauge contains several fluids, its indicating fluid being a good conductor of electricity and denser than oil. Such indicator fluid fills the U-tube formed by the two branches P and 15. Tube 15 is narrower and is the indicating tube. The tube P is filled with oil at its upper part, and such oil column is prolonged at the upper part of the adjacent tube M which, with the upper part of tube P, constitute an inverted U-tube. The lower part of tube M constitutes, in turn, a first branch of the U-tube the second branch R of which is connected to the lower part of the generator by means of a valve A. The tube 15 is filled with oil at its upper part, and that upper part constitutes the first branch N of an inverted U-tube the second branch of which is formed by the tube S (concentric with tubes M and P in the figure), and such inverted tube is filled with oil. The lower part of tube S constitutes, in turn, the first branch of a U-tube whose second branch is formed by the tube T, tube T being connected with the steam chamber of the generator by the valve B. In order to insure that tube T will be always filled with condensation water, a tube 20, not insulated, produces through its cooling by the air, a constant condensation which maintains the level in tube T.

The gauge is constituted by the U-shaped column of the fluid which is a good conductor of electricity, and that column receives, from one part, the steam pressure of the generator and, from another part, the pressure of the liquid at a given height of the same generator, the first of these two pressures being transmitted to the in-

dicating fluid through a column of condensation water and a column of oil, and the second one through a column of water from the generator and a column of oil. A gauge of that shape reproduces, by its indications in tube 15, the variations of level in the generator and on a larger scale.

The improvement in said gauge represented in Figure 2 consists in the increase of the section of branch T of the U-tube filled with condensation water and connecting with the generator. This modification has for its object to diminish the level variations that would be produced in that tube in consequence of the level variations in the generator. Instead of increasing the section of tube T along its whole height, it is sufficient to increase the section of its upper part in order to obtain the same result as represented in Figure 2. The level variations by reason of this arrangement are imperceptible in the branch T and are immediately compensated by the condensation in tube 20. In consequence, the constancy of the condensation water level in branch T becomes assured.

Figure 2 represents the regulation of the steam engine applied in the form shown at the right of Figure 4, that is, operated by valve V. In order to simplify the figure, there has not been represented the electrical connection of the indicating liquid with the entering line of the circuit operating the gauge, nor the connections of the coils a', 11, c', e', f and g with the outgoing lines of the same circuit, that are directly established. In order to facilitate the explanation of the figure, it is noted that the electrodes indicated by the letter a and 10 are the only ones whose function is the regulation that is desired in relation to the water level of the generator, and that the electrodes c and d have for their function to lessen the oscillations of that regulation. All these electrodes are situated in the narrow branch 15 of the U-tube which contains the indicating liquid, that is, in the indicating tube of the gauge which is employed for regulation.

We shall survey separately, the operation of both groups of electrodes. We shall assume, in the first place, that only the electrodes a and 10 exist, electrodes c and d being omitted, and the electrodes a and 10 being directly connected with the coils of the designated a' and 11 respectively. The coil a' operates on the contacts a₁, a₂ and a₃ in such a way that those three contacts are closed when the current of the coil is cut off, and are opened when the current passes through that coil. The coil 11 acts in turn upon the contacts 12, 13 and 14 in an inverse sense, that is, in such a way that these contacts are closed when the current passes through that coil and are opened when the current is cut off in that coil. The current acting on the motor m which effects the regulation of the valve V is alternate, and is provided by an outside plant through lines 1 and 2. Lines 5 and 6 connect such current with the entrance and exit for normal operation of the motor, and lines 7 and 8 connect the same current with the starting circuit of said motor.

When the level in the generator is lower than the normal level and is descending, it is because the generator receives an insufficient quantity of water in relation to its consumption. The indicating liquid is then at a lower level in tube 15 than the electrode a, and the electric currents in coils a' and 11 are cut off. Line 1 is then connected with line 5 and line 2 with line 6 through the contact a₁, so that the circuit operating the

motor *m* is established as follows: 1—5—motor—6—*a*₁—2. Line 1 is also connected with line 8 through the contact *a*₃, and line 6 with line 7 through the contact *a*₂, so that the starting current is established as follows: 1—*a*₃—8—motor—7—*a*₂—6—*a*₁—2; and by reason of the flow of both currents in that direction the motor revolves, driving the stem of the valve in the appropriate direction to open it. By reason of the slow and progressive opening of the valve the speed of the steam engine increases also slowly and progressively and in consequence also the quantities of the respective pumpings of water and petroleum.

The increase of the water pumped tends to balance the water feed with the steam consumption. Once that balance has been obtained, inasmuch as the regulating motor keeps on going in the proper direction to increase the opening of the valve, the water feed keeps on increasing also, and the excess of such feed tends to reestablish the normal level in the generator. When the normal level has been reestablished in that way, the indicating liquid in tube *Q* is higher than the electrode *a*. As soon as the indicating liquid passes the electrode *a* in tube 15, the current is established in the coil *a'*; the contacts *a*₁, *a*₂ and *a*₃ are opened and in consequence the current that was passing from line 2 to lines 6 and 7 is interrupted. Motor *m* does not then receive any more current either in its operating circuit or in its starting circuit. Its motion is suspended and the opening of the regulating valve *V* remains invariable from that moment. As long as the water level in the generator stays relatively normal, namely, when the indicating liquid in tube 15 is situated between the electrodes *a* and 10, the motor *m* remains motionless and the opening of the valve invariable. But since that valve is opened in excess, the water level in the generator keeps on rising and in consequence the level of the indicating liquid in tube 15 rises in a short time above the electrode 10, and this represents an exaggerated water level in the generator.

The current is then established in the coil 11 and the contacts 12, 13 and 14 are closed. By reason of these conditions the currents in the circuit of the motor *m* are established as follows.

Normal operating current: circuit 1—5—motor—6—12—2.

Starting current: circuit 1—13—7—motor—8—14—2.

The starting current is then reversed, while the operating current keeps on operating in the same direction. Those conditions cause the starting of the motor in reverse direction to that of its preceding motion. The new direction of motion of the motor rotates the stem of the valve in the direction to slowly and progressively close said valve, and in consequence reduces the water feed in the same slow and progressive way. Thus, when the water level is lower than the normal level, the regulation tends to increase the water feed. When the level in the boiler is normal, the water feed remains invariable. When the water level is too high, the feed tends to become reduced. In that way the regulation of the water is obtained.

The electrodes *c* and *d* have for their object, as described in my Cuban patent application No. 68,978, to lessen the oscillations that such a regulation as has been previously described would produce. If there is assumed a regulation established previously in a perfect manner and that a lack of balance occurs, for instance by an in-

crease of steam consumption causing the lowering of the water level in the generator while the regulation of the slow opening of the valve is obtaining the proper opening for the new water needs of the generator, the water level in that generator keeps on descending. Such descent is the starting point of the oscillations that are produced, with the same amplitude above and below the normal level of the generator; because during the time required by that generator to reestablish its normal level, the opening variation that is being effected in the regulating valve is the cause of the following oscillation. Operating in that way, there is always maintained at least the same amplitude of oscillation; and that amplitude is moreover increased by reason of the inertia of the regulating motor *m*.

The supplementary electrodes *c* and *d* have for their function to lessen those oscillations. Their function is based upon the fact that the proper opening of the valve occurs at the extremes of the oscillations; either the descending motion of the water having finished, its level is on the point of rising again in the boiler, or, on the contrary, its ascending motion having finished it is on the point of descending again. It is at these maxima and minima of the water level of the generator that the valve is opened exactly in accordance with the real needs of the boiler. The electrodes *c* and *d* tend to reduce the modifications of such perfect opening during the recession of the oscillation; to which end they produce in advance the stoppage of the motor *m* when the boiler level recedes toward normal, in that manner preventing that during the rest of the oscillation the opening of the valve continues to be modified and removed farther from the proper opening.

We shall now survey the practical operation of that idea as represented in Figure 2. We shall first consider the operations effected by the electrode *c*. This electrode is placed in the indicating tube 15 above the electrode 10, within the portion of that tube covered by the oscillations. We shall suppose that, within the limits of movement of the regulation, one oscillation carries the water level in the boiler to a higher point than that corresponding to the indicating liquid at the level of electrode *c*. We shall consider the operations effected with said electrode.

When the level of the indicating liquid is lower than the electrode *a*, the contact *e*₂ is closed and the contact *e*₁ is open because the coil *e* is without current. That state of things does not become modified until the level of the indicating liquid reaches the electrode *c*. In consequence, when said liquid comes in contact with the electrode 10, while rising, current is introduced into the coil 11 and the motor starts revolving in the proper direction for reducing the opening of the valve *V*. When the indicating liquid continues rising and reaches the electrode *c*, the current is established in the coil *c'*, the contact *c*₁ is closed establishing the current in the coil *c'*. By reason of the functioning of that coil, the contact *e*₁ is closed and establishes communication between *a* and the coil *c'*; that is, from that moment the coil *c'* maintains automatically by itself its feed of current from the electrode *a* by reason of the contact *e*₁. On the other hand, the contact *e*₂ has become open; but since the contact *c*₂ has become closed, the current from the electrode 10 keeps on passing in the coil 11 through *c*₂ and closing of the valve *V* is continued closed.

When the indicating liquid has passed the electrode *c* the oscillation arrives at its maximum

point and ready to decline; the valve is then at its proper opening and keeps on closing because the coil *b* maintains its current. When in the descending part of the oscillation the indicating liquid loses contact with the electrode *c*, the coil *c'* is deenergized and ceases to function, the contact *c₂* is opened and in turn leaves the coil *11* isolated from the electrode *10*, that is, without current. In that the suspension of the current in the coil *11* is anticipated, which, as has been explained, represents the suspension of the motion of the motor and the suspension of the motion of the valve *V*. By reason of such suspension of motion, the aperture of the valve *V* becomes fixed in a much nearer position to the proper opening than if the closing motion of that aperture had continued until the indicating liquid had arrived at the electrode *10*. The electrode *d* operates in a similar way in the lower part of the oscillation.

When the water level in the boiler is normal, with the indicating liquid above the electrode *a*, the coil *f* receives current from the electrode *a* and the contacts *f₁* and *f₂* are closed. The current from *d* passes then to the coil *g* through the contact *f₂* and the contact *g₂* is closed. On the contrary, the contact *g₁* is open, so that coil *a'* is fed with current by the electrode *a* through the contact *f₁*, but it is isolated from the electrode *d* by the open contact *g₁*. The coil *g* is in contact with the electrode *d*, not only by reason of the contact *f₂* but also by reason of the contact *g₂*, since both of those contacts are closed. When the level of the boiler descends below normal, the indicating liquid loses contact with the electrode *a*, the current in the coil *a'* is suspended, the current in the coil *f* is also suspended and the contacts *f₁* and *f₂* are opened; but the current continues passing in the coil *g* through the contact *g₂* which is closed, and the contact *g₁* stays open.

The coil *a'* which continues to be isolated from the electrode *d* by the contact *g₁* which stays open, remains then without current; the contacts *a₁*, *a₂* and *a₃* are closed and the motor *m* begins to revolve, causing the stem of the valve *V* to rotate slowly, slowly and progressively increasing the valve aperture. When by reason of that descent in the boiler level the indicating liquid falls in tube *15* below the electrode *d*, the current in coil *g* is suspended, the contact *g₁* is closed and the contact *g₂* is opened. When after having reached its minimum the level in the boiler rises again and, by reason of that rise, the indicating liquid inside the tube *15* comes again in contact with the electrode *d*, the current of *d* passes to the coil *a'* through the contact *g₁*, which is closed. At that moment, the contact *f₁* is open, thus isolating the coil *f* and the electrode *a* from the electrode *d*.

The coil *a'* receiving current from the electrode *d* opens the contacts *a₁*, *a₂* and *a₃*, which interrupts the running of the motor in the same way as if the indicating liquid had reached the electrode *a*. The opening motion of the valve is suspended at that moment when such aperture is relatively near to the proper aperture represented by the aperture registered at the point of the lower level of the oscillation. When, in its ascending motion, the indicating liquid reaches the electrode *a* the coil *f* receives the current from *a*, closes the contacts *f₁* and *f₂* and connects the coil *a* with the electrode *a* through *f₁*, and the coil *g* with the electrode *d* through *f₂*; and, coming into operation, coil *g* opens the contact *g₁* and closes the contact *g₂*. Opening contact *g₁* causes the isolation of the coil *a* from the electrode *d*

and from that moment on the coil *a'* is fed only with the current from electrode *a*. On the other hand, contact *g₂* establishes a second connection of coil *g* with electrode *d*.

By reason of the described installations both electrode *c* and electrode *d* operate to anticipate the stopping of the motor in each oscillation that may have carried the level of the indicating liquid beyond those electrodes, when that level returns toward normal, that is, toward the electrodes *a* and *b*. The opening of the valve is thus suspended when the aperture is relatively near to the proper aperture, which reduces the oscillation. The electrodes *c* and *d* do not operate except upon the oscillations that carry the level of the indicating liquid beyond these electrodes, and in consequence it is convenient that these electrodes be unequally distant from the electrodes *a* and *b*, as I have pointed out in my Cuban application No. 68,978.

In the way described, the regulating level can operate upon the steam engine regulating valve, as it is represented in Figure 2, or upon the Stephenson link, producing the variation of the steam expansion in the steam engine. Such an arrangement is represented in Figure 4, at the left of the steam engine. The regulating motor *m'*, acts in that case upon the arm *J*, which in turn causes the position of the link *K* to vary.

When the pumping of the feed water and of the petroleum are jointly operated by an electric motor, the regulating motor *m* can act upon the rheostat of that electric motor in order to govern the velocity of such electric motor. Any one known regulating system of the motors operating the pumping of water and fuel can be operated by the motor *m*, said motor *m* being in turn governed in the way which has been pointed out, or in any other way, through the variations of the water level in the generator.

The second regulation has for its object to adjust the stock of petroleum to the exact needs of the generator, in the way described in my Cuban patent application No. 68,796. Figure 3 represents in detail an application of that process. The steam pressure regulates the subtraction that is made of a part of the petroleum stock in order to adapt it to the needs of the generator. When the steam pressure rises, it is a sign of too much steam having been produced, and the regulation acts by increasing the aperture of the valve *V'* that governs the subtraction of the petroleum which is returned to the inlet of the same pump.

In Figure 3, *Bp* is the petroleum pump, *a* the feed pipe of that pump, *b* the discharge pipe and *V'* the valve that governs the return to the suction of the pump of a part of the stock pumped by the same. *m'* is the motor which acts on the stem of valve *V'* through an endless screw, and by reason of that motion either opens or closes the valve. Figure 3 has been adapted to cases in which only direct current is available; and the indicating liquid of the manometer cannot then be made of a saline solution. The employment of mercury as the indicating liquid has been assumed in the figure. The sensitiveness of the manometer then decreases, owing to the high density of the mercury.

The regulating manometer utilizes compressed air and is made up of a U-tube which contains mercury in the lower part of the branch directly connected with the generator and condensation water in the upper part, and mercury in the lower part of the other branch *M*, branch *M* being

connected at its upper part with a receptacle for compressed air. There is reproduced in such manometer, though in a varied form, the method utilized in the regulating gauge for the water feed that we have previously considered. In Figure 3, as in the previous one and with the object of simplifying the drawings, there have not been represented the connection of the feed line of the circuit operating the manometer with the electrode *m* and the connections of the coils *p*, *q*, *kc*, *rc*, *jc*, *lc*, *vc*, *wc* and *n* with the outgoing line of the same circuit.

The two electrodes *j* and *r* are the ones that establish the regulation normally, that is, they might operate alone, because the supplementary electrodes *l*, *k*, *v* and *w* have for their function only to restrain the oscillations produced by the regulation itself. In consequence let us suppose, in the first place, that the electrodes *l*, *k*, *v* and *w* do not exist, and let us study in what way the electrodes *j* and *r* would then operate. *j* and *r* are placed at levels representing the limits of the ideal pressure of the generator pressure, so that when the level of the mercury stands in the manometer between *j* and *r* the motion of the motor *m'* must be suspended and the aperture of the valve *V'* invariable. When the level of the mercury is higher than the electrode *r*, it is a sign that the steam pressure is too high, and the motor *m'* must move in the direction to increase the aperture of valve *V'* in order to reduce the supply of petroleum slowly and progressively. When, on the contrary, the mercury level in the manometer stands below the electrode *j*, it is a sign that the steam pressure is too low, and the motor *m'* must move in the direction to decrease the aperture of the valve *V'* slowly and progressively, thus increasing the supply of petroleum destined for combustion in the generator's furnace. If the electrodes *k*, *l*, *v* and *w* did not exist in the figure, the electrode *r* would be directly connected with the coil *q*, and the electrode *j* with the coil *p*.

Change in direction of motion of the motor *m'* is produced, causing the direction of the inductive current of its field to change while the current passing in its armature remains the same in direction. The inductive current passes through the rheostat through lines 1 and 2 and enters the electric motor *m'* through lines 3 and 4. When line 1 is connected with line 3, and line 2 with lines 4, the motor revolves in one direction; and when, inversely, the line 1 is connected with line 4, and line 2 with line 3, the motor revolves in the contrary direction. The second combination is obtained when, the level of the mercury being below the electrode *j*, the contacts *p1* and *p2* are closed and the contacts *q1* and *q2* open. The first combination takes place when, the level of the mercury being above the electrode *r*, the contacts *q1* and *q2* are closed and the contacts *p1* and *p2* open. When the level of the mercury stands between *r* and *j*, all the contacts are open; and the current being interrupted, the motor is stationary. In this manner the desired regulating effect is obtained automatically in each case.

The other electrodes *v* and *w* have a special function that we shall study later. In order to study the operations of the electrodes *k* and *l* let us suppose that those electrodes *v* and *w* do not exist. The electrodes *k* and *l* have the function of lessening the oscillations produced by the regulation itself; but in the present case, the process that has been described for operating

other similar electrodes in the case of the water regulation is insufficient. This is so because a modification in the water feed has an immediate effect in the reestablishment of the equilibrium that must exist between the water injected in the generator and the steam consumed; while a variation in the fuel feed has no effect upon the thermal management of the generator until after a certain time. Such time for the transmission of the regulating effect is also variable according to the condition of the generator, some being more sensitive than others.

It is thus convenient that the regulating action be suspended in advance to partially compensate for the delay in the transmission of the effect of that suspension, thus preventing that during the transmission of such suspension effect the regulating action shall continue, giving rise to new deficiencies in the fuel feed in an inverse direction from the previous ones, by reason of which the magnitude of the oscillation would be amplified. Such advance action is obtained by operating the electrode *k* when, the pressure rising in the manometer above the electrode *r*, such pressure reaches the electrode *k*; and in the same way the electrode *l* operates when the pressure falling below the electrode *j*, reaches a lower level than that of the electrode *l*. Of course, the locations of the electrodes *k* and *l* must be previously determined experimentally, be it in the same boiler or in a boiler of the same type, so that the anticipated suspension of the regulating motion by the electrode *k* may never establish the supply of fuel at a greater amount than the needs of the boiler, and the anticipated suspension of the regulating motion by the electrode *l* may never establish the supply of fuel at a smaller amount than the needs of the boiler.

The desired effect is obtained through the arrangement shown in the figure. Let us suppose the boiler to be at a normal pressure and, in consequence, the level of the mercury in the manometer to be situated between the electrode *j* and *r*. The coil *p* then acts because the coil *jc* maintains the contact *j'* closed. On the other hand, since the contact *j''* is open, the coil *n* is without current and the contact *n'* is closed. Then the coil *lc* receives current and the contact *l'* is open, isolating the coil *p* from the current that might arrive through *m*. If, under those conditions, the pressure falls, depressing the manometer level below electrode *j*, the current through coil *jc* is broken, contact *j'* opens and contact *j''* closes; but, since contact *l'* is open, neither the coil *n* nor coil *p* can receive current from *m*. In consequence, those two coils remain without current and the motor *m'* is acting in the proper direction to diminish the aperture of the valve *V'*.

If the fall of pressure continues and that fall of pressure leads to a manometer level lower than electrode *l*, the current is suspended in coil *lc*, contact *l'* then closes and the electrode *m* provides coils *p* and *n* with current; in consequence, contact *n'* opens and isolates coil *lc* from the electrode *l*. At the same time, since coil *p* is energized, contacts *p1* and *p2* open and the current is suspended in the inductive circuit of the motor, stopping said motor. When, after having reached the minimum of its oscillation the pressure rises again and the manometer level passes the electrode *l*, inasmuch as the contact *n'* continues open, coil *lc* continues isolated from electrode *l*, contact *l'* continues closed and the current from *m* continues to feed coil *p*.

This condition is modified only when the mer-

cury rises in the manometer to electrode *j*, because at that moment the coil *jc* receives current and opens the contact *j''*, cutting off the current of coil *n*; contact *n'* closes in consequence, connecting coil *lc* with electrode *l*. Said coil *lc* then opens again contact *l'*, suspending the energizing of coil *p* through *m*. At the same time coil *jc* closes contact *j'*, so that coil *p* is energized from electrode *j*. Coil *p* continues to act and contacts *p1* and *p2* open. Electrode *l* operates to anticipate the suspension of the motion of motor *m'* and of the valve *V'*, effecting that suspension as soon as the manometric liquid reaches, in its descending motion, a level below electrode *l*.

Going back to the situation existing when the manometric liquid stands between *j* and *r*, at that moment contact *r''* is closed and coil *q* connected to electrode *r* through good conductors of electricity. But inasmuch as the current does not reach *r*, coil *q* does not act and contacts *q1* and *q2* are open. When the manometric liquid rises owing to an increase of pressure and comes in contact with electrode *r*, that electrode furnishes current to the coil *q* through contact *r''*, contacts *q1* and *q2* close, and the motor begins to move in the proper direction to increase the aperture of valve *V'*. When, as the rise of pressure increases, the manometric liquid reaches electrode *k*, coil *kc* actuates and closes contact *k'*, thus energizing coil *rc*. Coil *rc* closes in turn contact *r'*, which produces direct energizing of coil *rc* through electrode *r*. At the same time coil *rc* opens contact *r''* isolating coil *q* from its source of current and in consequence producing the opening of contacts *q1* and *q2*, that is, the stoppage of the motor *m'*.

When, after having risen to its maximum, the pressure falls again below electrode *k*, coil *rc* continues acting and keeping contact *r'* closed, because it receives current from electrode *r* through the same contact; in consequence contact *r''* is kept open, coil *q* without current, contacts *q1* and *q2* open and the motor without motion. When, in its descending motion, the manometric liquid falls below electrode *r*, the current in coil *rc* is suspended and contact *r'* opens. At the same time, contact *r''* closes, the isolation of coil *q* ceasing; but since at that moment electrode *r* is isolated from the manometric liquid, it cannot supply any current to coil *q* and the motor is kept without motion.

Thus the action of electrode *k* consists in prematurely producing the suspension of the motion of the motor and of the valve when, in its ascending motion, the pressure reaches the height of said electrode, the valve maintaining the same aperture from that moment on as long as the pressure does not fall below the electrode *j* in its descent. The electrodes *k* and *l*, operating in the way pointed out, must be situated at sufficient heights in such a way that there exists in every case the assurance that when the manometric liquid reaches the height of electrode *k* the valve *V'* will have a greater aperture than the proper one; and that when the manometric liquid falls below electrode *l* the aperture of valve *V'* will be smaller than the proper one.

Those conditions compel the location of electrodes *k* and *l* sufficiently distant from electrodes *r* and *j*, and in consequence limiting the action of these electrodes to oscillations of great amplitude. Even when the electrode *k* is situated rather higher than electrode *r*, there never exists the assurance when operating as has been pointed out, that is, suspending the opening of the

valve during upward motion of the oscillation when the pressure still rises that the aperture of the valve is at that moment greater than the proper one. For example, if at that moment or shortly before, the steam consumption has diminished, even if the aperture of the valve were too large for the earlier consumption, the aperture might prove to be too small by reason of such decrease in consumption. On the other hand, if the valve remains closed excessively long without the possibility of increasing the aperture subsequently while the pressure is ascending, the too small aperture of the valve would constitute a great danger. That danger is avoided by properly locating the supplementary electrodes *v* and *w* in the gauge.

With normal operation of electrode *k*, when the boiler pressure raises the manometric liquid to the height of that electrode, the aperture of valve *V'* must remain in such a position that it represents insufficient fuel feed for the generator. By reason of that fuel insufficiency, the upward movement of the pressure is bound to be suspended as soon as that fuel insufficiency shall have been reflected in an effect upon the pressure through the transmission delay. The height of the electrode *v* is so fixed that, if the opening motion of the valve *V'* is suspended when the pressure rises to the level of the electrode *k*, and that aperture is greater than the proper one for the valve at that moment, the pressure of the boiler may not rise to the level of *v*, provided the steam consumption remains constant. In consequence, the rise of the pressure to the level of electrode *v* indicates an excessive closing of valve *V'*, whether because electrode *k* had operated with an excess of anticipation, or, subsequent to the action of electrode *k*, the steam consumption had been reduced.

In order to correct that situation, electrode *v* starts the motor *m'* again in the proper direction to increase the aperture of valve *V'*. Said electrode *v* acts also when, by reason of the aperture increase of the valve produced by the same electrode acting during the ascent of the oscillation, that oscillation descends again after reaching its maximum, and passes again the level of said electrode *v*, suspending at that moment the motion of the motor and fixing the aperture of the valve at its dimension at that moment, so as to prevent that, in the descent of the oscillation, the aperture should increase excessively and in that way a new oscillation of at least an equal amplitude be produced. In order to obtain those results, electrode *v* is electrically connected with coil *vc* which governs contact *v'* situated in the electric circuit starting from electrode *k*.

In that way, when the rise of pressure locates the mercury of the manometer at the height of electrode *v*, coil *vc* comes into action, contact *v'* opens and electrode *k* is isolated. By reason of that isolation its action ceases, and in consequence the current passes again through coil *q* and motor *m'* revolves again in the direction proper to reduce the stream of fuel. When, responding to the fuel reduction, the pressure descends again after passing through a maximum, and in that descent it comes to the level of electrode *v*, the current of coil *vc* is suspended, contact *v'* closes again and electrode *k* acts again, suspending the motion of the motor and in consequence immobilizing the valve *V'*, fixing its aperture in a position relatively near to its proper one. Electrode *w* operates in a similar way in the descents of the oscillation.

When, after the closing motion of the valve having been stopped by electrode *l*, the pressure continues falling until the level of the manometer comes to the level of electrode *w*, as soon as it falls below the level of that electrode coil *w* which received its current through electrode *w* is without current, contact *w'* opens and isolates the line *m* from coil *p*. By reason of that, the motor operates again in the direction proper to close the valve, that is, to increase the supply of fuel to the boiler. When, by reason of that fuel increase, the pressure rises again and in that rise the mercury manometric column reaches again the level of electrode *w*, coil *w* comes again into action, contact *w'* closes and reestablishes the connection of the line *m* with coil *q*, suspending the motion of the motor and, in consequence, the closing of the valve; thus preventing that, by continuing its closing, that aperture might depart from its proper one during the rest of the oscillation, which would constitute the origin of new oscillations of at least equal amplitude.

The same electrodes *v* and *w* might be supplemented by other electrodes operating prematurely, with the electrodes *v* and *w* operative only at the return of the oscillation toward the normal pressure, as in the Figure 2 electrodes *c* and *d* operate respectively with the electrodes *a* and *b*; that is, suspending the opening of the valve at a position nearer to its proper one.

The example previously described has referred to the employment of direct current; but evidently, using an alternate current even if only for the regulating manometer, the advantage is obtained of being able to employ less dense liquids and in consequence to increase the sensitiveness of the apparatus. When a saline solution is utilized in that way as indicating liquid, that saline solution must be isolated by a column of a lighter liquid from the condensation water that transmits the steam pressure to the U-shaped column of the indicating liquid. A description of that gauge has been given in my Cuban patent application No. 68,796.

As regards to the auxiliary electrodes, the arrangement can be the same, whether direct or the alternate current is employed; and as regards the electric arrangements that can be adopted in order to govern the electric circuits of the motor through the principal electrodes, there exist appropriate known arrangements, and I have myself presented several employments of them in my previous patent applications.

The description that has been made of the aggregate of the arrangements adopted for the regulation of a generator and of its details, has been confined to the particular case in which the following circumstances concur: (1) steam consumption varying in a proportion not greater than from single to double; and (2) the employment of liquid fuel. When the variation of the steam consumption may be in higher proportions, the automatic regulation that has been described in my Cuban patent application #68,796 can be advantageously applied.

I must note that such automatic regulation is established in a complementary way to the regulation effected by reason of the boiler pressure differences. It was thought of in view of the efficiency variations shown by steam generators. As long as the steam consumption does not exceed double the consumption of the range of greatest efficiency, that efficiency has little variation. When, in relation to that range of greatest

efficiency, the steam consumption is doubled, the efficiency begins to diminish, and it diminishes more and more as the consumption increases, with a greater and ever increasing progression in relation to the acceleration of the steam consumption increase.

Taking those conditions into account, there is hence deduced the possibility of establishing a regulation automatically increasing the proportion of fuel feeding as the steam consumption also increases; and in that way the part of fuel feed supply which can be the object of definite regulation by reason of pressure variation is reduced to a small proportion. The details of that regulation have been described in the account of my Cuban patent application #68,796. For the employment of the invention in cases where solid fuel is used, the arrangement described in said Cuban patent application #68,796 can also be employed.

The air must be injected in proportion to the fuel, and in consequence the regulation of the air must also be established in parallel with the fuel regulation. Figure 5 represents the air supply apparatus which can be installed as complementary to the installation of Figure 4. According to said figure, the air is provided by a blower *S'* driven by the same motor which operates the pumping of petroleum and of water, so as to obtain a production of air appreciably proportional to the production of the first petroleum pumping, when the valve *Ma* is in a fixed position. The complementary regulation of the air is effected by the aperture increase or decrease of said valve *Ma* which is governed by the motor *m'* which regulates the petroleum supply. When the complementary regulation of the fuel is divided into two, one of them governed by the steam consumption differences and the other by the pressure differences, the air regulation is preferably effected in the same way.

The air regulations previously described assume the forcing of that air into the furnace; but if the air is drawn in by a chimney instead of being injected by a blower, the regulations are effected by governing the air admission valves in the furnace. The first one of those regulations is effected in order that the air may correspond to the petroleum supply pumped, and that the complementary regulations shall correspond to the analogous complementary regulations of the petroleum supply. These regulations operate cumulatively as regards the supply of air when quantitatively combined, that is, they are applied to two different air admissions in the furnace, and they operate by subtraction as regards the supply of air when combined in series on the same stream of air. When the complementary regulations of the petroleum stock are effected by subtraction, the air might be regulated independently from the petroleum and by addition; that regulation being governed either by the variations of the supply of the fuel stream, or by the same motor motion that is proportional to the supply of water. The small differences that the employment of this last system of regulation might produce in the supply of air in relation to the real necessities of the generator are, possibly, of a minor order relative to those produced by the imperfection of the system of regulation by aspiration itself.

All the regulations connected with the pressure variations have been described as effected with a compressed air manometer; but they

might evidently be also effected with a metallic manometer, in which the needle would be substituted for the indicating liquid of the compressed air manometer.

I do not pretend to describe all the possibilities that fall within the application of the processes of this invention, which are extraordinarily numerous.

The disclosures of Cuban applications Nos. 68,434, 68,796 and 68,978 referred to herein have been included in my pending United States application Serial No. 342,792, filed June 27, 1940.

I have described what I believe to be the best embodiments of my invention. I do not wish, however, to be confined to the embodiments shown, but what I desire to cover by Letters Patent is set forth in the appended claims.

I claim:

1. A process for regulating steam generators of the type provided with water drums comprising simultaneously providing feed supplies of water, fuel and air to a generator by the action of a single drive motor through apparatus having volumetric discharges substantially proportional to the speed of the drive motor, in proportion to the exact needs of the generator when operating at its worst efficiency conditions within the limits of its actual operation; automatically slowly and progressively regulating the speed of the drive motor in accordance with variations in the water level in the generator alone so as to adjust the water supply at all times to the steam consumption; subtracting from the fuel supply thus provided the excess that it may include in relation to the real needs of the generator, and simultaneously reducing the air supply, such subtraction and reduction being effected slowly and progressively through pressure variations alone in the generator so as to maintain such pressure substantially constant.

2. A process for decreasing the oscillations that may be produced in automatic regulation of the supplies of heating means to a boiler by pressure variations in the boiler with slow and progressive variations in the fuel supply, consisting in locating a pair of supplementary electrodes in a manometer at pressure levels respectively higher than the normal regulating electrode operating at highest normal pressure and lower than that of the normal regulating electrode operating at lowest normal pressure, combining therewith an electrically operated regulating system such that, when by reason of a steam pressure variation which takes such pressure away from the normal range of pressure of the generator, the indicating element of said system comes in contact with either one of such supplementary electrodes, said contact produces in said system a suspension of the slow and progressive regulating action.

3. A process having for its object the prevention of dangers arising from operating irregularities in the application of the regulation set forth in claim 2 comprising locating in the regulating manometer a supplementary high pressure electrode set at a higher pressure than the highest pressure normal electrode of that system, combined with an electrode system in which when the manometric indicator reaches the level of such supplementary electrode, the action of the normal electrode is automatically suspended; and when subsequently during descent the pressure falls below the level of said supplementary electrode, said high pressure normal electrode again comes into operation; in the same way, locating a supplementary low pressure electrode in the

same manometer at a lower pressure than that at which the lowest pressure normal electrode in the process set forth in claim 2 operates, electrically connected in such a way that, when the pressure falls to the level of such supplementary low pressure electrode, there is automatically suspended the action of such lowest pressure normal electrode in the process set forth in claim 2; and when upon its return toward normal conditions the pressure arises again to the height of the said supplementary low pressure electrode, said lowest pressure normal electrode again comes automatically into operation in accordance with the process set forth in claim 2.

4. An improvement in the process having as its function the prevention of dangers from operating irregularities in the application of the regulation set forth in claim 2, comprising placing two supplementary electrodes in the regulating manometer outside (with relation to the normal generator pressure) the normal electrodes that operate in the process mentioned, the supplementary electrodes being provided with the necessary electric systems in order that they may operate upon the return of pressure oscillations which may have carried such pressure to greater extremes in level than the level of said supplementary electrodes in relation to normal pressure, so as to suspend the motion of the regulating motor upon passing said supplementary electrodes during such return motion, it being possible for each of such supplementary electrodes to be in turn supplemented by one more auxiliary electrode relative to the normal pressure of the generator, in addition to the necessary electrical circuits, in order to permit such auxiliary electrode to effect in advance the action corresponding to the supplementary electrode which it supplements, when upon return to the pressure oscillations toward its normal condition, the level of the manometer crosses said latter supplementary electrode.

5. The application of the regulating processes set forth in claim 2 to automatic regulation of the feed supplies of fuel and air to the boiler.

6. A steam generator regulating system comprising means for adjusting a feed to the steam generator and means for automatically operating the adjusting means to correct variations in the water level in said system comprising a liquid gage connected at its ends to the water chamber and steam chamber of the generating system respectively, and a column of liquid filling the gage, including a conducting liquid and condensation water extending to the connection with the steam chamber, the gage adjacent said latter connection being of substantially enlarged diameter forming a reservoir for a substantial body of said condensation water, arranged to contain that end section of said column of liquid in communication with said steam chamber and to minimize level variations in the end of said column of water adjacent said connection to the steam chamber.

7. A process for regulating a steam boiler of the type provided with a water drum in which the regulation is effected in accordance with variations in only two factors, namely, the water level variations in the boiler as an indication of the variable volume of the water reserve and the steam pressure variations, which process comprises providing by action of a single drive motor operating feeding mechanisms having speeds causing volumetric discharges substantially proportional to the speed of the drive motor, to establish original relative rates of feed of water, fuel

and air corresponding to the general needs of the boiler, applying the regulating action of the water level variations only slowly and progressively to the regulation of the speed of said motor independently of steam pressure variations to effect changes in said motor speed without affecting the relative speeds of said feeding mechanisms, and without affecting the relative rates of feed of the water, fuel and air to the boiler, and complementally applying only steam pressure variations to the regulation of the relative rates of feeding of the water, fuel and air independently of the water level variations to change said relative rates of feeding according to the actual needs of the boiler.

8. A process for regulating steam boilers of the type provided with a water drum, which comprises utilizing the water level variations in the drum as a control factor, and the steam pressure variations as another control factor, operating the means for feeding water and the means for feeding the combustion elements from a single drive motor to cause proportional feed of said water and said combustion elements to the boiler according to the general needs of the boiler, adjustably varying the speed of all of the feeding means in unison in response to the first of said control factors alone independently of the other control factor without affecting the relative rates

of feed of the water and the combustion elements of the boiler, and adjustably varying the rate of feed of one of the combustion feeding means in response to the pressure control factor alone independently of the other control factor to maintain said water level and said steam pressure substantially constant.

9. An apparatus for regulating steam boilers of the type provided with a water drum to maintain the water level condition and the steam pressure condition substantially constant, comprising means for feeding combustion elements to the boiler, means for feeding water to the boiler, a single motor for driving said feeding means, means automatically operable only in accordance with variations in the water level conditions and independent of variations in the other condition for varying the speed of said drive motor, to vary the speed of all of said feeding means in unison, while maintaining the relative rates of feeds of said feeding means constant, and means automatically responsive only to variations in said last-mentioned condition independently of variations in the first condition for varying the rate of feed of one of said combustion feeding means in relation to the other feeding means.

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