Feb. 5, 1957 J. E. LA ROCQUE ET AL 2,780,206

MULTIPLE BOILER CONTROL SYSTEM

Filed June 23, 1953 4 Sheets-Sheet 1

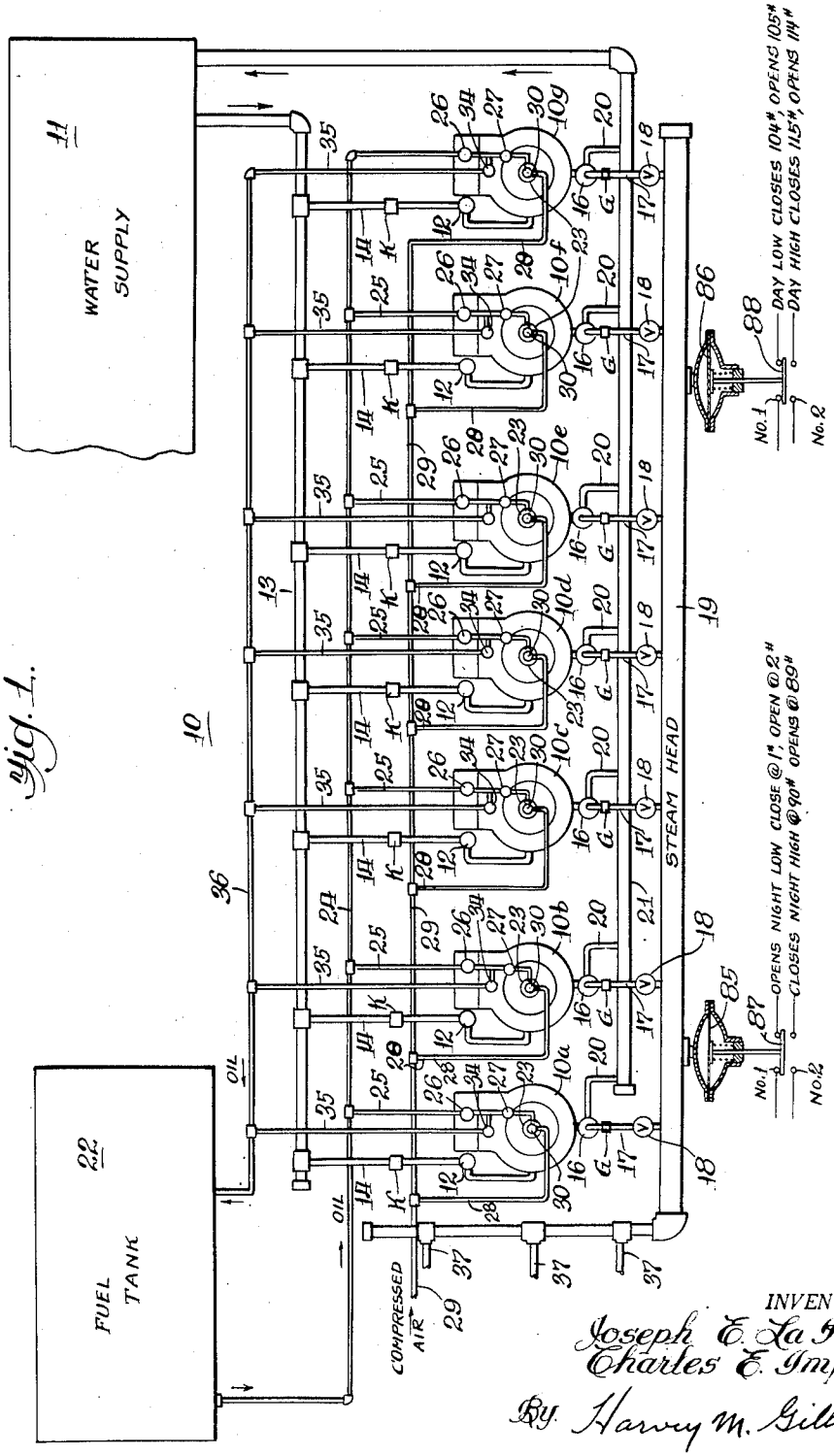

Fig. 1.

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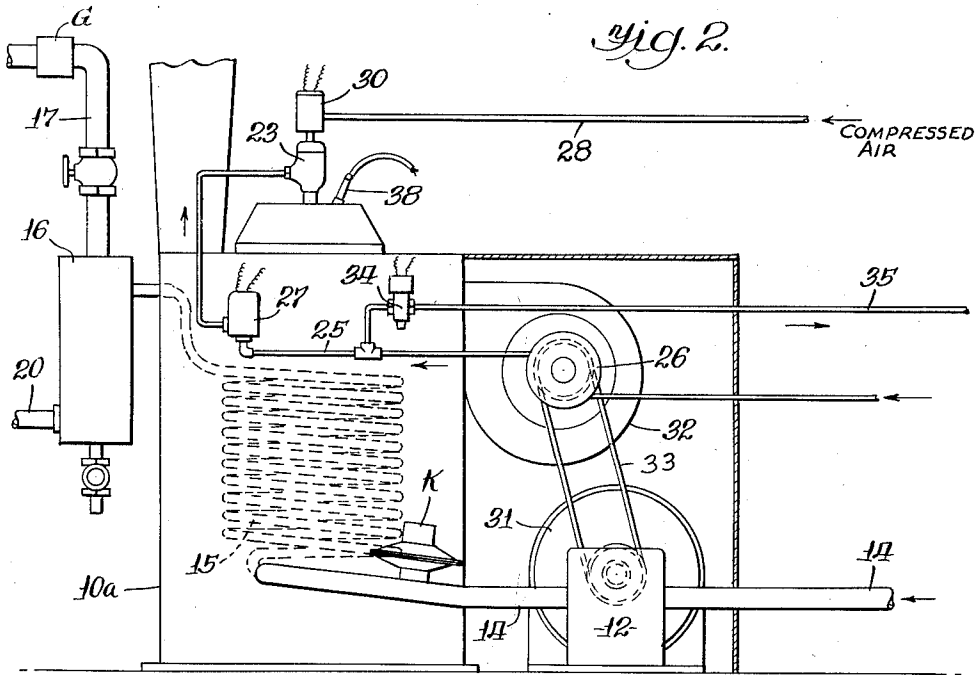
Fig. 2.



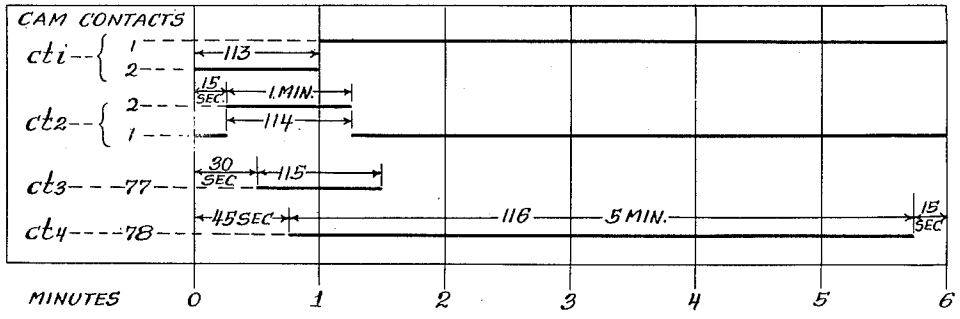


Fig. 5.

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MULTIPLE BOILER CONTROL SYSTEM

Filed June 23, 1953 4 Sheets-Sheet 3

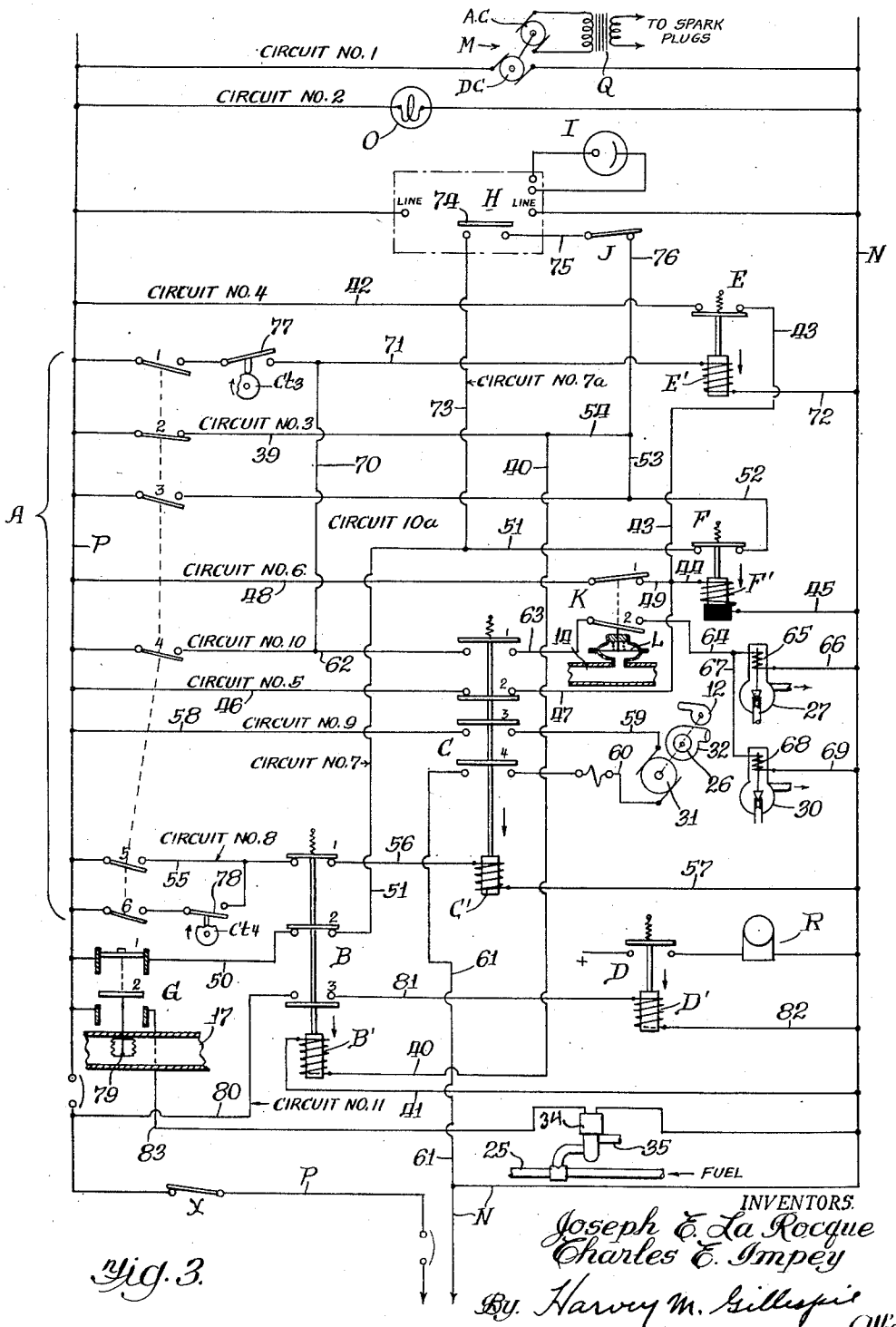

Fig. 3.

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MULTIPLE BOILER CONTROL SYSTEM

Filed June 23, 1953 4 Sheets-Sheet 4

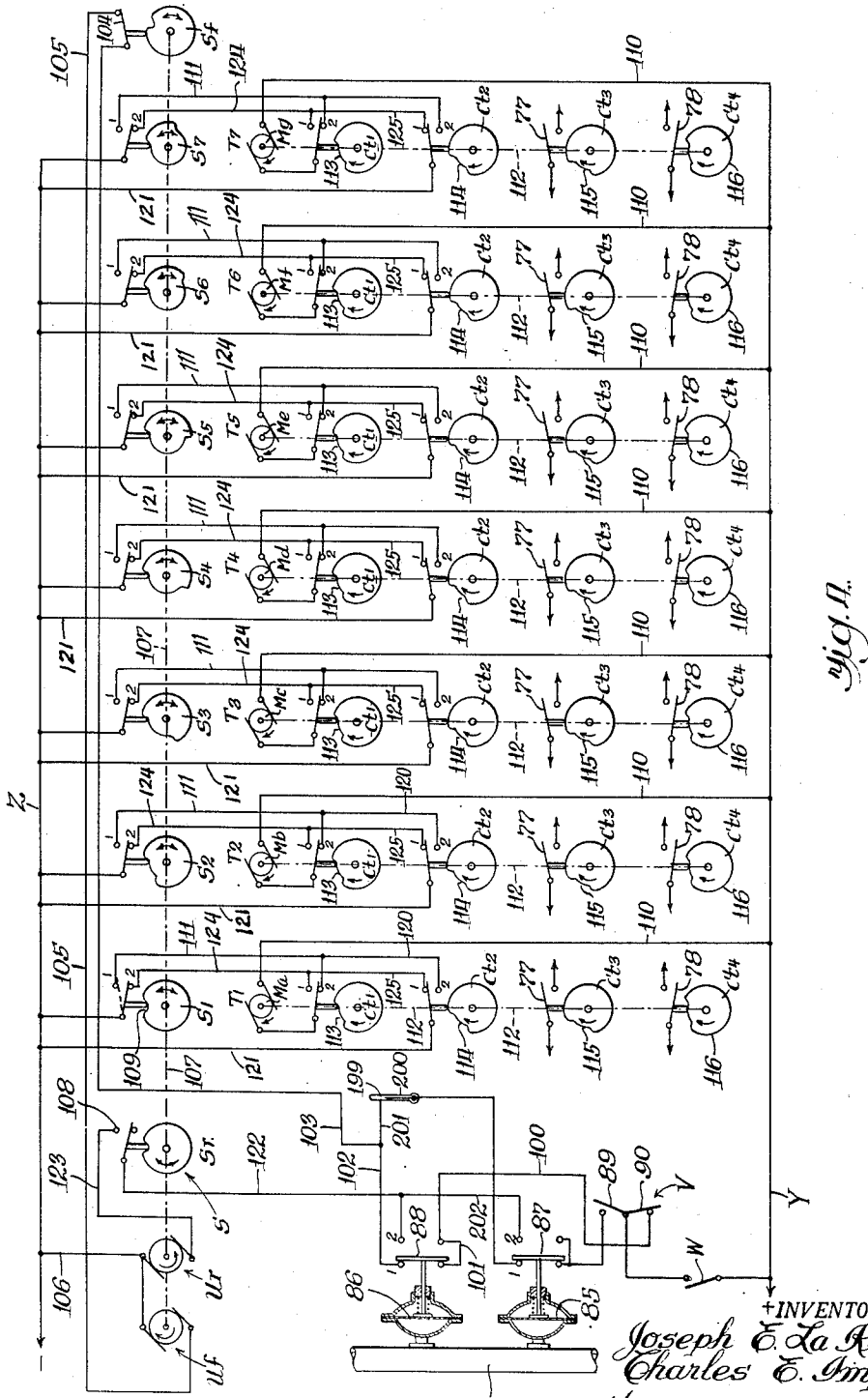

Fig. 4.

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2,780,206

MULTIPLE BOILER CONTROL SYSTEM

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Application June 23, 1953, Serial No. 363,548

9 Claims. (Cl. 122—448)

The present invention relates to an improved control system for automatically regulating the operation of a multiple boiler steam generating plant to meet a varying demand for steam.

Steam generating plants of the type herein shown may be used advantageously and economically in situations in which the demand for steam fluctuates to a considerable extent from time to time. For example, the heating of railway passenger cars which are temporarily out of service and stationed in railway terminal yards. When such terminal yard is filled with trains of passenger cars the demand for steam may be very high and require the full output capacity of several steam generators. At other times, with only one or two trains of cars on hand, the demand may be considerably reduced and require the output of but a single generator. Likewise in large laundry establishments when the plant is in full capacity operation, the services of several steam generators may be required while at other times, during night operation for instance, a single generator or two at the most may be adequate to care for the demand for steam.

These are but two suggested situations in which multiple steam generating units may be used and to which the present control mechanism may be advantageously applied. However other uses for such a system will readily suggest themselves. Regardless of the particular use to which the multiple boiler system may be put, the control system of this invention is designed to automatically regulate the operation of the system to satisfy varying demands for steam at any time without needlessly exceeding the demand and without requiring a large maintenance personnel to manually regulate the operation of the generators.

According to the invention a control system is provided whereby when the demand for steam, as reflected by the steam pressure maintained in a header or manifold connected to a series of generators, is sufficiently low that a single generator is capable of satisfying the demand; one generator of the series is set into operation to satisfy that demand. If the first generator fails to supply the necessary volume of steam within a predetermined time period its output is augmented by the automatic setting into operation of a second generator calculated to deliver the necessary additional steam to provide the desired pressure in the common header. Similarly, if the first two generators do not supply the amount of steam required to maintain the desired steam pressure, a third generator will be set into operation and thereafter, if the demand is not satisfied, additional generators will be brought into operation in succession until such time as all of the available generators are operating. However, if after a particular generator has been set into operation the desired steam pressure is attained in the said header, no further generators will be set into operation. The generators which have been put into operation will be maintained in operation until such time as the demand for steam warrants disabling of

one or more of them. In such an instance the present control system is designed to automatically cut out of operation one or more generators until the steam pressure in the header is reduced a point. In order to accomplish this result, the system operates to disable the generators in the reverse order from which they were initially brought into operation.

In bringing the various generators into operation or in cutting them out of operation, the fire and water are controlled automatically to protect the generator structure. For example, prior to cutting a particular generator into operation certain routine procedure wherein the fuel and atomizing air apparatus are first set into operation, followed by operation of the water pump and blower apparatus is invariably followed. Similarly in shutting down a generator from a full fire condition to a stand-by condition the fuel and air apparatus is first disabled and the water pump is allowed to run for a short period of time so as to cool the generator and insure the fact that the coils are filled with water and that the generator is left in a stand-by condition prior to a subsequent operation.

The control apparatus as briefly outlined above will so function that the operation of a generator may be interrupted after the generator has been selected for operation and before it has reached its full operation, if the demand for steam is such as to indicate that the service of the generator is not required. In this connection, the portion of the control apparatus which affects the operation of the selected or partially operated generator will complete a cycle which may not necessarily bring the generator to full operation but which nevertheless will leave the generator in readiness for a subsequent operation if a later demand for steam requires its operation.

Other objects and advantages of the invention, not at this time enumerated, will be expressed as a further statement of invention after a description of one particular steam generating plant to which the invention is applicable has been made and after its intended operation has been set forth. In this manner a better understanding of the principles of the invention may be had and repetitious description of function will be avoided.

In the accompanying drawings, one illustrative embodiment of the invention has been shown, wherein:

Fig. 1 is a schematic view of a multiple boiler steam generating system or plant provided with the improved control system of the present invention;

Fig. 2 is a view partly in section and partly in elevation illustrating a steam generator unit and showing the several electrical control elements associated therewith;

Fig. 3 is a circuit diagram showing the said electrical control elements connected in their associated control circuits;

Fig. 4 is a schematic view of an electrically operated timing control mechanism employed to initiate and control the operation of the control apparatus of the individual steam generators of the system;

Fig. 5 is a timing chart illustrating the operation of the timing control mechanism of Fig. 4.

Multiple unit steam generating system

Referring to the drawings and in particular to Fig. 1, a multiple-unit steam generating system is designated generally by the reference numeral **10** and includes a plurality of substantially identical steam generators. For convenience of illustration, a bank of seven such units are shown schematically and the individual generators are designated **10***a* to **10***g* inclusive. It will be understood, however, that a greater or lesser number of such units may be employed according to the desired maximum capacity of the system. The steam generators are prefer-

ably, though not necessarily, of the water-tube type. For convenience, the steam generator **10***a* is shown in Fig. 2. Water is drawn from a source of supply **11** by means of the individual feed pump **12** associated with each of the steam generators. The flow path of the water includes a manifold supply line **13** and a series of branch pipes **14** in which the feed pumps **12** are interposed to deliver the water to a coil **15** (see Fig. 2) of its associated generator **10***a*–**10***g* as operating conditions may require. Hot water and steam discharged from any one of the steam generators is received by an associated steam separator **16**. The steam passes from the top of the separator through a pipe **17** and check valve **18** into a steam header **19**. The water separated from the steam is discharged from the separator **16** through a branch conduit **20** into a water return manifold **21** leading back to the source **11**.

Fuel, which preferably is oil, is supplied from a fuel tank **22** to a spray head or nozzle **23** of each steam generator through a fuel supply manifold **24** and branch conduit **25** in which there is interposed a fuel pump **26** and a solenoid opened fuel valve **27**, which is energized open. Compressed air for atomizing the liquid fuel is delivered to the spray head **23** through a branch conduit **28** leading from an air supply manifold **29**. Each air branch conduit is provided with a solenoid opened valve **30**.

The water pump **12** is operated by a motor **31** and the combustion air is supplied to the fire chamber by means of a blower **32**. The fuel pump **26** is preferably operatively connected with the operating shaft of the blower **32** and the blower is operatively connected, for example by means of a belt **33** with the motor **31**, whereby the fuel pump, blower and water feed pump are all operated by the motor **31**. Consequently, when it is desired to shut off the delivery of fuel while the blower **32** and the pump **12** continue their operation, a fuel by-pass valve **34** opened either electrically or by pressure permits the fuel in branch pipe **25** to return to the fuel tank **22** through branch pipe **35** and manifold return pipe **36**.

The steam header **19** may be employed for supplying steam to all manner of steam powered equipment such as heat exchangers, turbines, steam engines, nozzles, steam expansion or steam escapement devices and the like. Such devices have not been illustrated herein but it will be understood that each device is operatively connected to the header **19** by a suitable steam take-off or leader line such as the lines indicated at **37**.

Individual generator control

The control of the multiple steam generators **10***a*–**10***g* involves the exercise of control, by means of master and individual timers (Fig. 4) of the individual control systems of the several generators. It is deemed desirable, therefore, to describe the operation of the individual control system for one of the generators before describing the manner in which the individual generators are cut in and out of the multiple control system.

Referring now to Figs. 2 and 3: Certain of the control elements are illustrated in Fig. 2, and these elements, together with other elements not shown in Fig. 2, are connected in the circuit diagram shown in Fig. 3. The component parts of the control mechanism of Fig. 3 includes a manual cut-out switch X interposed in positive line P, a main switch A capable of being set for either manual control or for automatic control under the influence of the timing mechanism of Fig. 4. The main switch A may be a rotary type switch having contacts **1** to **6** inclusive adapted to be opened and closed in predetermined sequence, but the particular construction of the switch is not important for an understanding of the present invention. Therefore, it can be regarded as six manually operated contacts **1** to **6** inclusive.

The system further includes four relay operating switches including a master relay B having movable contacts **1**, **2** and **3**; a motor control relay C having contacts **1** to **4** inclusive; a single contact alarm relay D; a single contact interlock relay E; a single contact out-fire relay F; a temperature control switch G having contacts **1** and **2**; a relay control switch H which operates under the control of a photo-electric cell (I) disposed in the fire chamber of the generator and having a manual cut-out switch J; and a water pressure switch K having contacts **1** and **2** controlled by the water pressure, the contacts being operable under the control of a pressure actuated element L whereby contact **1** is opened during the presence of water pressure and contact **2** is closed during the presence of water pressure in the generator.

Additional operating devices associated with the system are relay actuating magnets B′, C′, D′, E′ and F′ for the relays B, C, D, E and F, respectively.

The various operating elements illustrated in Fig. 3 are shown in the positions which they assume when the manual switch X is closed, but the main switch A is in its off position. In this position the contact **2** of said main switch is closed. The closing of the manual switch X establishes circuit No. **1** for energizing motor generator M which in turn energizes a transformer Q for supplying electrical current to a spark plug **38** (Fig. 2). Also, a visual signal, for example an electric light "O" is interposed in a circuit No. **2** connected across the positive and negative lines of the system.

When the main switch A is in its off position its No. **2** contact is closed, thereby establishing circuit No. **3** for energizing the master relay B. This circuit leads from the positive line P through said No. 2 contact of the main switch A, leads **39**, **40**, relay magnet B′ and lead **41** to the negative line N. The energization of relay B closes its No. **1** and **2** contacts and opens the No. **3** contact. A circuit No. **4** leads from positive line P through lead **42** through a normally closed contact **1** of relay E, leads **43** and **44** through the magnet F′ of out-fire relay F and thence through lead **45** to the negative line N. A second circuit designated No. **5** is also effective for energizing the out-fire relay. This circuit leads from positive line P through lead **46**, normally closed contact **2** of relay C, leads **47** and **44** through the magnet F′ and lead **45** to the negative line N.

Assuming that there is no water pressure in the generator, the contact No. **1** of water pressure switch K is closed and thereby establishes a circuit No. **6** through the magnet F′ of said out-fire relay F. This circuit leads from positive line through lead **48**, contact No. **1** of water pressure switch K, leads **49** and **44**, magnet F′ and lead **45** to the negative line N. The energization of the out-fire relay F by any one of the said circuits **4**, **5** or **6**, establishes a holding circuit for maintaining the master relay B energized. This holding circuit is designated circuit No. **7** and leads from the positive line P through a normally closed low temperature No. **1** contact of temperature switch G, lead **50**, energized closed No. **2** contact of master relay B, lead **51** through energized closed contact of out-fire relay F, leads **52** and **53** and leads **54** and **40**, magnet B′ of relay B and thence through lead **41** to the negative line N. This holding circuit (circuit No. **7**) will be effective to maintain the master relay B energized so long as the out-fire relay F is energized closed. The said out-fire relay F is constructed to delay its opening for five seconds after all energizing circuits therefor have been opened. This feature is not important for the present, but is important as a safety measure to interrupt the operation of the system in the event of failure of fuel to ignite for a period of five seconds.

The heating coil **15** of the generator is filled with water before fuel is ignited in the fire chamber of the generator. The operation for filling the coil is accomplished by positioning main switch A to open its No. **2** contact and close its No. **5** contact. This operation of the main switch can be effected without disturbing the closed position of the master relay B, since its holding circuits through the out-fire relay (circuits Nos. **4**, **5** and **6**) remain effective.

The closing of said No. 5 contact of the main switch A establishes an energizing circuit for the relay C and thereby effects energization of the motor 31 for operating the fuel pump 12. The circuit for energizing relay C is designated circuit No. 8 and extends from the positive line P through the closed contact 5 of the main switch A, lead 55, energized closed contact 1 of relay B, lead 56, magnet C', of relay C and thence through lead 57 to the negative line N. The energization of relay C opens its contact No. 2 and, therefore, breaks circuit No. 5, but closes its contact Nos. 3 and 4 to establish an operating circuit designated circuit No. 9 through the motor. This circuit extends from positive line P through lead 58, energized closed contact 3 of relay C, lead 59 through the motor 31 and thence through negative lead 60, energized closed contact 4 of relay C and lead 61 to the negative line N.

The said motor 31, in addition to operating the said pump 12, also operates the fuel pump 26 and the blower fan 32, but the fuel valve 27 is de-energized during the coil filling operation, and, consequently, the fuel from pump 26 is by-passed through the by-pass valve 34 and conduit 35 to the fuel tank, the by-pass valve 34 being opened in this instance by pressure of the fuel created by the operation of pump 26 while the fuel valve 27 is closed. If it is desired to continue the operation of the generator under manual control, the contact No. 5 of the main switch remains closed and the contact No. 4 is closed and the operation just described is continued until the water pressure in the generator coils 15 is sufficient to close No. 2 contact of pressure switch K and opens No. 1 contact thereof. The closing of the said No. 2 contact of pressure switch K establishes circuit No. 10 for energizing open the fuel valve 27 and the air valve 30 to deliver atomized fuel into the fire chamber of the generator where it is ignited by the sparking plug 38 of the ignition circuit. The said circuit No. 10 leads from positive line P through the closed contact 4 of the main switch A, lead 62, energized closed contact No. 1 of relay C, lead 63, closed contact No. 2 of pressure switch K and lead 64 through the magnet winding 65 of fuel valve 27 and lead 66 to the negative line N. The air valve 30 is connected in parallel with the fuel valve 27 by means of a branch lead 67 connected in lead 64 and extending through magnet winding 68 and lead 69 to the negative line N. The closing of contact No. 4 of the main switch A establishes a second circuit designated 10*a* for energizing the interlock relay E and thereby de-energizing circuit No. 4 through the magnet F' of relay F. The circuit 10*a* leads from a junction in lead 62 through leads 70, 71, magnet E' of relay E and lead 72 to the negative line N. It will be noted in this connection that circuit No. 6 for energizing the magnet F' of out-fire relay F is also de-energized by the opening of the low pressure contact No. 1 of pressure switch K. Consequently, all energizing circuits through the magnet F' of out-fire relay F are now de-energized. However, the relay F' is constructed to remain closed for a period of five seconds after its energizing circuits have been open. If the fuel fails to ignite in the fire chamber within the period of five seconds the relay F is de-energized to open its contact and thereby opens the holding circuit No. 7 through the magnet B' of the master relay B and thereby de-energizes the control system. However, the ignition of the fuel in the fire chamber within said period of five seconds results in activating the photo-electric cell (I) so as to close relay contact H and thereby establish a holding circuit through the magnet B' of master relay B, which holding circuit maintains the master-relay energized as long as ignition of the fuel continues in the generator. This circuit is designated circuit No. 7*a* and extends from a connection in lead 51 through lead 73, closed contact 74 of relay H, lead 75, closed manual cut-out switch J, leads 76, 54 and 40 through the relay magnet B' and thence through lead 41 to the negative line N.

The manual operation may be interrupted by opening the No. 4 and No. 5 contacts of the main switch and closing switch No. 2 whereupon the delivery of fuel and feed water to the generator is discontinued and the control elements of the system are returned to the positions illustrated in Fig. 3 so as to correspond to the "off" position of the main switch A.

Steam generator automatic control

After the generator has been filled with water and is otherwise conditioned for operation, the main switch A is set for automatic operation. In this position of the switch A its contacts Nos. 1 and 6 are closed and its contacts 2, 3, 4 and 5 are open. The control elements B, C, D, E, F, will assume the positions shown in Fig. 3 by virtue of the existence of circuit No. 7. The valves 27 and 30 will be closed and the low temperature contact No. 1 of temperature switch G will be closed. Closure of the Nos. 1 and 6 contacts of said main switch A are ineffective at this time inasmuch as they are in series, respectively, with timer cam contacts 77 and 78, which are open. However, the generator otherwise stands in readiness for operation when called for by closure of the cam operated timer contacts 77 and 78.

At this point it should be noted that the entire control apparatus attains a static condition with certain circuits under energization and certain other circuits potentially available for energization, all awaiting closure of the timer controlled contacts 77 and 78 to place the generator in immediate operation. The opening and closing operations of the contacts 77 and 78 under the control of the timer mechanism of Fig. 3 will be described subsequently but for the present the function of these contacts 77 and 78 in the system will be set forth.

Closure of the timer contact 77 establishes a circuit through magnet E' and thereby energizes relay E to open circuit No. 4 through the out-fire relay magnet F'. The closing of timer contact 78 re-establishes parts of circuits No. 8 so as to energize relay C and thereby open circuit No. 5 through out-fire relay magnet F' and closes the circuit No. 9 through the motor 31 to initiate operation of the pump 12. Operation of the pump 12 produces sufficient pressure in the water coil 15 to open closed contact No. 1 of pressure switch K and thereby open the remaining energizing circuit (circuit No. 6) through magnet F' of out-fire relay F. However, as before indicated, the out-fire relay remains closed for five seconds after its energizing circuits are opened. The water pressure in the generator coil 15 also closes the contact No. 2 of pressure switch K and thereby completes parts of circuits Nos. 10 and 10*a* to energize open the fuel valve 27 and the air valve 30. The parts of circuits 10, 10*a* thus established lead from the positive line P through closed contact No. 1 of main switch A, closed timer contact 77, leads 71, 70, 62, closed contact No. 1 of relay C, lead 63, closed contact 2 of pressure switch K, magnet coil 65 of fuel valve 27 and lead 66 to negative line N. The air valve 30 is simultaneously energized open by a branch lead 67 extending through magnet coil 68 of valve 30 and thence through lead 69 to the negative line.

Ignition of the fuel delivered into the fire chamber will normally take place within the period of five seconds that the out-fire relay remains closed. Such ignition activates the photo-electric cell I and thereby closes the contact 74 of relay H and thereby establishes a holding circuit 7—7*a* and part of circuit No. 3 to maintain the master relay B energized, so long as the ignition continues in the fire chamber.

If for any reason the temperature at the discharge end 17 of the generator exceeds a predetermined maximum, a thermal element 79 of the temperature switch G functions to close its No. 2 contact. The closing of No. 2 temperature contact energizes the solenoid of the fuel by-pass valve 34 and thereby cuts off two-thirds of the normal volume of fuel delivered to the fire chamber. This re-

duction in the delivery of fuel is accomplished without affecting the delivery of water. The circuit for energizing open the fuel by-pass valve 34 extends from positive line P through closed contact No. 2 of temperature switch G and lead 83 through the solenoid of by-pass valve 34 and thence to negative line N.

If the reduction of the fuel delivery is sufficient to correct the high temperature conditions of the steam and thereby prevent the development of superheated steam, the contact No. 2 will again open and the full operation of the generator will be resumed. However, if the steam temperature at the outlet 17 increases above such maximum, contact No. 1 of temperature switch G will open and thereby open the holding circuit 7 and 7*a* through the solenoid B' of relay B. The opening of the said holding circuit and consequent de-energization of relays B and C opens the operating circuits Nos. 9 and 10*a* so as to shut down the boiler operation. The de-energization of relay B also closes its contact No. 3 and thereby energizes the signal R to notify the attendant that the boiler requires inspection. After the boiler is completely shut down, it cannot be again activated until certain manual adjustments are made as follows:

(1). The temperature switch G must be manually reset to close its contact No. 1 and open its contact No. 2.

(2). The main switch A must be turned to its off position so as to close its contact No. 2 and thereby establish an energizing circuit through solenoid B' to close contacts No. 1 and No. 2 of relay B.

(3). If the water coil 15 is filled with water the No. 2 contact of water pressure switch K will be closed and if the timer switch 78 still remains closed the boiler may be set into operation by shifting main switch A from its off position to its automatic run position to close its switch contacts Nos. 1 and 6. However, if the water coil 15 is not filled with water the No. 2 contact of pressure switch K will be open. Consequently, the main switch must be turned to a position to fill the water coils as previously described and thereby open the No. 1 contact of pressure switch K and close its No. 2 contact before fuel will be delivered into the fire chamber of the boiler.

Multiple generator control

It will be seen that the demand for steam by the various steam-consuming devices connected to the several conduits 37 will vary widely, depending upon the number of such devices actually in operation at any given instant and according to the combined steam consuming capacity of the devices in operation at such time. This demand for steam will, of course, be reflected by the varying pressure of steam existing within the header 19.

According to the present invention, control means are provided whereby when the demand for steam is sufficiently low that a single generator is capable of satisfying this demand, the generator 10*a* will be set into operation to supply the necessary head or steam. If the continued demand does not exceed the capacity of the single generator, that generator will remain in operation indefinitely to maintain the necessary balance of steam pressure in the header 19. If, however, the single generator 10*a* fails to maintain the desired steam pressure in the header 19, a second generator 10*b* is set into operation to augment the supply of steam delivered to the header. If and when the demand for steam increases beyond the capacity of the said two generators, additional generators are cut in until such time as all of the available generators 10*a*–10*g* in the bank are in operation.

The control system is so designed that when two or more generators 10*a*, 10*b*, etc., are in operation and the demand for steam is decreased and as a result of the reduced demand, the steam pressure within the header 19 rises above a predetermined maximum, one of the generators will be automatically cut out of operation without disturbing the operation of the other generator or generators which may be functioning at the time. If the demand for steam is further decreased to such an extent as to justify the shutting down of one or more additional generators, these additional generators will be automatically cut out successively at predetermined time intervals.

According to the present control system, the various generators 10*a* to 10*g* inclusive are cut into operation in a definite sequential order, i. e. in the order named as the demand for steam increases. Likewise during a decrease in the demand for steam the various generators are cut out of operation in the reverse order so that in such an instance the last generator which has been set into operation will be the first generator to be cut out of operation. Furthermore, the control system is so designed that in the event that after a particular generator has been set into operation due to a sudden increased demand for steam, if that demand is reduced before the the generator attains its full operation, the firing of the generator is interrupted, but its feed water pump will continue operations to cool down the generator and insure the filling of the water coils thereof so as to leave the generator in readiness for a subsequent operation if occasion so demands.

The multiple generator control system of the present invention is predicated upon the use of the individual control mechanism hereinbefore described for generators 10*a* to 10*g* inclusive, together with a timing mechanism such as shown schematically in Fig. 4, which timing mechanism is employed for the purpose of controlling the operation of the various individual control apparatus. The timing mechanism of Fig. 4 is cyclic in its nature and is capable of a complete cycle of operation from an initial starting time until completion of a full cycle, during which time it will cause all of the generators 10*a* to 10*g* to be sequentially cut into operation at definite spaced time intervals. The mechanism is also capable of being interrupted or reversed in its cyclic operation as the demand for steam in the header 19 lags or falls.

The cycling operations of the timing mechanism of Fig. 4 is responsive to and depends solely for its reversible operations on a rise or fall of steam pressure from a predetermined normal in the steam header 19 as evidenced by the pressure exerted upon the respective diaphragms 85—86 of a pair of pressure actuated switches 87—88 (Fig. 1) operatively connected to the header 19. Said timing mechanism comprises a reversible master timer S and a number of sub-timing units T–1 to T–7, including a unidirectional motor M*a* to M*g*, respectively, are associated with the several generators. The master timer includes a plurality of time operating cams S*r*, S–1 to S–7, inclusive, and S*f* each of which, except S*r* and S*f*, when once set into operation, will activate a non-reversible sub-timer to set its associated steam generator 10*a*–10*g* into full operation. Each of these sub-timing units T–1 to T–7, inclusive, is operatively associated with one of the individual generator control systems shown in Fig. 3; the latter, when set up for automatic operation, is responsive to its own sub-timer T–1 to T–7, respectively, for cutting into or out of operation. All of the sub-timing units T–1–T–7 are responsive to the reversible master control S in a definite sequential order or pattern and the master control S operates on a predetermined time basis so that during an uninterrupted operating phase of the master timer for increasing the number of operating generators, the sub-timing units T–1 to T–7 will initiate their individual cycles at equally spaced intervals of time. Each sub-timing unit T–1 to T–7, once it has entered upon its unidirectional cycle of operation, will progress to a mid-cycle point wherein it causes the control mechanism (Fig. 3) of its associated generator to bring the generator up to full operation and at that point the sub-timer unit will automatically come to rest. If the operation of the master timer continues in a direction to increase the number of operating generators, the activated sub-

units will remain inactive with their associated generators in full operation until such time as the cam *Sf* of the master timer S is operated to open the forward circuit through the timer motor U*f* and the cam *Sr* operates to close a circuit through the reversing timer motor U*r*. On a reverse operation of the master timer cams S–1–S–7, the sub-timing units are successively released from their mid-cycle point and are allowed to finish out their previously commenced cycles. During the reversal of operation of the master timer S the sub-timer units exert an influence on the generator control mechanism to cut out the generators successively, while at the same time maintaining the cut-out generators in condition for subsequent instant operation if occasion demands.

Timer control mechanism

As previously set forth, the timer control mechanism of Fig. 4 is designed to control the operation of all of the steam generators **10***a* to **10***g* inclusive, cutting them in one at a time and successively as the demand for steam in the header **19** rises and cutting them out singly and in the reverse order as the demand for steam diminishes. The timer mechanism operates under the control of the said pressure switches **87** and **88**.

In certain installations the demand for steam during one period of time may be greater than the demand for steam during a different period of time. Such class of operation may be prevalent in the operation of large laundry and dry cleaning establishments, particularly where a night shift is not employed and where, as a consequence, machinery operation is relatively heavy during the day and relatively light or non-existent at night. Similarly, in bus or railroad terminals where according to schedule a large number of vehicles may be on the stand-by line during certain hours and only a few at other hours, this class operation is required. Purely for purposes of illustration herein, it is assumed that the class of operation illustrated is applicable to day and night maintenance where operating steam pressures are to be maintained in a range of from approximately 105 pounds to approximately 115 pounds during the day and in very low range not exceeding 90 pounds at night. Obviously these ranges may be varied if desired and a greater number of ranges may be accommodated by the simple expedient of providing additional pressure responsive circuitry.

Referring now to Fig. 4 in detail, the previously mentioned pressure operated switch **87** is responsive to relatively low steam pressure in the header **19**. Accordingly its No. **1** contacts are designed to close at 1 pound of pressure and to open at 2 pounds. Its No. **2** contacts are adapted to close at 90 pounds and to open at 89 pounds. The switch **88** is responsive to higher pressures and its No. **1** contacts close at 104 pounds and open at 105 pounds. Its No. **2** contacts close at 115 pounds and open at 114 pounds. It will be understood that the pressures specified are purely arbitrary and in practice they may be approximate pressures.

A selector switch V is provided with contacts **89** and **90** and is arranged in series relation to each of the switches **87** and **88** and to a circuit breaker switch W.

With the switch W closed and with the switch V set for day operation with its contact **90** closed, a circuit will exist from the positive line Y through the contact **90** of the switch V, leads **100**, **101**, No. **1** contacts of the switch **88**, leads **102**, **103**, cam controlled contacts **104**, lead **105**, motor U*f* and lead **106** to the negative line Z.

The motor U*f* is a unidirectional motor and it is operatively connected to a cam shaft **107** on which there are mounted a series of seven cams S–1 to S–7 inclusive, one for each of the steam generators **10***a* to **10***g* inclusive, and two additional cams including a forward drive cam *Sf* and a reverse drive cam *Sr*. The cam *Sr* controls the opening and closing movements of a pair of contacts **108** disposed in the circuit of a motor U*r*. The motor U*f*, when energized serves to drive the cam shaft **107** in a forward direction as indicated by the arrow while the motor U*r* when energized serves to drive the shaft **107** in a reverse direction, likewise indicated by the arrow.

Each of the cams S–1 to S–7 inclusive constitutes a master control cam for initiating operation of one of the previously mentioned sub-cycle units associated with the timing mechanism. The sub-cycle units are designated as T–1 to T–7 inclusive and each controls the operation of one of the steam generator units **10***a* to **10***g* inclusive as far as its cutting-in and cutting-out operations are concerned. The various sub-cycle units T–1 to T–7 inclusive are identical in their mechanism construction as well as in their electrical function with respect to the particular control mechanism of Fig. 3 which they in turn control. Therefore, a description of one of these sub-cycle units will suffice for all such units. The unit T–1 has been selected for descriptive purposes and similar reference characters have been applied to certain of the other units.

As soon as the pressure of steam in the header **19** attains its setting of 104 pounds, the No. **1** contacts of the switch **88** will close to establish the previously described circuit through the motor U*f* and initiate forward rotational movement of the cam shaft **107**. Immediately thereafter the contact **108** of cam *Sr* will close without function because the No. **2** contacts of the switch **88** are open. The No. **2** contact of the cam S–1 of master timer (normally closed at this time) is adapted to remain closed for a period of one minute after closure of the main circuit switch W due to a dwell **109** provided in the cam. When this period of time has elapsed the No. **2** contact of the cam S–1 becomes open and the No. **1** contact closes, thereby energizing a unidirectional timing motor M*a* through a circuit leading from the line Y through lead **110**, motor M*a*, No. **2** contact of a timer cam C*t*–**1**, lead **111**, No. **1** contact of the cam S–1 to the negative line Z.

The timer cam C*t*–**1**, together with three other timer cams C*t*–**2**, C*t*–**3** and C*t*–**4** are disposed on a motor shaft **112** for movement in unison. The shaft **112** is adapted to make one complete revolution in six minutes unless previously interrupted. The cam C*t*–**1** is provided with a one minute dwell **113** during which dwell the No. **2** contact of its switch remains closed with the No. **1** contact open. The cam C*t*–**3** has a one minute dwell **115** for maintaining its switch **77** (see individual boiler control Fig. 3) closed. The cam C*t*–**4** has a five minute dwell **116** for maintaining its switch **78** closed.

As shown in the timing chart of Fig. 5 the dwell **113** is effective immediately upon energization of the timer motor M*a*; the dwell **114** is effective fifteen seconds after the motor M*a* is energized; the dwell **115** is effective thirty seconds after the motor is energized, and the dwell **116** is effective forty-five seconds after the motor is energized.

With the No. **1** contacts of the control cam S–1 closed and the motor M*a* in operation, the No. **2** contact of the cam C*t*–**2** will close at fifteen seconds in the cycle (see chart—Fig. 5) and establish a concurrent parallel circuit with the previously described motor circuit which extends through lead **110**, motor M*a*, No. 2 contact of the cam C*t*–**1** (still closed), lead **120**, No. 2 contact of the cam C*t*–**2**, and lead **121**. At thirty seconds in the cycle, the switch **77** of the cam C*t*–**3** closes. This function results in energizing relay E and thereby opens circuit No. **4** through out-fire relay magnet F'. The closing of said switch **77** also conditions circuits **10** and **10***a* so that they will be effective to energize open the fuel and air valves **27**, **30** when No. **1** contact of relay C is closed and No. **2** contact of pressure switch K closes. At 45 seconds the switch **78** of the cam C*t*–**4** closes to energize circuit No. **8** and thereby energize relay C to open its contact No. **2** so as to break out-fire magnet circuit No. **5**

and also close contacts 1, in fuel and air valve circuits 10, 10*a* and to close contacts 3, 4 and 5 of said relay to complete said motor operating circuits Nos. 9 and 9*a*. This operation, as previously described, sets the pump motor 31 into operation, whereby the No. 2 contact of pressure switch closes to complete the circuits through said fuel and air valves 27, 30 and thereby cuts the generator 10*a* into full operation.

At sixty seconds in the cycle the No. 2 contact of the cam C*t*–1 will open both of the two parallel motor circuits for the motor M*a* and, since the No. 1 contact of the cam C*t*–2 is still open there is no closed path for motor current through any of the contacts associated with the timer cam C*t*–1 or C*t*–2, so the motor M*a* will stop, leaving the cam switches 77 and 78 closed and allowing the generator 10*a* to function to supply its steam to the header 19.

Increasing steam demand

Assuming now that the generator 10*a* is incapable of supplying the demand for steam at the header 19 as reflected by failure of the No. 1 contact of the pressure switch 88 to open. In this event, the motor U*f* will continue to operate and three minutes after the switch W has been closed (which is two minutes after closure of the No. 1 contact of the cam control S–1, or one minute after stopping of the motor M*a*), the No. 1 contact of the master timer cam S–2 will close and energize the timer motor M*b* and set the sub-cycle unit T–2 into operation exactly in the same manner that was described in connection with the sub-cycle unit T–1. Such operation of the sub-cycle unit T–2 will close the contacts 77 and 78 in due course at thirty and forty-five seconds in the six minute cycle respectively, and if the demand for steam still exists, the control cam S–3 will set its respective sub-cycle unit T–3 into operation five minutes after closure of the switch W or two minutes after the No. 1 contact of the cam S–1 has closed.

The operation of the various sub-cycle units T–1 to T–7 inclusive will progress sequentially in the order named as long as there is a progressively increasing demand for steam at the header 19 or until such time as the last sub-cycle unit T–7 has brought its respective generator 10*g* into operation. Thereafter, i. e. fifteen minutes after the switch W has been closed, the cam S*f* will open switch contact 104 to thus de-energize the circuit of the motor U*f*.

From the above description it will be seen that at sixty seconds in the operation of each sub-cycle unit a period of dwell will exist wherein the respective motors M*a*, M*b*, M*c*, etc., thereof will come to rest and switches 77 and 78 will remain closed to maintain their associated generator in operation. The generator will continue to function in a normal manner until such time as the demand for steam in the header 19 warrants shutting down that particular generator.

Constant steam demand within a fixed range

Assuming now for instance that sub-cycle units T–1, T–2 and T–3 are at their period of dwell with their associated switches 77, 78 closed, that the steam generators 10*a*, 10*b*, and 10*c* are operating and that the remaining generators are in a stand-by condition. If the steam pressure in the header 19 rises to 105 pounds, the No. 1 contacts of the switch 88 will open and the previously described circuit for the motor U*f* will become open so as to stop the motor U*f* and bring all of the control cams S–1 to S–7 inclusive to a standstill. This dwell in the operation of the various control cams will remain effective during the range existing from 104 pounds to 115 pounds, this being the range between the closing pressures of the Nos. 1 and 2 contacts of the switch 88. Within this range of pressure the steam generators 10*a*, 10*b* and 10*c* will function normally until such time as the pressure range is exceeded as evidenced by closing of the No. 2 contacts of the switch 88.

Decreasing steam demand

When the pressure of steam in the header rises, during normal daytime operation, to its upper limit, for example 115 pounds, it reflects a decreased steam demand and closes No. 2 contacts of the switch 88 to establish a circuit through motor U*r*, the circuit extending through switch W, closed contact 90 of switch V, lead 100, closed No. 2 contacts of switch 88, lead 122, closed contact 108 of cam switch S*r*, lead 123, motor U*r* and lead 106. Energization of motor U*r* will rotate shaft 107 in a direction to reverse the rotation of all cams of the master timer S and drive them counterclockwise to the positions indicated in Fig. 4. As soon as the previously opened No. 2 contact of the cam S–3 is reclosed, a circuit will exist through the sub-cycle timing motor M*c* which will permit this sub-cycle timing mechanism to complete or run out its previously interrupted six minute cycle. This circuit exists through lead 110, motor M*c*, No. 1 contact of the cam C*t*–1 (previously closed at the beginning of the sub-cycle dwell), lead 124, and No. 2 contact of cam switch S–3. The motor M*c* will thus drive its cams C*t*–1, C*t*–2, C*t*–3 and C*t*–4 in a clockwise direction and at one minute and fifteen seconds in the interrupted cycle, i. e. fifteen seconds after the completion of the first one minute period of the cycle, the No. 2 contact of the cam C*t*–2 will open and the No. 1 contact thereof will close. Opening of the No. 2 contact of the switch C*t*–2 will open the motor circuit through this contact but closure of the No. 1 contact of the cam C*t*–2 will establish a new motor circuit extending through lead 110, motor M*c*, No. 1 contacts of the cam C*t*–1, lead 125, contact No. 1 of the cam C*t*–2, and lead 121. The motor M*c* will thus continue to drive the cams C*t*–1, C*t*–2, C*t*–3 and C*t*–4 and during this time the switch 78 of cam C*t*–4 will maintain the energizing circuit No. 9 closed through feed pump motor 31.

At one minute and thirty seconds in the cycle, the switch 77 of the cam C*t*–3 will open and de-energize the solenoid of the fuel and air valves 27, 30 and thereby close these valves. The switch 78 of the cam C*t*–4 however will remain closed until five minutes and 45 seconds in the sub-cycle, thus allowing five minutes for the motor 31 to function after the resumption of the interrupted cycle or four minutes and 15 seconds after the fuel and air valves have closed as a result of the opening of their energizing circuits. The prolonged operation of the motor 31 and fuel pump 12 and blower 32 performs the function of cooling down the generator and filling the coil 15 in readiness for renewed operation of the generator should the conditions require such operation.

At the end of the six minute cycle, the cam C*t*–1 will cause the No. 1 contacts of the cam C*t*–1 to open, thus opening the circuit through the motor M*a* at which time the cams C*t*–1, C*t*–2, C*t*–3 and C*t*–4 will assume their original positions as shown in Fig. 4 and the generator 10*c* will be in a stand-by condition of inactiveness. The master timer cam S–3 however at this time will be in mid-dwell condition wherein the No. 2 contact thereof is closed. It will continue to rotate in a counter-clockwise direction until it assumes its initial position as shown in Fig. 4, at which time the cam S*r*, operating as a limit cam, opens its contact 108 after all of the generators have been automatically cut out of operation.

It will be understood that if, after the No. 2 contact of the master timer cam S–3 is closed during the reverse movement of the cam, the steam pressure in the header 19 is such as to warrant cutting out of the generator 10*b*, the No. 1 contacts of the pressure switch 88 will remain closed to maintain the circuit previously described through the motor U*r*. Two minutes after the No. 2 contact of the cam S–3 has closed, the No. 2 contact of the cam S–2 will close to allow the interrupted cycle of

the sub-cycle unit T–3 to finish its cycle and reduce the generator **10***b* to a stand-by condition.

Disabled or malfunctioning generator

If one or more of the steam generators **10***a* to **10***g* have been purposely disabled, due to manipulation of the respective master switch A in the control mechanism of Fig. 3, or if any of these generators are disabled due to malfunctioning thereof, the system will operate as intended and in the manner previously described and the sub-cycle unit will enter upon its cycle, become interrupted at the sixty second point in the cycle, and continue the interrupted cycle when directed to do so by closure of the No. **2** contact of its respective master timer cam S–**1**, S–**2**, S–**3**, etc. However, due to the failure of the generator to deliver steam to the header **19** at the designated time, the demand for steam will fall upon the next succeeding generator in the series and although the switches **77** and **78** will close or open as the case may be, at their designated time, such opening and closing thereof will either fail to operate the relay mechanism of Fig. 3 which will not be conditioned for such operation or failure of the photoelectric cell I to actuate the switch H will negative the operation of the relay mechanism.

Mid-cycle change in steam demand

Under certain circumstances an occasion may arise wherein a particular sub-cycle unit has commenced its operation and immediately thereafter a change in the demand for steam will set the reverse drive motor U*r* into operation. Under these circumstances the sub-cycle unit will function until the sixty second point of the cycle has been reached and it will not go into the usual dwell but will continue to function to the end of the cycle without interruption. This is made possible by the provision of the timer cam C*t*–**2**. As previously stated in connection with the sub-cycle mechanism T–**1**, the sub-cycle unit will not commence its operation until the No. **1** contact of the control cam S–**1** has closed the circuit extending through lead **110**, motor M*a*, No. **2** contact of the cam C*t*–**1**, lead **111**, and No. **1** contact of the master timer cam S–**1**. If now this latter contact is opened almost immediately after its initial closure, the motor circuit just described will be broken. But meanwhile the control cam C*t*–**2** will have established a parallel circuit through the motor M*a* extending through lead **110**, motor M*a*, No. **2** contact of the cam S–**2**, lead **120**, No. **2** contact of the cam C*t*–**2** and lead **121**.

Low range operation

The operation of the timer control mechanism of Fig. 4 is not altered if the switch V is set for a lower range of pressures by closing of the contact **89** thereof and opening of the contact **90**. In such case, the switch **87** will prevail over the switch **88** and potential circuits through the motors U*f* and U*r* will be available for such low pressure regulation of the timer apparatus.

In the case of low pressure operation, the circuit for the motor U*f* exists through the switch W, contact **89** of the switch V, No. **1** contacts of the switch **87**, the contacts **199** of a space thermostat **200** which may be arranged in series in the motor circuit, leads **201**, **103**, contacts **104** of the cam S*f*, lead **10***r*, motor U*f* and lead **106**. The circuit for the motor U*r* in the case of low pressure operation extends through the switch W, contact **89** of the switch V, No. **2** contacts of the switch **87** (now closed), leads **202** and **122**, contacts **108**, lead **123**, motor U*r* and lead **106**. Utilizing these two motor circuits in place of the circuits previously traced through the Nos. **1** and **2** contacts of the switch **88**, the operation of the entire control system remains unchanged.

We claim:

1. In combination with a multiple boiler steam generating plant including a steam header for receiving the steam output from each activated boiler of the system, electrically activated means individually associated with each boiler for delivering fuel, air and water thereto, and electrical control circuits therefor comprising a plurality of cooperative circuit closers including a pair of timer controlled switches operable to energize the control circuits for said electrically activated means, and timer control means responsive to predetermined pressure conditions in said steam header for closing the pairs of timer controlled switches to activate the several boilers in predetermined sequence.

2. In combination with a multiple steam generating plant including a steam header for receiving the steam output for each activated boiler of the system, electrically activated means individually associated with each boiler for delivering fuel, air and water thereto, and electrical control circuits therefor comprising a plurality of cooperative circuit closers including a pair of timer controlled switches operable to energize said electrically activated means; and timer control means responsive to predetermined pressure conditions in said steam header for closing the pairs of said timer controlled switches to activate the several boilers in predetermined sequence; the said control circuits for the individual boilers including means directly responsive to the continuance of fire in the individual boilers for maintaining its control circuits effective.

3. In a control system for regulating the operation of a bank of steam generator units arranged in parallel in a steam-generating circuit, each unit including a steam generator provided with a fluid fuel burner and adapted to feed steam into a common steam header, a fuel pump for supplying fuel to said burner, a water pump for supplying feed water to said generator, an electric motor for driving said fuel and water pumps in unison, a normally closed fuel valve interposed between said fuel pump and said burner, a solenoid for opening said fuel valve, an individual control system for each generator unit comprising an electrical energizing circuit including a relay switch for energizing said motor, a plurality of selectively energized circuits including an additional relay switch and a plurality of selectively operable switches connected in series therewith for energizing said valve opening solenoid, a relay including an actuating magnet for closing both of said relay switches, a circuit for energizing said relay actuating magnet comprising a plurality of cooperating circuit closers including a timer controlled switch, and timer control means responsive to a predetermined pressure in said header for closing said timer controlled switch.

4. In a control system for regulating the operation of a bank of steam generator units arranged in parallel in a steam-generating circuit, each unit including a steam generator provided with a fluid fuel burner and adapted to feed steam into a common steam header, a fuel pump for supplying fuel to said burner, a water pump for supplying feed water to said generator, an electric motor for driving said fuel and water pumps in unison, a normally closed fuel valve interposed between said fuel pump and said burner, a solenoid for opening said fuel valve, an individual control system for each generator unit comprising an electrical energizing circuit including a relay switch for energizing said motor, a plurality of selectively energized circuits including an additional relay switch and a plurality of selectively operable switches connected in series therewith for energizing said valve opening solenoid, a relay including an actuating magnet for closing both said relay switches, a circuit for energizing said relay actuating magnet comprising a plurality of cooperative circuit closers including a timer controlled switch, and timer mechanism responsive upon the attainment and maintenance of a pressure within a predetermined range in said header for closing said timer controlled switch.

5. In a control system for regulating the operation of a bank of steam-generator units arranged in parallel in a

steam-generating circuit, each unit including a generator provided with a liquid fuel burner and adapted to feed steam into a common steam header, a fuel pump for supplying liquid fuel to said burner, a water pump for supplying feed water to said generator, an electrical motor for driving said fuel and water pumps in unison, a normally closed fuel valve interposed between said fuel pump and said burner, a solenoid for opening said fuel valve, an individual control system for each generator unit comprising an electrical energizing circuit including a relay switch for energizing said motor, a plurality of selectively energized circuits including an additional relay switch and a plurality of selectively operable switches including a timer controlled switch connected in series therewith for energizing said fuel valve opening solenoid, a relay including an activating magnet for closing both of said relay switches, a circuit comprising a plurality of circuit closers including a master relay switch and a relay magnet for closing the same and an additional timer controlled switch connected in series with said master relay switch and operative in timed relation to the first mentioned timer control switch for energizing the actuating magnet of the first mentioned relay subsequent to the closing of the first mentioned timer controlled switch, and timer mechanism responsive to the attainment and maintenance of a pressure in said header within a predetermined range for actuating the first mentioned timer controlled switch and for operating said additional timer controlled switch.

6. A combination structure as defined in claim 5 characterized in that said timer mechanism for actuating said timer controlled switches for the individual control system for each of the several generator units includes separate cam elements operatively engaging said timer controlled switches and further characterized by the provision of separate unidirectional motors for each control system of the several generator units to operate both said cam elements associated with such control system.

7. A combination structure as defined in claim 6 characterized in that the timer control mechanism for controlling the timer controlled switches for the individual control systems of the several generator units comprises a cyclicly operable subcycle unit operable upon initial actuation thereof to close said timer controlled switches and to thereafter become interrupted within the limits of its cycle, and further characterized by the provision of reversible means responsive to the attainment and maintenance of a predetermined pressure range in said header for initially actuating said sub-cycle units in a predetermined sequential order and responsive to the attainment of a pressure higher than said range for initiating completion of the interrupted cycles of said sub-cycle units successively in reverse order.

8. A combination structure as defined in claim 6 characterized in that said reversible means is a timer controlled portion of said timer mechanism and functions to control initial energization of said unidirectional motors in a sequential order and is responsive to the attainment of a pressure higher than said predetermined range for energizing said unidirectional motors in the reverse order to move said cam elements through the remainder of the interrupted cycle.

9. The combination structure as defined in claim 8 characterized in that one of the selectively operable switches in the circuit for energizing the fuel valve opening solenoid is responsive to the water pressure in the generator.

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