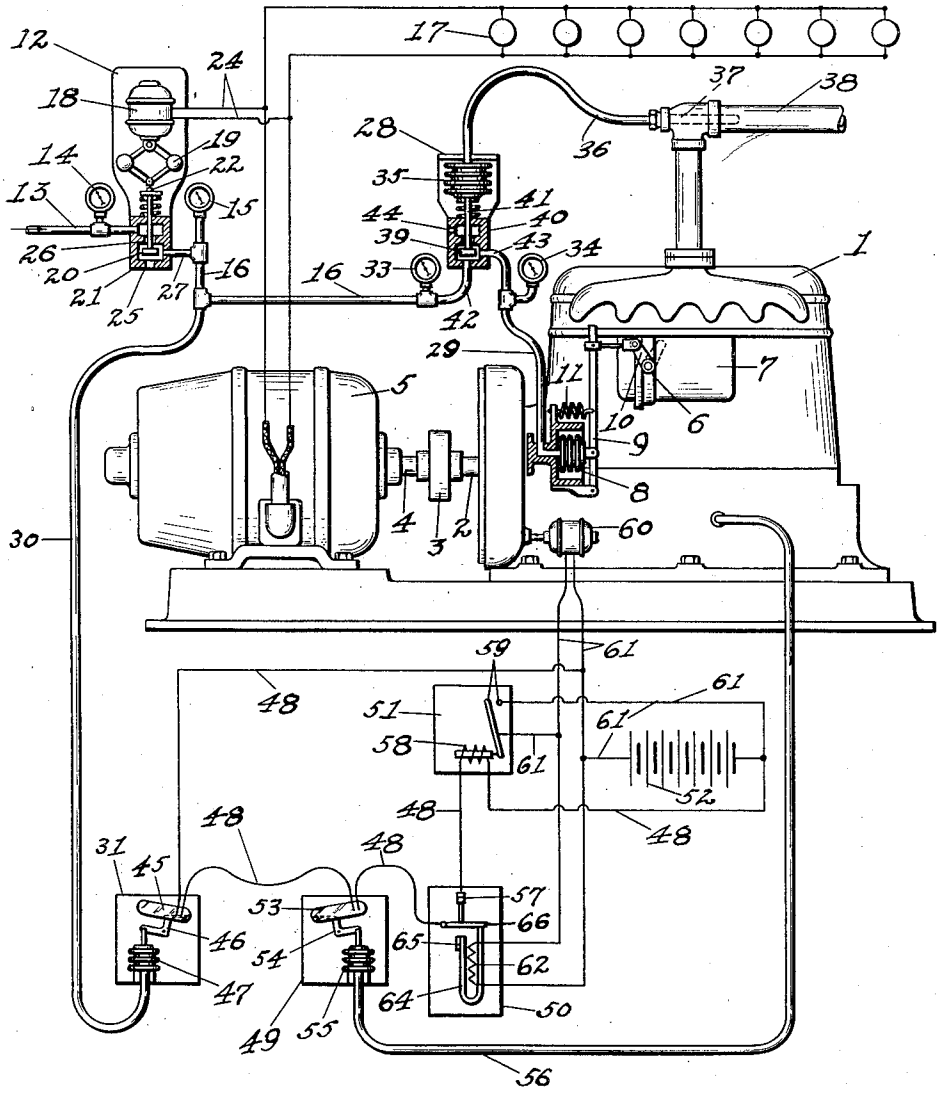
July 5, 1938. G. B. BAILEY 2,122,402

MEANS FOR THE AUTOMATIC CONTROL OF THE POWER DELIVERED BY INTERNAL COMBUSTION ENGINES

Filed April 13, 1936 2 Sheets-Sheet 1

Fig. 1



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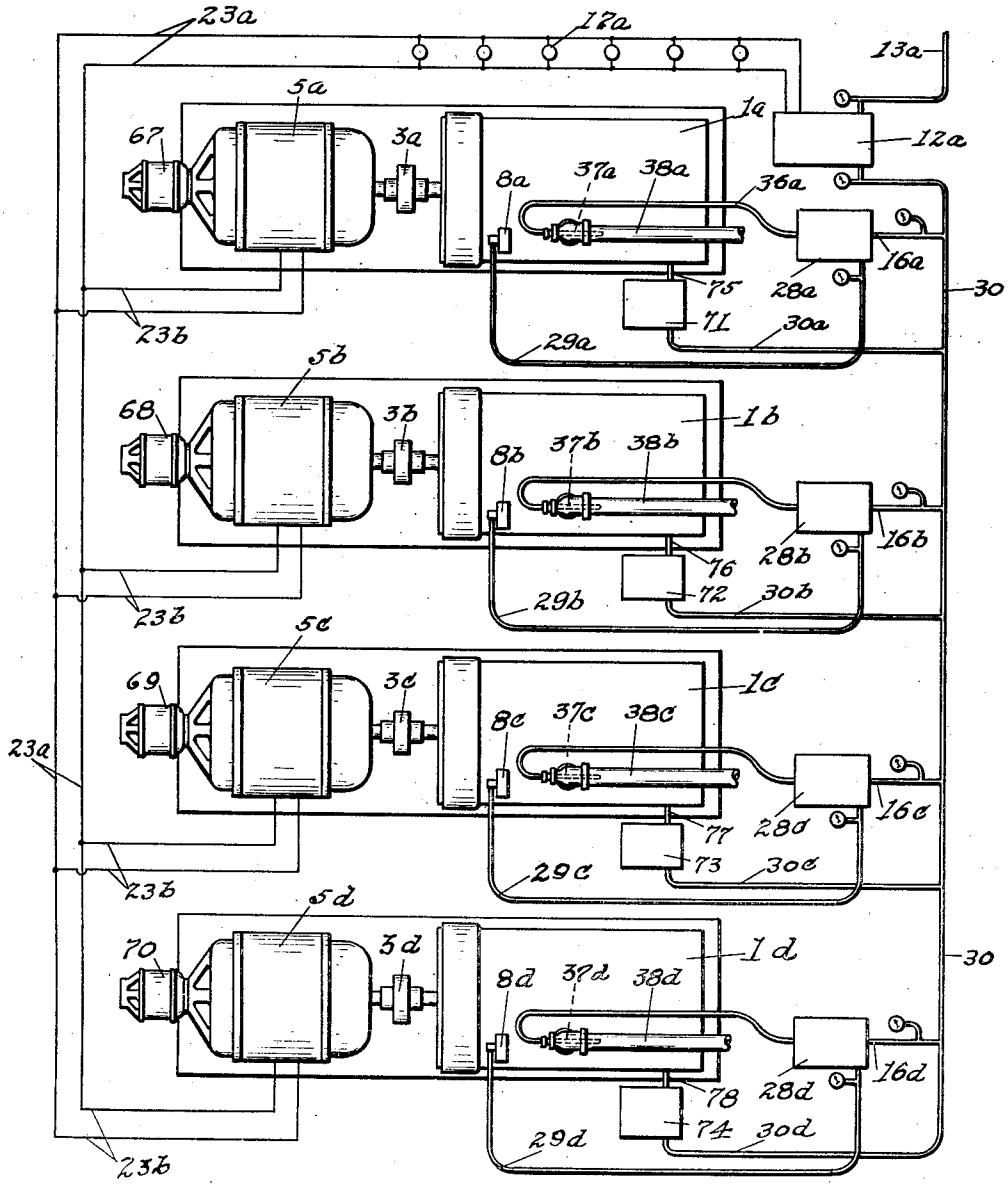


Fig. 2

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Patented July 5, 1938 2,122,402

UNITED STATES PATENT OFFICE

2,122,402

MEANS FOR THE AUTOMATIC CONTROL OF THE POWER DELIVERED BY INTERNAL COMBUSTION ENGINES

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Application April 13, 1936, Serial No. 74,017

3 Claims. (Cl. 290—4)

My present invention relates to improved control systems for the automatic control of the power delivered by internal combustion engines either singly or in multiple.

The object of the invention is to simplify and improve the operation and control of internal combustion engines.

Another object is to provide a simple method of coupling a multiplicity of internal combustion engines together electrically, mechanically or otherwise, in parallel, and to provide against any one engine from being overloaded when so coupled.

Still another object is to provide improved means for automatically starting and stopping of internal combustion engines either singly or in multiple, as may be desired.

Other objects and advantages of my invention will appear from the following detailed description and appended drawings of a preferred embodiment of my invention applied to an internal combustion engine driven electric generating plant.

In co-pending applications Serial No. 15,166 filed April 8, 1935 and Serial No. 18,721 filed April 29, 1935 are claimed certain features of my invention disclosed herein. These include the use of the temperature of the exhaust of an internal combustion engine for control purposes; the use of an over-riding clutch coupling between a multiplicity of internal combustion engine prime movers and their respective driven members such as dynamos, which couplings will allow said dynamos to continue to rotate, being coupled electrically to the system, whereas their respective prime movers may be started and stopped at will; and the use of the differential gear with torque balancing means as a transmission means between the internal combustion engine prime mover and a dynamo.

In the present invention I am disclosing an improved method of automatic controlling and coupling of these features together as applied to internal combustion engines either singly or in multiple, with a view of controlling their power output in such a way that with a varying demand of the system, voltage or cycles will be substantially uniform in an electric generating system, pressure will be substantially uniform in a pumping system, speed will be substantially uniform in any system if desired and, at the same time, engine or engines can be started and stopped automatically, and engine or engines cannot be overloaded.

An advantage of my invention is that it makes possible the coupling up in parallel operation, electrically or mechanically, any number of internal combustion engine driven power units, at the same time providing full automatic control. This results in saving in first cost because of application of standardized high speed units of low cost, saving in operating cost due to elimination of attendants and increased efficiency, minimizing the chance of complete failure in a multiple unit application, etc.

In the accompanying drawings the principles of my invention are illustrated in their application of driving dynamos singly and in multiple. While the best mode in which I have contemplated applying the principle of my invention is shown in the accompanying drawings, these are to be taken as merely illustrative, for it is intended that the patent shall cover by suitable expression in the appended claims, whatever features of patentable novelty exists in the invention as a whole.

Fig. 1 is a diagrammatic showing of apparatus embodying my invention.

Fig. 2 is another diagrammatic showing of a multiple arrangement of units.

Referring more particularly to the drawings, there is disclosed in Fig. 1 a Diesel internal combustion engine 1 as representative of any prime mover whose drive shaft 2 is suitably connected to coupling 3 which, for the purpose of illustration, is to be taken as an over-running clutch type. It is to be noted that the coupling can be solid, flexible or over-running; the latter being used in multiple unit application where it is desirous to keep the driven member rotating but, at the same time, allowing the slowing down or stopping of the prime mover. Coupling 3 is, in turn, connected through shaft 4 to dynamo 5 which, for the purpose of illustration, may be of the shunt or compound wound direct current type. It is well known that such a generator will deliver a current, having a desired, substantially uniform voltage at a substantially uniform speed. Heretofore, the maintaining of a substantially constant speed and, therefore, a substantially constant voltage, has been accomplished by control of the fuel delivered to the engine by a standard governor mechanism 6, operation of which is a function of the engine speed and which may be incorporated on a Diesel engine with the fuel injection pump 7, it being adjusted to maintain substantially uniform the speed at which the dynamo 5 will deliver a substantially constant voltage.

However, in my invention the governor mechanism 6 is supplemented with further control mechanism such as diaphragm motor 8 which, through lever linkage 9 controls the adjustment of governor mechanism 6 through throttle lever 10. This throttle lever 10 is standard equipment on commercial Diesel engines and will control the speed and, therefore, the power input of the engine by adjusting the governor 6, all the way from full speed, and therefore full power input, down to a minimum speed and finally to a point where it cuts off fuel supply completely, thus stopping the engine.

Diaphragm motor 8 may be operated and thus control the governor adjustment or throttle lever by any suitable medium such as compressed air, water pressure, vacuum, etc. For the purpose of illustration it will be assumed that compressed air is used. It is to be noted that diaphragm motor 8 will react to the air pressure in such a way that an increase in air pressure will cause the lever linkage 9 to move which, in turn, causes throttle lever 10 to move say in a direction to increase the speed of the engine. On a decrease in air pressure, spring 11 will pull the lever linkage 9 and, therefore, the throttle lever 10 back into a closed position. It is obvious that by using springs of various tension at 11 the diaphragm motor mechanism can be made to react at various pressure differentials say, for instance, (*a*) 0 lb. pressure to be closed, 6 lbs. to be fully opened, (*b*) 4–10 lbs., (*c*) 6–12 lbs., (*d*) 8–14 lbs. etc.

As shown, compressed air is delivered at a pressure say of 30 lbs. from a pressure source to voltage control 12, through supply tubing 13 and supply pressure gauge 14. Voltage control 12 is connected to the control system through controlled pressure gauge 15 and controlled pressure line 16, and is so designed that it will cause an increase in pressure in the control system on a decrease in voltage due say to an increase in load 17, or decrease the pressure in the control system on an increase in voltage.

Voltage control 12 may consist of a small motor 18, speed of which is a function of the voltage, connected to and driving centrifugal ball governor 19 which, in turn, is connected to double disc 20 of three-way valve 21 through stem 22. Motor 18 is connected across the main electric line 23 through wires 24. A decrease in voltage caused by an increase in load 17 results in slowing up of motor 18 and governor 19, action of which causes disc 20 to restrict or close vent port 25, at the same time opening pressure supply port 26 and allowing compressed air to pass through controlled pressure port 27, to controlled pressure line 16, thereby increasing pressure in control system. An increase in voltage causes a reverse action to take place; i. e., motor 18 and governor 19 speed up; double disc 20 restricts or closes pressure supply port 26; vent port 25 is opened allowing air to escape from control system, thereby decreasing pressure in same.

Controlled pressure tubing 16 is connected to diaphragm motor 8 through an exhaust temperature control 28 and tubing 29 and is also connected through tubing 30 to as many diaphragm motors and pressure switches 31 as there may be units in the system.

Exhaust temperature control instrument 28 may be air operated, equipped with air supply gauge 33 and controlled pressure gauge 34. As shown, it may consist of a bellows 35 which is connected to, through tubing 36, and operates cooperatively with thermostatic bulb 37 placed in engine exhaust 38. Bellows 35 is connected to double disc 39 of three-way valve 40, through stem 41. Ports 42 and 43 of three-way valve 40 are connected to the controlled pressure tubing 16 through supply gauge 33 and diaphragm motor 8 through tubing 29 respectively. Port 44 is a vent to the atmosphere. The action of temperature control 28 is such that it will pass air from the control system to the diaphragm motor 8 so long as the exhaust temperature is below that for which the instrument is set. However, if the exhaust temperature starts to exceed the temperature for which it is set, it reduces the pressure in tubing 29 and, therefore, on diaphragm motor 8. It accomplishes this through the movement of disc 39 by bellows 35. An increase in the exhaust temperature beyond that for which the instrument is adjusted reacts on thermostatic bulb 37, causing bellows 35 to expand which, in turn, causes disc 39 to restrict or close air pressure supply port 42, open vent port 44, thereby allowing air to escape from diaphragm valve 8 through tubing 29 and port 43. Conversely, a decrease in temperature will cause bellows 35 to contract, in which case disc 39 will restrict or close vent port 44 and open supply port 42, allowing air to pass through port 43 into tubing 29 and increase pressure on diaphragm 8.

The exhaust temperature of a Diesel engine increases with the load and it is generally accepted that with an exhaust temperature of 700° F. a Diesel engine is fully loaded. Therefore, with an arrangement as described, it can be readily seen that the engine cannot become overloaded if its temperature controller is set for a temperature of 700° F. or less, due to the fact that as soon as the temperature for which it is set is reached, pressure on the diaphragm 8 is decreased, resulting in a decrease in the power input of the engine with accompanying lowering of exhaust temperature. It might be stated here that a continuance of exhaust temperature in excess of 700° F. will result in excessive valve burning and lowered efficiency. It is to be noted that by adjusting this controller, the operator can definitely set the maximum per cent of the total power that any one engine will deliver. For instance, an exhaust temperature of 640° F. represents 90% full load capacity; an exhaust temperature of 580° F. represents 80% full load capacity; etc.

Pressure switch 31 may be of the single circuit mercury tube type with mercury tube 45 being operated through lever linkage 46 by bellows 47, its function being to automatically start the engine on a predetermined pressure in the air pressure control system, by closing the electric circuit consisting of connecting wires 48, pressure switch 49, thermostatic time switch 50, solenoid switch 51 and storage battery 52. Pressure switch 49 may also be of the single circuit mercury tube type with mercury tube 53 being operated through lever linkage 54 by bellows 55 which, in turn, is actuated by the lubricating oil pressure in the engine lubricating oil circuit, being connected to same through tubing 56. Pressure switch 49 is normally closed during the starting operation, its function being to break the electric starting circuit after the engine gets to operating. Thermostatic time switch 50 is also of the single circuit type, its contact points 57 being normally closed during the starting operation.

The closing of the electric circuit described energizes solenoid coil **58**, causing solenoid switch contacts **59** to close which, in turn, closes an electric circuit consisting of electric starting motor **60** mounted on engine **1**, storage battery **52** and connecting electric wires **61**. This not only throws the current through the starter motor but also throws current through the resistance **62** in thermostatic time switch **50**, the resistance **62** being connected in parallel with starter motor **60** through wires **63**. Resistance **62** immediately starts to heat up and affect U shaped thermostatic control metal element **64**, which is fixed on one side at **65**, causing it to expand at a definite rate. One of the contact points **57** of thermostatic time switch **50** is mounted on lever linkage **66** which, in turn, is supported on that part of the U shaped thermostatic metal element **64** which is free to move. If, for any reason, the engine fails to start, thus causing the starting circuit to remain closed for too long a period, the expanding U shaped thermostatic element **64** reaches the end of lever linkage **66** ceasing to support same, causing contact point **57** to open, thus breaking the starting circuit.

Pressure switch **31** is so adjusted as to operate at a pressure in the air pressure control line which, also, is such that governor adjustment lever **10**, due to the action of diaphragm motor mechanism **8**, is in a position where fuel will be delivered to the cylinders and, therefore, the engine will be started. As soon as the engine is started the lubricating oil pressure in the lubricating oil circuit immediately starts to rise, due to the operation of the lubricating oil circulating pump which is built into the engine. Pressure switch **49** is so adjusted that an increase in the oil pressure breaks the electric starter circuit. It is to be noted that in the event the engine fails to start and thermostatic time switch **50** breaks the circuit the circuit will remain broken until the time switch **50** is manually adjusted, at which time the trouble will be attended to.

In Fig. 2 I have illustrated a plurality of four engines *1a*, *1b*, *1c*, and *1d* connected through over-running clutches *3a*, *3b*, *3c*, and *3d* to dynamos *5a*, *5b*, *5c*, and *5d* which are synchronous, single-phase alternating current generators with direct connected exciters **67**, **68**, **69**, and **70**, all feeding into main bus wires *23a* through wires *23b* to variable load *17a*. Each engine is equipped with its own diaphragm motor mechanism *8a*, *8b*, *8c*, and *8d* respectively, each motor mechanism being controlled by and through its own exhaust temperature controller *28a*, *28b*, *28c*, and *28d* respectively, through tubing lines *29a*, *29b*, *29c*, and *29d* respectively; all in turn being controlled by speed regulator *12a*. Controllers *28a*, *28b*, *28c*, and *28d* are the same type of instruments as temperature control **28**, Fig. 1, which has already been fully described; while speed regulator *12a* is the same as voltage control **12** Fig. 1, which also has been fully described, except that it may be equipped with a synchronous motor, speed of which is a function of the speed of the synchronous alternating current generators.

The temperature controllers *28a*, *28b*, *28c*, and *28d* are connected to their respective thermostatic bulbs *37a*, *37b*, *37c*, and *37d* located in engine exhausts *38a*, *38b*, *38c*, and *38d* through tubings *36a*, *36b*, *36c*, and *36d*. Each engine is equipped with its own automatic starting instruments all housed in cabinets **71**, **72**, **73**, **74**, each cabinet containing the same instruments connected electrically and otherwise as previously described and illustrated in Fig. 1; i. e., pressure switch **31**, pressure switch **49**, and thermostatic time switch **50**. These, in turn, are connected to solenoid switch and starter mounted on engine, similar to solenoid switch **51** and electric starting motor **60** in Fig. 1 through cables **75**, **76**, **77**, and **78**. The automatic starting instruments in the cabinets are connected to the control line **30** through tubing *30a*, *30b*, *30c*, and *30d*. Temperature controls *28a*, *28b*, *28c*, and *28d* are connected to a main control header **30** through tubing lines *16a*, *16b*, *16c*, and *16d*.

The diaphragm motors *8a*, *8b*, *8c*, and *8d* are each equipped with a spring similar to spring **11**, Fig. 1. For the purpose of illustrating the operation of this plant, it is to be understood that the tension of these springs are all different. It is obvious that if pressure is introduced to the control system the first diaphragm motor to operate would be the one equipped with the spring of least tension. The starting pressure switch of each unit would be so adjusted that it would close the starter circuit at a pressure which would be such that its respective diaphragm motor mechanism with which it is cooperating would have its respective governor adjustment in such a position that when the engine is turned over fuel would be injected to the cylinders and therefore the engine would start.

Let it be assumed that diaphragm motor *8a* on engine *1a* in Fig. 2 is equipped with the spring of the least tension, with diaphragm motors *8b*, *8c*, and *8d* of engines *1b*, *1c*, and *1d* equipped with springs of increasingly greater tension respectively. This being the case, with controller *12a* arranged to introduce air pressure from supply tubing *13a* to the control system through header **30** engine *1a* will be the first one to start. All the generators would be connected across the line and all of them would come up to speed as engine *1a* brings generator *5a* up to speed, due to the fact that they are free to turn because of the overrunning clutches *3b*, *3c*, and *3d*. This illustrates a decided advantage of connecting the generators to the engine through over-running clutches. In bringing the generators in an alternating current generating system to speed in said manner, no synchronizing equipment is necessary.

As soon as the proper speed is reached speed control *12a* will, if there is a tendency for the speed to increase beyond the desired speed, let air pass out of the control system, thus reducing the pressure on diaphragm motor *8a*, retarding governor position until the desired speed is reached. If, on the other hand, the variable load *17a* is increased, the power input of engine *1a* will be increased by increasing the speed setting of the governor of that engine. Overloading of engine *1a* is, of course, prevented by its exhaust temperature control *28a* operating in the manner previously described for temperature control **28** in Fig. 1. If the load increases beyond the capacity of engine *1a*, pressure in control system will continue to increase through the action of speed control *12a*, with a result that engine *1b* will be started up and will deliver power into the system due to the fact that its diaphragm motor *8b* will be the next one to be affected by the increase in pressure, being equipped with a spring of less tension than that on diaphragm motors *8c* and *8d* on engines *1c* and *1d*, although greater in tension than that

on diaphragm motor 8a on engine 1a. In the same manner, a further increase in the load will cause a still further increase in pressure, with the result that engines 1c and 1d will be brought into operation in the order named. In each instance, their overloading is prevented by the action of their respective exhaust temperature controls 28c and 28d.

It can be seen that speed controller 12a in the alternating current system described and illustrated in Fig. 2, not only functions to start and stop the various engines upon an increase or decrease in demand, but also acts as a master governor operating cooperatively with each of the individual engine governors to maintain a more nearly constant speed. Constant speed characteristics in an alternating curernt generating system are important in order to maintain constant cycling. The ordinary engine governor being dependent upon a speed variation as its source of force to move the fuel control throttle, may give a variation of 5% or higher in speed between no load and full load, with the result that the cycles vary in the same proportion. However, with the master speed controller 12a operating cooperatively with the engine governor constantly adjusting it, it can be seen that the uniformity of speed or cycles is limited only by the accuracy of the master controller 12a. This type of instrument can be made extremely sensitive. For instance, it can be designed so that its air pressure pilot valve control mechanism will operate over the full control pressure range of 15 lbs. by a variation of not over one-half of one per cent of speed.

It might be noted that an advantage of the multiple unit arrangement of synchronous, alternating current generators as shown in Fig. 2, is the fact that those generators that are not supplying power will be floating on the line or operating as synchronous motors under no load, or synchronous condensers. As such, they will correct the power factor in the system, with a resulting increase in overall efficiency.

I claim:

1. In a control system, in combination, an internal combustion engine; means for controlling the fuel supplied to said engine; a fluid pressure supply system; means responsive to said fluid pressure for actuating said control means; an electric dynamo driven by said engine; means responsive to changes in the load on said dynamo for varying inversely the fluid pressure in accordance with said load changes; and means actuated by the temperature of the exhaust gases of said engine to limit the fluid pressure acting on said pressure responsive means.

2. In a control system, in combination, a series of internal combustion engines; an electrical dynamo connected to each engine through driving mechanism permitting the dynamo to rotate while its engine is idle; a load circuit connected in parallel to each dynamo; means controlling the fuel supply to each engine; a fluid pressure supply system connected to each engine control means; means responsive to changes in the load of said circuit for varying inversely the fluid pressure imposed on said engine control means; and means actuated by the temperature of the exhaust gas of each engine to limit the fluid pressure acting on its control means; the said engine control means being set to respond at different fluid pressures whereby the engines of said series are successively brought into operation to drive their respective dynamos, the latter being all rotating in synchronism with the dynamo that is initially driven by the engine responding to the lowest determined fluid pressure.

3. In a control system, in combination, a plurality of internal combustion engines; an electrical dynamo connected to each engine through driving mechanism permitting the dynamo to rotate while its respective engine is idle; said dynamos being electrically connected so that upon one dynamo being driven all dynamos will rotate in electrical synchronism; an electrical power line connected to said dynamos; means actuated by variations in the load of said line to effect the operation of successive engines in accordance with predetermined load changes; and means responsive to the temperature of the exhaust gases of each engine to limit the share of the load imposed on said engine.

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