Sept. 8, 1953

D. O. DAVIES

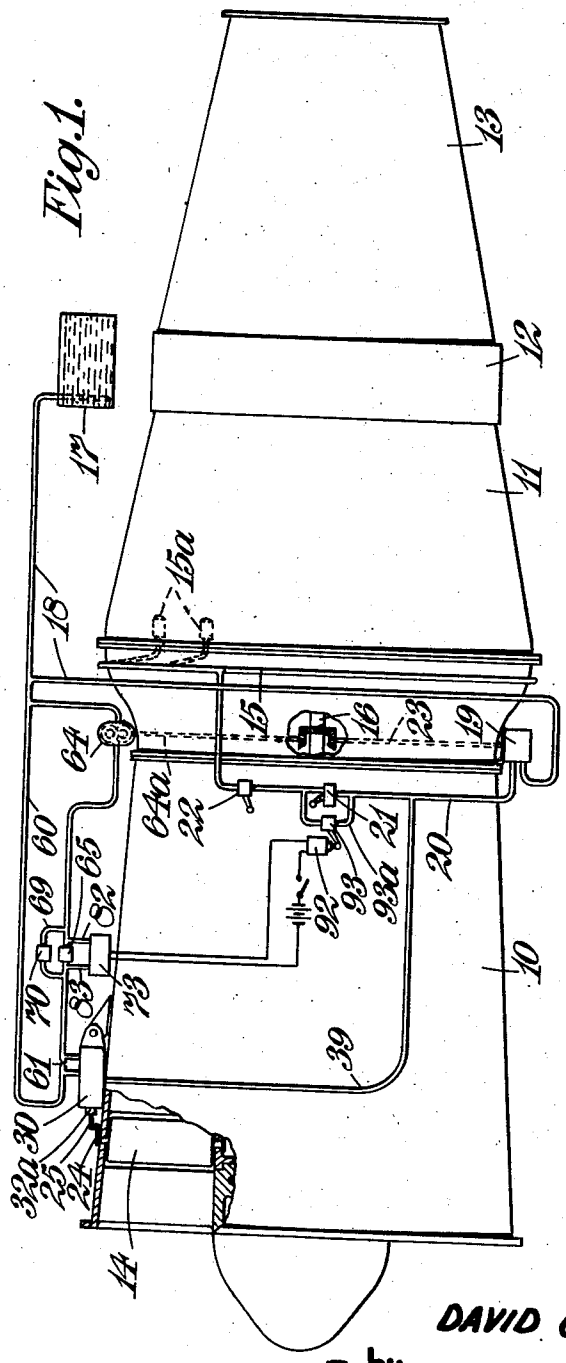
HYDRAULIC, SPEED-SENSITIVE CONTROL SYSTEM FOR PRIME MOVERS

2,651,261

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4 Sheets-Sheet 1

Fig. 1.



INVENTOR

DAVID O. DAVIES

by Wilkinson, Mawhinney

Attys.

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D. O. DAVIES

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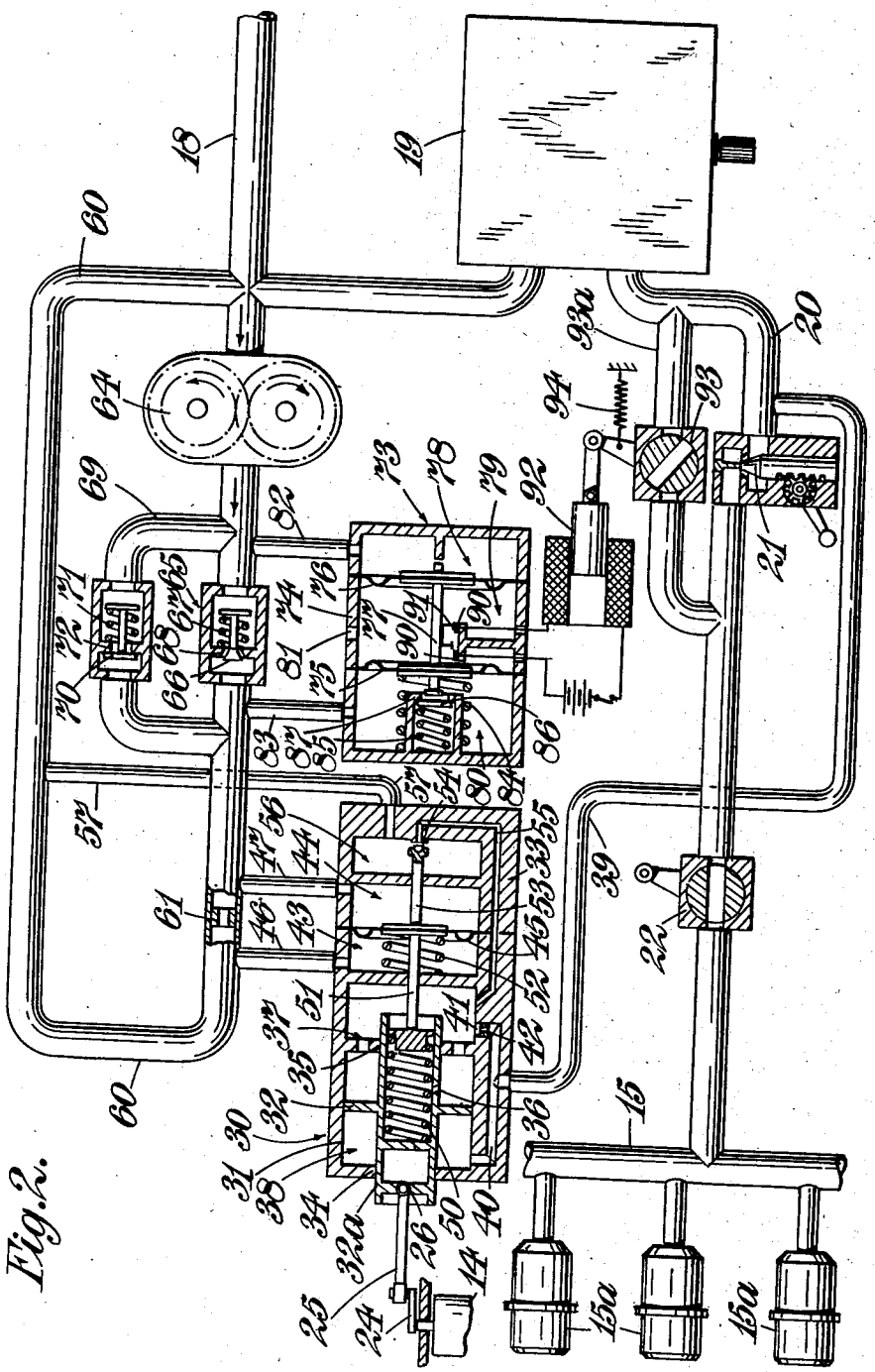


Fig. 2.

INVENTOR
DAVID O. DAVIES
by Wilkinson, Huxley, Hemphill & Montgomery
Attys.

Sept. 8, 1953

D. O. DAVIES

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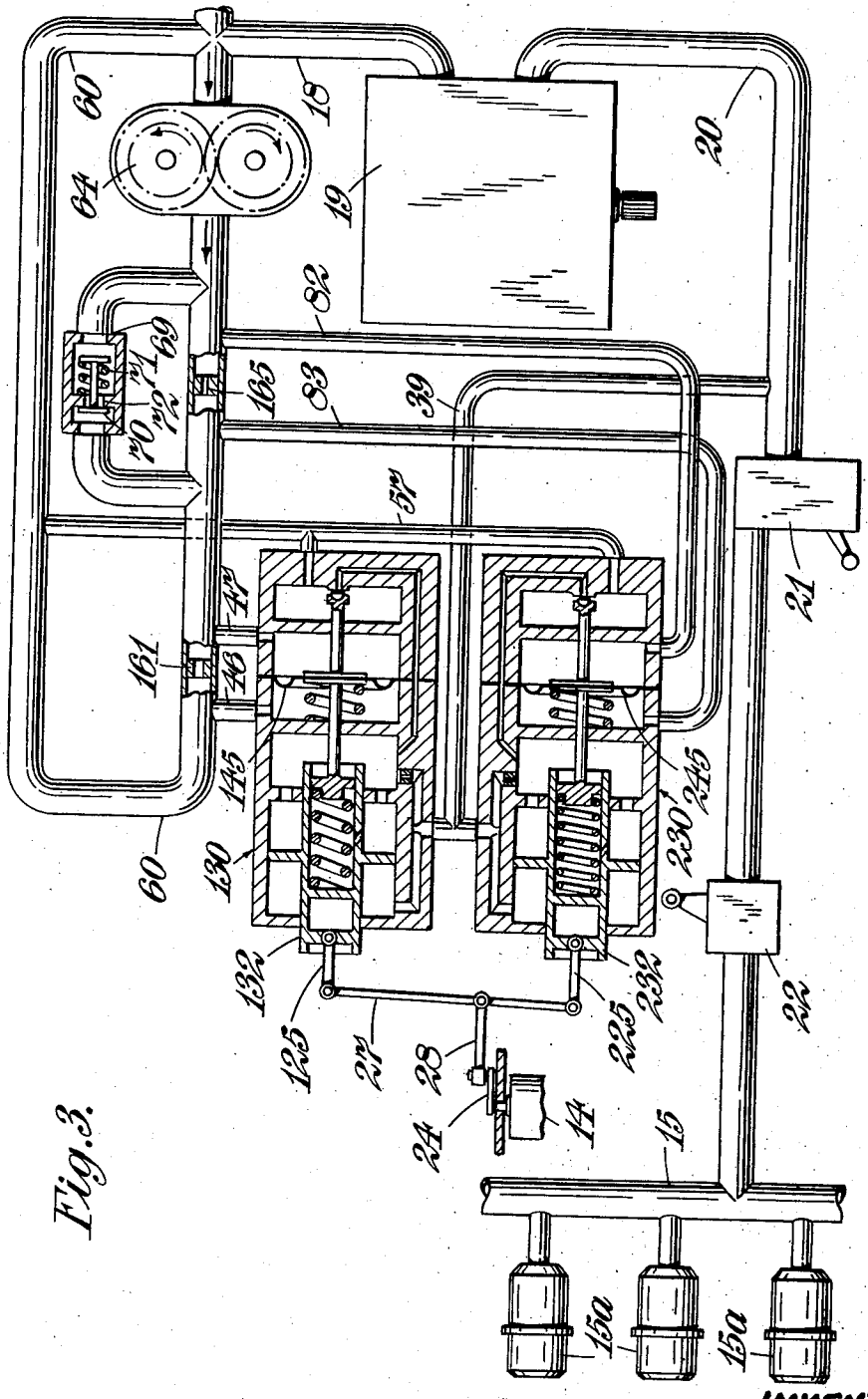


Fig. 3.

INVENTOR
DAVID O. DAVIES
by Wilkinson & Mawhinney
Attys.

Sept. 8, 1953

D. O. DAVIES

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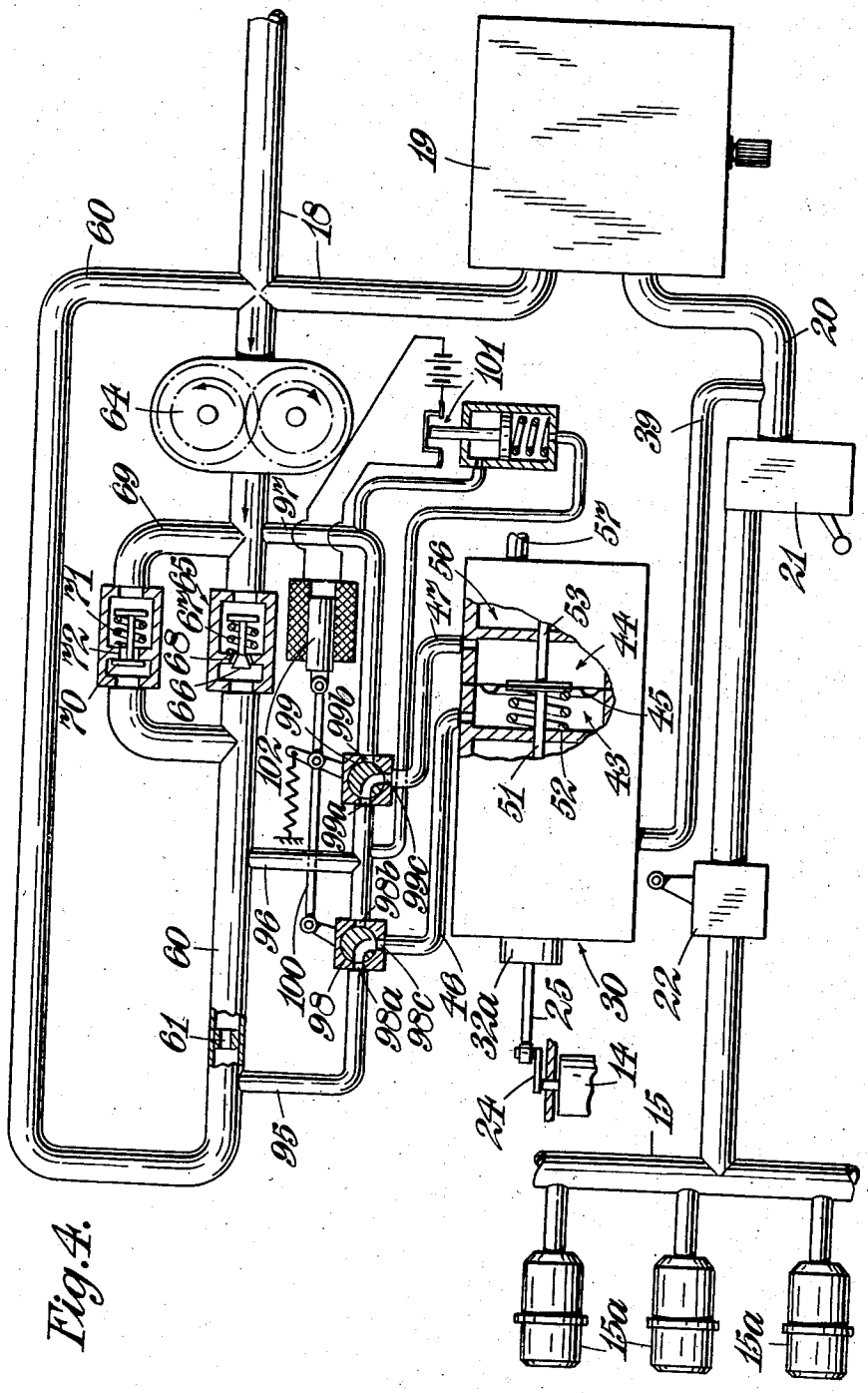


Fig. 4.

INVENTOR
DAVID O. DAVIES
by Wilkinson, Mawhinney & Theobald
Attys.

Patented Sept. 8, 1953

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UNITED STATES PATENT OFFICE

2,651,261

HYDRAULIC SPEED-SENSITIVE CONTROL SYSTEM FOR PRIME MOVERS

David Omri Davies, Edgware, England, assignor to Rolls-Royce Limited, Derby, England, a British company

Application December 2, 1950, Serial No. 198,766
In Great Britain December 7, 1949

17 Claims. (Cl. 103—11)

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This invention relates to hydraulic, speed-sensitive systems of the type (hereinafter referred to as the type specified) comprising a positive-displacement fixed-capacity hydraulic pump driven by a prime mover at a rotational speed proportional to that of the prime mover, flow restricting means through which is passed the delivery flow from the pump, thereby to cause across the flow restricting means a pressure drop which is a function of the rotational speed of the prime mover, and pressure-sensitive means subjected to the pressure drop and arranged to effect a controlling action associated with the operation of the prime mover.

For example, a hydraulic speed-sensitive system of the type specified may be used to control the fuel supply to the prime mover in a manner such as to maintain a preselected rotational speed, or to avoid a predetermined maximum rotational speed being exceeded. As a further example, a hydraulic system of the type specified may be used to actuate, in pre-determined manner related to the rotational speed of the prime mover, control means affecting an air flow in the prime mover; such an arrangement is suitable for controlling gas-turbine engines, for instance by adjustment of swirl or stator vanes in a compressor, adjustment of nozzle-guide vanes in a turbine, or variation of the effective area of a propelling nozzle receiving exhaust gases from a turbine.

In such arrangements, the hydraulic system is usually designed to be operative at a relatively high rotational speed of the prime mover, and therefore, the capacity of the pump and the speed at which it is driven, are so chosen in relation to the restriction afforded by the flow-restricting means that an excessive pressure drop across the flow-restricting means is avoided. Such arrangements, consequently, do not have a high sensitivity at low rotational speed of the prime mover.

According to the present invention, a hydraulic speed-sensitive system of the type specified is characterised in that said flow-restricting means comprises a first flow-restricting device to create a first pressure difference to which said pressure-sensitive device responds in a range of high rotational speeds of the prime mover, and an additional flow-restricting device having a greater restriction to flow than said first flow-restricting device to create a second pressure difference to which the pressure sensitive means responds in a range of low rotational speeds of the prime mover, and in that there is provided by-

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pass means to prevent said second pressure difference being excessive when the prime mover is operating at rotational speeds in said range of high rotational speeds.

The by-pass means conveniently comprises a relief valve sensitive to the pressure difference across the additional flow-restricting device, and arranged to open when a predetermined pressure difference is reached and to prevent any substantial increase in said pressure difference with increase of rotational speed beyond the rotational speed at which said predetermined pressure difference is reached.

In certain cases, either or both the additional flow-restricting device and the first flow-restricting device may comprise a movable valve element sensitive to the pressure drop across the flow-restricting device so as to reduce the restriction afforded by the flow-restricting device with increase of pressure difference, the movable valve element being resiliently loaded in the sense of closure; with such a construction of the flow-restricting device, the pressure difference across a flow-restricting device can be arranged to be substantially directly proportional to the rotational speed of the prime mover and not, as in the case of a fixed-area restriction, proportional to the square of the rotational speed.

In certain preferred applications of this invention, the control action effected by the additional flow-restricting device may differ from that effected by the first flow-restricting device.

According to a feature of the invention, therefore, the pressure sensitive means of the hydraulic speed-sensitive system according to this invention may comprise a pair of pressure sensitive devices connected to respond to said first pressure difference and said second pressure difference respectively, the pressure-sensitive device which responds to the second pressure difference may be arranged to effect a control of the prime mover in said range of low rotational speeds and the pressure-sensitive device which responds to the first pressure difference may be arranged to effect a control of the prime mover in said range of high rotational speeds.

An important application of this aspect of the invention is the use for introducing extra fuel into the combustion equipment of a gas-turbine engine throughout a limited range of rotational speeds within the lower range of rotational speeds of the engine, for instance during starting. The invention may also be used with advantage for effecting a control of adjustable stator blading in such a limited range of speeds.

In an alternative preferred embodiment of the invention, the control operation of the prime mover effected by said additional flow-restricting device may be the same as that effected by the first flow-restricting device. In certain cases two separate pressure-responsive devices are provided, the first being sensitive to the pressure drop across the first flow-restricting means and the second being sensitive to the pressure drop across the second flow-restricting means. In one preferred embodiment of such an arrangement described hereafter actuator members of said pressure-responsive devices are connected through common linkage mechanism to means controlling adjustable guide vanes of an axial flow compressor.

In an alternative arrangement in which the control operation effected by the additional flow-restricting device is the same as that effected by the first flow-restricting device a single pressure responsive means is used, and a device sensitive to the rotational speed of the prime mover is provided for transferring the control from the additional flow-restricting device to the first flow-restricting device. In a preferred arrangement increased sensitivity of control in the lower speed range may be obtained by providing that the additional flow-restricting device is of the kind in which the pressure drop is directly proportional to the flow therethrough, whilst the first flow-restricting device is of the kind in which the pressure drop is proportional to the square of the flow therethrough. To obtain progressive control over the whole speed range it is arranged that the transfer of the control from the additional flow-restricting device to the first flow-restricting device takes place when the pressure drop across the first flow-restricting device, i. e. the square law device is equal to that across the additional flow-restricting device.

The transfer of the control from one flow-restricting device to the other may be effected by any known or convenient means responsive to the rotational speed of the prime mover; conveniently, the response to speed is obtained from the pressure drop within the hydraulic governing circuit itself. Said pressure drop may, for example, be used for the purpose of controlling an electric circuit including solenoid means effecting the transfer.

Three embodiments of the invention are described with reference to the accompanying diagrammatic drawings in which:

Figure 1 illustrates a gas turbine engine of the simple jet propulsion type suitable for aircraft propulsion.

Figure 2 illustrates a control system incorporating a control according to this invention applied to introducing extra fuel to the engine combustion equipment during starting, and

Figures 3 and 4 illustrate embodiments in which the two flow-restricting devices effect a single control in adjusting stator blades of an axial-flow compressor.

Referring to Figure 1, the engine comprises a compressor **10** illustrated as an axial-flow compressor whereof the entry ring of stator blades **14** are adjustable as to their angle of incidence, combustion equipment **11** to receive compressed air from the compressor and to have fuel burned in the air to heat it, the fuel being supplied through an injection manifold **15** and injectors **15***a*, a turbine **12** receiving hot gases from the combustion equipment and having its rotor driving the compressor rotor shaft through a shaft **16**, and an exhaust assembly **13** through which exhaust gases from the turbine pass to atmosphere.

Fuel is supplied to the injection manifold **15** from a tank **17** through a suction pipe **18** of a fuel pump **19** the delivery of which is connected by pipe **20** to the manifold, there being a throttle **21** and a shut-off cock **22** in the pipe **20**. During operation of the engine the shut-off cock is fully-open and the fuel supply to the engine is controlled by the throttle device **21**. The pump **19** is driven from the engine through take-off shaft **23**.

The adjustable stator blades **14** may be interlinked to simultaneous operation in any convenient manner and are arranged for adjustment by a hydraulic ram device **30** the stem **32***a* of the ram piston **32** being connected to a radius arm **24** on one of the adjustable blades **14** by a link **25** and universal joint **26**. The ram device **30** comprises (Figure 2) a cylinder **31** in which the piston **32** reciprocates, and a control mechanism **33** whereby the position of piston **32** in cylinder **31** is determined in accordance with the engine rotational speed in the higher range of rotational speeds of the engine. The stem **32***a* is hollow and works in guides **34**, **35** which also act as limit stops for the piston **32**. The interior of stem **32***a* communicates through bore **36** with the space **37** to one side of piston **32** so that the effective area of the piston exposed to the space **37** is greater than that exposed to cylinder space **38**. Pressure fluid is conveyed from pipe **20** to cylinder **31** through a pipe **39** and bores **40**, **41**, the bore **41** having in it a restrictor **42**.

The control mechanism **33** comprises two compartments **43**, **44** separated by a flexible diaphragm **45**, whereof the compartment **43** is connected by pipe **46** to a pipe **60** downstream of a large area flow restrictor orifice **61** and compartment **44** is connected by pipe **47** to upstream of the restrictor **61**. The pipe **60** is connected as a loop to pipe **18** and has located in it a fixed-capacity positive-displacement pump **64** which is driven through take-off **64***a* (Figure 1) from shaft **16** so that the pressure drop across orifice **61** is a function of the engine rotational speed. The fluid pressure load on diaphragm **45** is therefore also a function of engine rotational speed.

The diaphragm **45** is loaded by a spring **50** through rod **51**, this load being dependent on the position of the piston **32** in cylinder **31**, and by a secondary spring **52** which acts in the same direction as spring **50** and against the fluid pressure load.

The diaphragm movements are communicated to rod **53** carrying a half ball valve element **54** controlling the outflow of fluid from space **37** through a duct **55** leading from space **37** to a chamber **56** from which a pipe **57** leads to the suction side of pump **19**.

It will be clear that when the fluid pressure acting on diaphragm **45** increases to a sufficient value to overcome spring **52**, the half ball valve will lift allowing fluid to bleed from space **37**, the pressure within which therefore falls and the piston **32** moves to the right until the load due to spring **50** overcomes the fluid pressure load on diaphragm **45**. Thus for each value of engine rotational speed in the range of speeds the piston **32** will occupy a corresponding position in cylinder **31** and the blades **14** will have a particular angle of incidence to the inflowing air.

The effective area of restrictor orifice **61**, the

area of diaphragm 45 and the strength of spring 52 are so selected in relation to the output of pump 64 that this control of the blades 14 is effective in a higher range of rotational speeds, spring 52 determining the lower limit of this higher range of speeds. The flow restrictor orifice 61 is made of relatively large area, so that at maximum rotational speed of the engine the pressure drop across this orifice does not reach an excessive value.

This form of control mechanism 33 for adjusting the stator blades 14 of axial-flow air compressors 10 of the engine progressively throughout a speed range within the higher range of rotational speeds does not form an essential part of this invention, but is merely exemplary of a pressure-sensitive means in the type of hydraulic speed-sensitive control with which this invention is concerned.

The control system illustrated in Figure 2 also includes means to control the introduction of extra fuel to the combustion equipment, in a limited speed range in the lower range of engine speeds, and in this instance during starting to increase the rate of engine run-up to idling speed.

In the pipe 60 on the delivery side of the positive-displacement pump 64 and upstream of orifice 61, there is provided an additional flow restriction device 65 which comprises a movable poppet-type valve 66 which is loaded by spring 67 towards a seating 68 around an orifice. This device 65 is designed to afford a greater restriction to flow of fluid through pipe 60 than the first-mentioned flow-restricting orifice 61 and the valve member 66 is arranged to be moved by fuel flow through the orifice against the action of spring 67 so that the pressure drop across device 65 is substantially directly proportional to the engine rotational speed throughout a predetermined speed range within the lower speed range of the engine.

A by-pass pipe 69 is provided around the flow-restricting device 65 and the by-pass 69 includes in it a poppet valve 70 which is loaded by a spring 71 in the sense of closure onto a seating 72 and is arranged to open when a predetermined pressure drop is reached across the additional flow-restricting device 65. This relief valve 70 is so designed that once it has opened, the pressure drop across device 65 does not substantially increase with increase of flow through the by-pass pipe 69 resulting from increase of rotational speed of the engine.

The pressure drop across the additional flow restricting device 65 is applied to a pressure-sensitive device 73, which is separate from that formed by diaphragm 45 to which the pressure drop across the first flow restrictor orifice 61 is applied, and which in this embodiment comprises a cylinder 74 closed at its ends and two diaphragms 75, 76 mounted on a common operating rod 77 and located in the cylinder to divide it into three spaces 78, 79, 80; the two diaphragms 75, 76 are of equal area and the space 79 between the diaphragms is open through port 81 to atmosphere.

Connections are made through pipes 82, 83 from the end spaces 78, 80 respectively to the upstream and downstream sides of the additional flow restriction device 65 so that the pressure drop across device 65 is applied to the diaphragm assembly.

The diaphragm assembly is loaded by a coil spring 84 accommodated in the end space 80 in which the pressure downstream of the additional flow-restricting device 65 is applied. In addition a further spring 85 is provided in the space 80, the spring 85 having a movable abutment 86 which is contacted by one end of the rod 77 when the diaphragm assembly has moved against the action of the first spring 84 by a predetermined amount. When the rod 77 is free from the movable abutment 86, the latter engages a fixed stop 87.

An electrical contact arrangement is provided within the space 79 between the two diaphragms 75, 76, the contact arrangement comprising a pair of fixed contacts 90 and a bridge contact 91 on the rod 77 to co-operate with the fixed contacts 90. The contacts 90, 91 are so arranged that when the pressure drop applied to the diaphragm assembly reaches a first predetermined value and the first spring 84 has been compressed to a predetermined extent, and the contact 91 bridges the fixed contacts 90 to complete an electrical circuit containing the contacts. At a second and higher predetermined value of the pressure drop resulting from an increase of speed, it is arranged that both the first and second springs 84, 85 are overcome and the resulting movement of the diaphragm assembly is arranged to carry contact 91 to a position in which contacts 90 are not bridged, thereby to open the circuit.

The electrical circuit includes in series with the contacts a solenoid 92 which is arranged to operate a valve 93 controlling the flow of extra fuel to the engine. The solenoid 92 is energised to open the valve 93 when the circuit is completed and is de-energised when the circuit is broken to permit the valve 93 to close under the influence of a loading spring 94.

The solenoid-operated valve 93 is arranged in a pipe 93a which is hydraulically in parallel with the main fuel throttle 21 thereby to by-pass the latter when the solenoid 92 is energised.

The operation of the system is as follows: During starting of the engine, the main fuel throttle 21 in the fuel supply pipe 20 to the combustion equipment is normally set for idling fuel flow and is thus almost closed and offers a large resistance to fuel flow therethrough. During the starting of the engine the pressure drop across the additional flow restricting device 65 builds up such that at a predetermined low rotational speed, say, 800 R. P. M. the first spring 84 is compressed to such an extent that the contacts 90 are bridged by contact 91 causing energisation of the solenoid 92 and opening of the valve 93 in the by-pass pipe 93a. Thus the restriction in the fuel delivery line 20 to the engine is reduced and an increase in the fuel supply to the combustion equipment occurs.

As the engine speed increases, the pressure drop across device 65 continues to build up, but the further movement of the diaphragm assembly 75, 76, 77 is restrained by engagement of the rod 77 against abutment 86 for the second spring 85 until the pressure drop reaches a second predetermined value when the load of the first and second springs 84, 85 is overcome; this may be arranged to occur for example at an engine speed of, say, 2,000 R. P. M. At this stage, the diaphragm assembly moves to break the circuit and the solenoid 92 is thus de-energised, allowing the fuel control valve 93 to close, so that the fuel supply to the engine is now defined by the idling setting of the main throttle valve 21 and the engine speed stabilises at its idling speed, say, at 2,500 R. P. M.

Thereafter, the engine can be controlled in the normal manner by opening and closing the throttle valve 21.

On further increase of engine rotational speed, the pressure drop across the additional flow-restricting device 65 causes the by-pass relief valve 70 to open, preventing further increase in this pressure drop across device 65 and avoiding excessive loads being applied to the diaphragm assembly 75, 76, 77.

In the higher range of rotational speed, e. g. from 4,000 R. P. M. to 8,000 R. P. M. the delivery flow from the hydraulic governor pump passing through the first flow-restricting orifice 61 effects the progressive adjustment of the compressor stator blades 14. In the arrangement described therefore a single hydraulic pump, the pump 64, of a hydraulic, speed-sensitive control is utilised to perform the two control functions in the operation of the engine in the two distinct ranges of rotational speed.

Whilst in the embodiment described above, the control functions are of a distinct nature, the invention may also be used for effecting a single control function over a wide speed range.

Such an arrangement is shown in Figure 3 in which, two pressure-sensitive devices 130, 230 are provided, the one 130 connected to be sensitive to the pressure drop across restricting orifice 161 and the other 230 connected to be sensitive to the pressure drop across the restricting device 165. Movements of the operating pistons 132, 232, of the pressure-sensitive devices 130, 230, are proportional to the pressure drops to which the pressure-sensitive devices 145, 245 are subjected, and it is arranged that the operating pistons are connected to links 125, 225 pivoted to the ends of a floating link 27. A rod 28 is pivoted to the floating link 27 intermediate its ends, and is connected to the operating radius arm 24 of the adjustable stator blades.

It is arranged that the effective area of the restricting device 165 is less than that of the restricting orifice 161, and consequently the pressure drop across it is higher for a given flow. The by-pass valve 70 is arranged to open at the desired maximum pressure drop across the restricting device 165.

In operation, over the lower part of the engine speed range, up to the engine speed at which the by-pass valve 70 opens, the arm 225 of the pressure-sensitive device 230 moves progressively over its full range of travel in accordance with the pressure drop across restricting device 165, thereby adjusting the angle of the adjustable stator blades, while arm 125 of pressure-sensitive device 130 moves simultaneously over a small part of its range of travel, because, as the restricting orifice 161 is of greater effective area than the restricting device 165, the pressure drop across diaphragm 145 is less than that across the diaphragm 245. When the by-pass valve opens, the pressure drop across the restricting device 165 remains substantially constant, and therefore the arm 225 remains in substantially the same position. As the engine speed, and therefore the flow through the restricting orifice 161 increase further, the arm 125 of the pressure-sensitive device 130 moves progressively over its full range of travel in accordance with the pressure drop across flow-restricting orifice 161. This movement is transmitted through the floating link 27 to the radius arm 24 by which the guide vanes are adjusted.

The rod 28 may be pivoted to the floating link 27 at any suitable point between its ends to achieve the desired movement of rod 28 due to the movement of pistons 132, 232. It will thus be seen that the control force available, as represented by the pressure drop applied across diaphragm 145, is greatly increased as compared with systems in which there is only a single diaphragm, sensitive to the pressure drop across a single restricting orifice.

In an alternative arrangement shown in Figure 4 a control is shown for adjustable stator blades 14 such that in the low speed range the diaphragm 45 of the device 30 is subjected to the pressure drop across restrictor device 65 and in a higher speed range the diaphragm 45 is subjected to the pressure drop across the restrictor orifice 61. To apply these pressure drops alternatively to the diaphragm, the pipe 60 is provided with three branches 95, 96, 97, whereof the branch 95 is connected to pipe 60 downstream of orifice 61 and leads to one port 98*a* of a changeover valve 98, branch 96 is connected to pipe 60 between the orifice 61 and the device 65 and leads to a second port 98*b* of valve 98 and to a first port 99*a* of a second changeover valve 99, and whereof branch 97 is connected to pipe 60 between the device 65 and pump 64 and leads to a second port 99*b* of the changeover valve 99. The outlets 98*c*, 99*c* from valves 98 and 99 lead respectively to pipes 46, 47 and thus to compartments 43, 44 on each side of diaphragm 45. The valves 98, 99 are coupled together, as indicated at 100, and are arranged so that in one position 98*c*, 99*c* are connected to ports 98*a*, 99*a* respectively and in a second position (ports 98*c*, 99*c* are connected) to ports 98*b*, 99*b* respectively. Thus in the first valve position the diaphragm is subjected to the pressure drop across orifice 61 and in the second position the diaphragm 45 is subjected to the pressure drop across device 65.

The valves 98, 99 are operated by a solenoid device 102 energised under control of a pressure-operated switch device 101 which operates when the pressure drop across the device 65 reaches a preselected value, say a value which is a fixed margin below the pressure drop at which by-pass device 70 is arranged to open, which value of the pressure drop is correlated with the rotational speed of the engine.

In the arrangement described, the pressure drop across orifice 61 varies as the square of the flow therethrough and the pressure drop across orifice 65 is directly proportional to the flow therethrough. To obtain progressive control of the guide vanes over the whole speed range it is arranged that the transfer of the control from the orifice 61 to orifice 65 by means of the valves 98 and 99 and pressure operated switch device 101 is effected when the pressure drop across the orifice 65 is substantially equal to that across the orifice 61, i. e. at the point of intersection of the linear and square law pressure/flow curves.

I claim:

1. A hydraulic speed-sensitive system comprising a fixed-capacity pump, means to drive said pump at a rotational speed proportional to the speed to which said device is to be sensitive, flow-restricting means connected to the pump to receive the delivery flow therefrom including a first flow-restricting device of relatively large effective area and in series therewith an additional flow-restricting device of relatively small effective area, pressure-sensitive means subjected to pressure differences across said flow-restricting devices, flow by-pass means connected to the

upstream and downstream sides of said additional flow-restricting device, and a valve in said by-pass means to control the flow therethrough.

2. A hydraulic speed-sensitive system as claimed in claim 1, comprising a pair of pressure-sensitive devices, the first such device being connected to be subjected to the pressure difference across said first flow-restricting device and the second such device being connected to be subjected to the pressure difference across said additional flow-restricting device.

3. A hydraulic speed-sensitive system, comprising a fixed-capacity pump, means to drive said pump at a rotational speed proportional to the speed to which said device is to be sensitive, flow-restricting means connected to the pump to receive the delivery flow therefrom, including a first flow-restricting device and an additional flow-restricting device in series, pressure-sensitive means, means to connect said pressure-sensitive means, in opposition, to locations upstream and downstream respectively of said first flow-restricting device, whereby said pressure-sensitive means is responsive to the pressure drop across said first flow-restricting device, and means to connect said pressure-sensitive means, in opposition, to locations upstream and downstream respectively of said additional flow-restricting device, whereby said pressure-sensitive means is responsive to the pressure drop across said additional flow-restritcing device, said additional flow-restricting device having a smaller effective area than said first flow-restricting device, by-pass means connected directly to the upstream and downstream sides of said additional flow-restricting device, and a valve in said by-pass means to control the flow therethrough.

4. A hydraulic speed-sensitive system comprising a fixed capacity pump, means to drive said pump at a rotational speed proportional to the speed to which said device is to be sensitive, flow-restricting means connected to the pump to receive the delivery flow therefrom, including a first flow-restricting device of relatively large effective area and in series therewith an additional flow-restricting device of relatively small effective area, a first pressure-sensitive device, a second pressure-sensitive device, means for subjecting said pressure-sensitive devices to pressure differences across said flow-restricting devices, flow-by-pass means connected to the upstream and downstream sides of said additional flow-restricting device, and a valve in said by-pass means to control the flow therethrough.

5. In combination, a prime mover, a hydraulic speed-sensitive system as claimed in claim 4, whereof said pump is driven at a speed proportional to that of said prime mover, means for effecting a first control action of said prime mover, means for effecting a second control action of said prime mover, an operative connection between said first pressure-sensitive device and said means for effecting the first control action, and an operative connection between said second pressure-sensitive device and said means for effecting the second control action.

6. In combination, a prime mover, a hydraulic speed-sensitive system as claimed in claim 4, whereof the pump is connected to be driven at a speed proportional to that of the prime mover, further comprising means for effecting a single control action on said prime mover and operative connections between said first and second pressure-responsive devices and said means for effecting the control action.

7. A hydraulic speed-sensitive system for effecting control of a prime mover, comprising a fixed-capacity pump, means to drive said pump at a rotational speed proportional to that of the prime mover, flow-restricting means connected to the pump to receive the delivery flow therefrom, including a first flow-restricting device and an additional flow-restricting device, the effective area of said additional flow-restricting device being less than that of said first flow-restricting device, a first pressure-sensitive device, conduit means connecting said first pressure-sensitive device to the upstream and downstream sides respectively of said first flow-restricting device, whereby said pressure-sensitive device is subjected to the pressure drop across said first flow-restricting device, a second pressure-sensitive device, conduit means connecting said second pressure-sensitive device to the upstream and downstream sides respectively of said additional flow-restricting device, whereby said second pressure-sensitive device is subjected to the pressure drop across said additional flow-restricting device, first control means for said prime mover connected to said first pressure-sensitive device for operation thereby in a first rotational speed range of said prime mover, second control means for said prime mover connected to said second pressure-sensitive device for operation thereby in a second rotational speed range of said prime mover, lower than said first rotational speed range, by-pass means connected respectively to the upstream and downstream sides of said additional flow-restricting device, and a valve in said by-pass means to control the flow therethrough.

8. A hydraulic speed-sensitive system as claimed in claim 7, characterised in that said prime mover is a gas turbine engine, including a compressor having adjustable compressor stator blading, combustion equipment, and a turbine, and comprising adjusting means to adjust said adjustable compressor stator blading, and means to interconnect said first control means and said adjusting means, whereby the adjustment is effected in accordance with the pressure drop sensed by said first pressure-sensitive device, second adjusting means for permitting the injection of additional fuel into the combustion equipment of said gas turbine engine, and control means connected to said second pressure-sensitive device and to said adjusting means, whereby introduction of said extra fuel is controlled in accordance with the pressure difference sensed by said second pressure-sensitive device.

9. A hydraulic speed-sensitive system for effecting control of a gas turbine engine, comprising a first conduit, a fixed-capacity pump delivering solely into said conduit, constant-ratio drive means by which said pump is driven from said engine, a first flow-restricting device in said conduit, a first casing, a diaphragm assembly dividing said casing into two chambers, one on each side of the assembly, a second conduit connecting one of said chambers with said first conduit on the upstream side of said flow-restricting device, a third conduit connecting the other of said chambers with said first conduit on the downstream side of said flow-restricting device, an additional flow-restricting device in said conduit in series with and having a lesser effective area than said first flow-restricting device, a second casing, a second diaphragm assembly dividing said second casing into two chambers one on each side of said second assembly, a fourth conduit connecting one of said last-mentioned chambers

with said first conduit on the upstream side of said additional flow-restricting device, a fifth conduit connecting the other of said last-mentioned chambers with said first conduit on the downstream side of said additional flow-restricting device, a by-pass conduit from upstream to downstream of said additional flow-restricting device, a relief valve in said by-pass conduit to control the flow therethrough, a first control system of said gas turbine engine connected to said first diaphragm assembly, and a second control system of said gas turbine engine connected to said second diaphragm assembly, whereby a given control force is obtained at a higher speed to actuate said first control system and at a lower speed to actuate said second control system.

10. A hydraulic speed-sensitive system for effecting control of a prime mover comprising a first conduit, a fixed-capacity pump delivering solely into said conduit, constant-ratio drive means by which said pump is driven from said prime mover, a first flow-restricting device in said conduit, a first casing, a diaphragm assembly dividing said casing into two chambers, one on each side of the assembly, a second conduit connecting one of said chambers with said first conduit on the upstream side of said flow-restricting device, a third conduit connecting the other of said chambers with said first conduit on the downstream side of said flow-restricting device, an additional flow-restricting device in said conduit in series with, and having a lesser effective area than, said first flow-restricting device, a second casing, a second diaphragm assembly dividing said second casing into two chambers, one on each side of the assembly, a fourth conduit connecting one of said last-mentioned chambers with said first conduit on the upstream side of said additional flow-restricting device, a fifth conduit connecting the other of said last-mentioned chambers with said first conduit on the downstream side of said additional flow-restricting device, a by-pass conduit from upstream to downstream of said additional flow-restricting device, a relief valve in said by-pass conduit controlling the flow therethrough, and a control system of said prime mover connected to said first and second diaphragm assemblies, whereby a given control force is obtained both at a higher speed and at a lower speed to actuate said control system.

11. A hydraulic speed-sensitive system as claimed in claim 10, wherein the prime mover is a gas turbine engine having adjustable compressor guide vanes, and wherein the control system is operatively connected to said adjustable guide vanes.

12. A hydraulic speed-sensitive system, comprising a fixed-capacity pump, means to drive said pump at a rotational speed proportional to the speed to which the system is to be sensitive, flow-restricting means connected to the pump to receive the delivery flow therefrom including a first flow-restricting device and an additional flow-restricting device, a pressure-sensitive device, means to connect said pressure-sensitive device, in opposition, to the upstream and downstream sides respectively of said first flow-restricting device, whereby said pressure-sensitive device is responsive to the pressure drop across said first flow-restricting device, and means to connect said pressure-sensitive device in opposition to the upstream and downstream sides respectively of said additional flow-restricting device, whereby said pressure-sensitive device is responsive to the pressure drop across said additional flow-restricting device, said additional flow-restricting device having a smaller effective area than said first flow-restricting device, a change-over mechanism interposed in said connections from the upstream and downstream sides respectively of said first and said additional flow-restricting devices, whereby the pressure-sensitive device is connected alternatively to the upstream and downstream sides respectively of said first flow-restricting device and to the upstream and downstream sides respectively of said additional flow-restricting device, by-pass means connected to the upstream and downstream sides of said additional flow-restricting device, and a valve in said by-pass means to control the flow therethrough.

13. A hydraulic speed-sensitive system as claimed in claim 12, wherein the first flow-restricting device is of the orifice type, the fixed area pressure drop varying as the square of the flow therethrough, and wherein the additional flow-restricting device comprises a movable valve element sensitive to the pressure difference across the flow-restricting device and arranged to reduce the restriction afforded with increase of said pressure difference, and resilient means loading said movable valve element in the sense of closure, whereby the pressure drop across said additional flow-restricting device is substantially directly proportional to the flow therethrough.

14. A hydraulic speed-sensitive system, comprising a fixed-capacity pump, means to drive said pump at a rotational speed proportional to the speed to which said device is to be sensitive, flow-restricting means connected to the pump to receive the delivery flow therefrom including a first flow-restricting device and an additional flow-restricting device, said additional flow-restricting device having a smaller effective area than said first flow-restricting device, a pressure-sensitive device, a first valve body part, first conduit means between said first valve body part and the downstream side of said additional flow-restricting device, second conduit means between said first valve body part and the downstream side of said first flow-restricting device, third conduit means between said first valve body part and said pressure-sensitive device, a second valve body part, fourth conduit means between said second valve body part and the upstream side of said additional flow-restricting device, fifth conduit means between said second valve body part and the upstream side of said first flow-restricting device, sixth conduit means between said second valve body part and said pressure-sensitive device, and valve means to connect said third and sixth conduit means alternatively to said second and fifth conduit means respectively in one position and to said first and fourth conduit means respectively in another position, operating means for moving said valve means between said one position and said other position, and by-pass means connected to the upstream and downstream sides of said additional flow-restricting device, and a valve in said by-pass means to control the flow therethrough.

15. A hydraulic speed sensitive system as claimed in claim 14, further comprising a speed-responsive device responsive to the speed of the prime mover and connected to said operating means to actuate it at a predetermined speed, whereby said valve means is shifted from said one position to said other position at said speed.

16. A hydraulic speed-sensitive system as claimed in claim 14, wherein said valve in said by-pass means comprises a relief valve sensitive to the pressure difference across said additional flow-restricting device and arranged to open when a predetermined pressure difference is reached and to prevent any substantial increase in said pressure difference with increase of rotational speed beyond the rotational speed at which said predetermined pressure difference is reached.

17. A hydraulic speed-sensitive system comprising a fixed-capacity pump adapted to be driven at a rotational speed proportional to the speed to which said system is to be sensitive, flow-restricting means connected to the pump to receive the delivery flow therefrom including a first flow-restricting device of relatively large

effective area and in series therewith an additional flow-restricting device of relatively small effective area, pressure-sensitive means subjected to pressure differences across said flow-restricting devices, flow by-pass means connected to the upstream and downstream sides of said additional flow-restricting device and a valve in said by-pass means to control the flow therethrough.

DAVID OMRI DAVIES.

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