

- [54] **ELECTRONIC SPEED GOVERNOR FOR A TURBINE**
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 [73] Assignee: **Standard Oil Company**, Chicago, Ill.
 [22] Filed: **Mar. 9, 1973**
 [21] Appl. No.: **339,533**

3,572,958	3/1971	Jensen	415/17
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 Willian, Olds & Cook, Ltd.

- [52] **U.S. Cl.**..... **415/30, 415/40, 415/17**
 [51] **Int. Cl.**..... **F01b 25/06**
 [58] **Field of Search** 415/20, 26, 30, 36, 40,
 415/43, 15, 17

- [56] **References Cited**
UNITED STATES PATENTS
 3,340,883 9/1967 Peternel..... 415/15

[57] **ABSTRACT**
 An improved electronic speed governor for a turbine wherein the speed of the turbine is controlled by the output of a pneumatic transducer and wherein the pneumatic transducer includes a hollow housing having enclosed therein the entire circuitry for the electronic speed governor.

11 Claims, 10 Drawing Figures

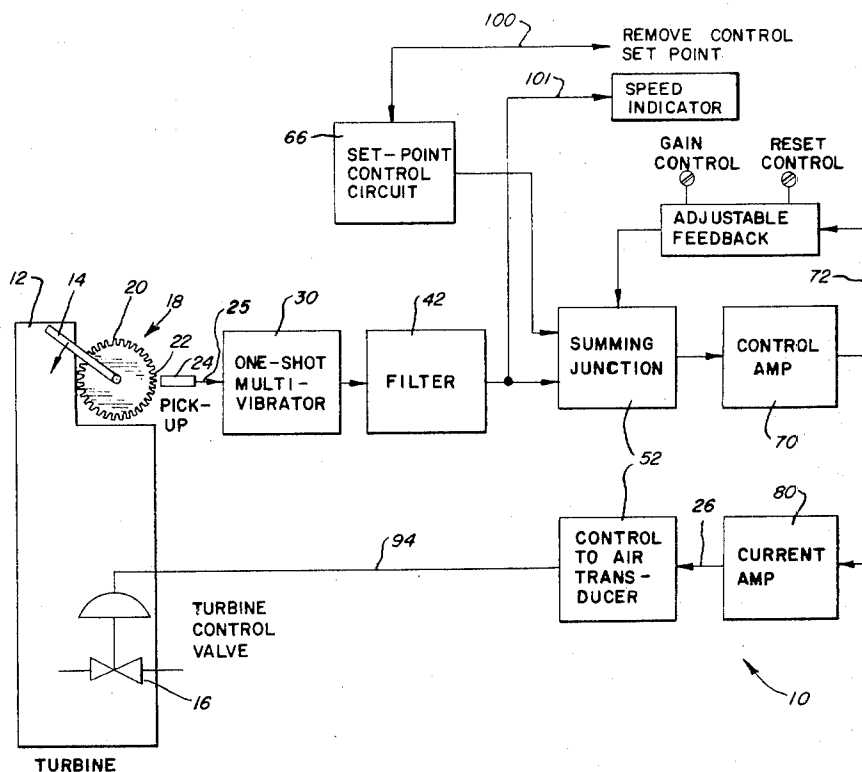


FIG. 3

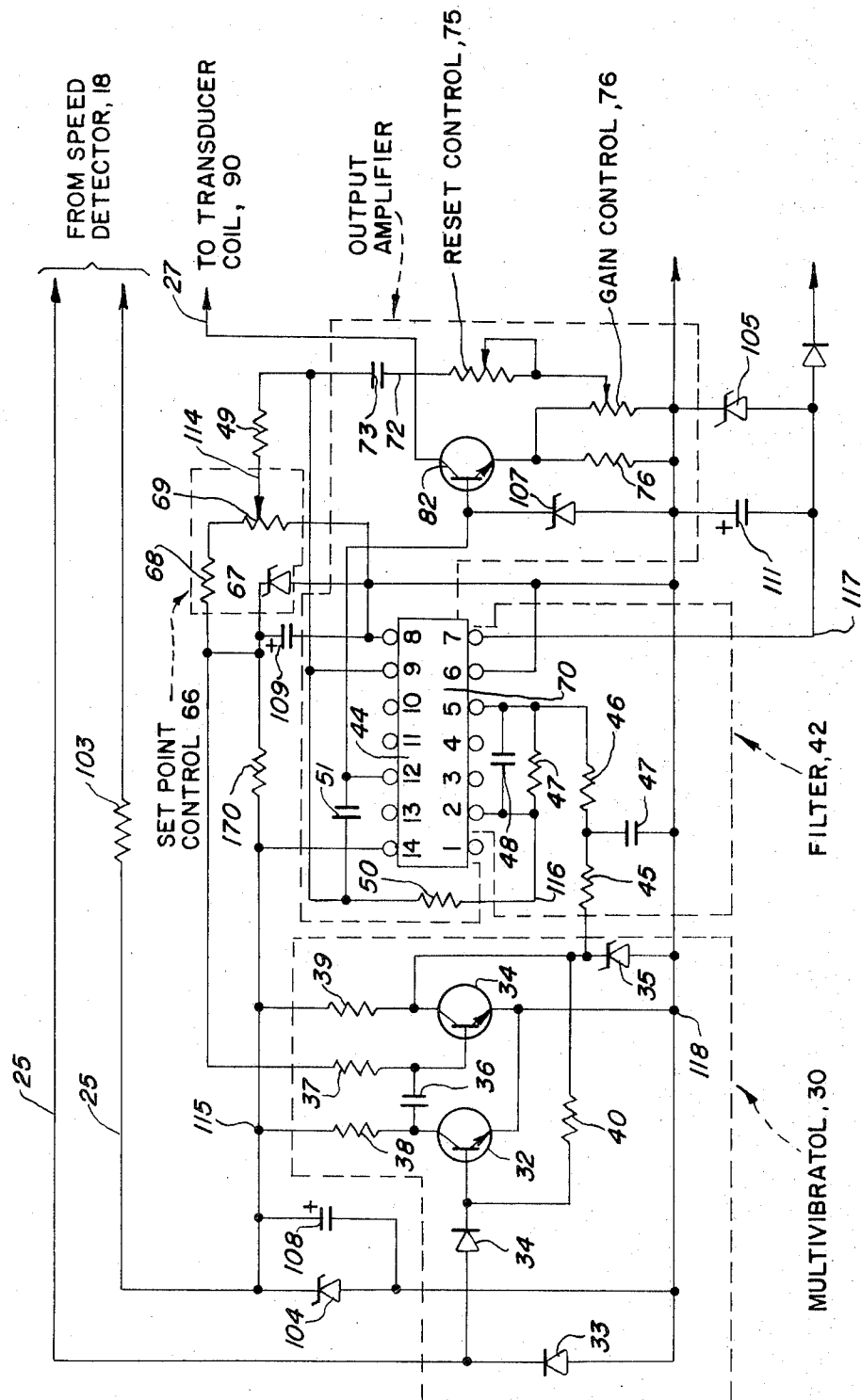


FIG. 4

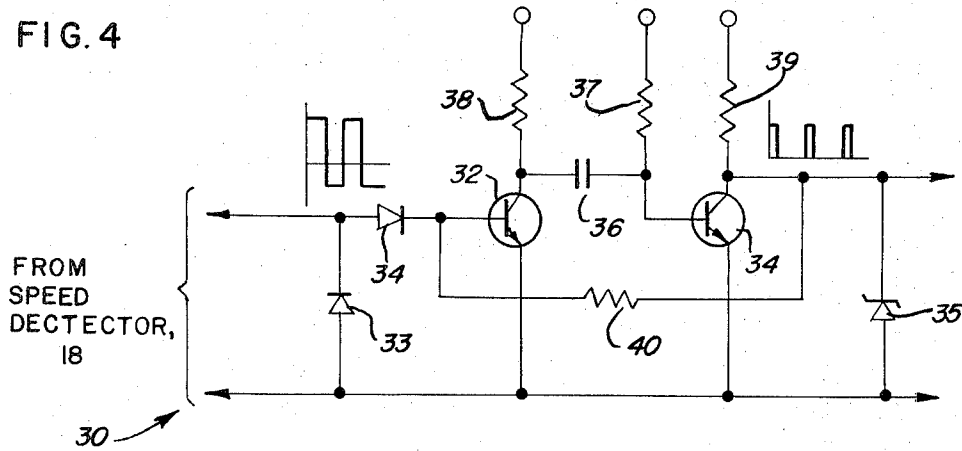


FIG. 5

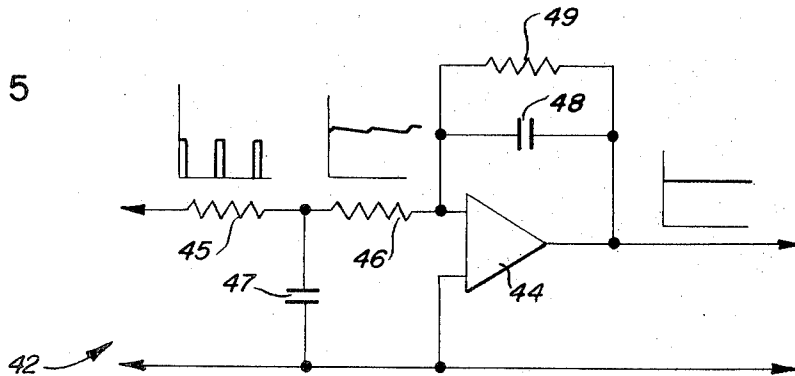


FIG. 6

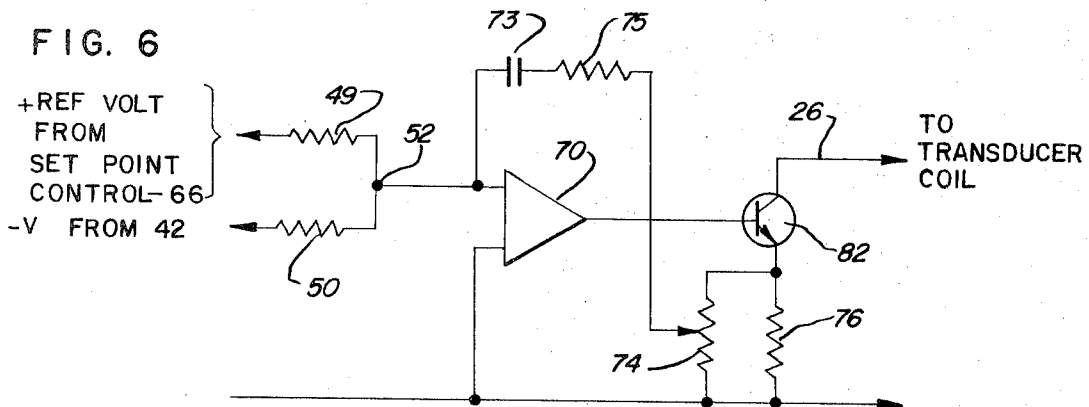


FIG. 7

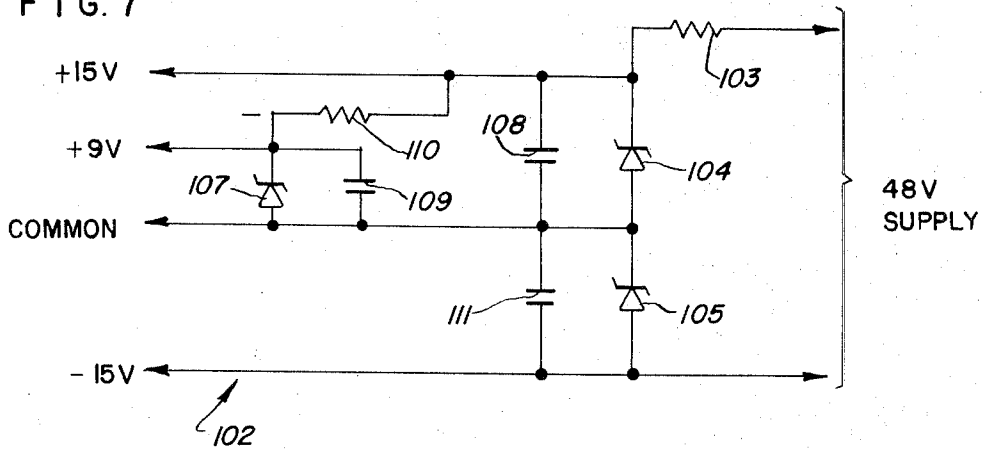


FIG. 9

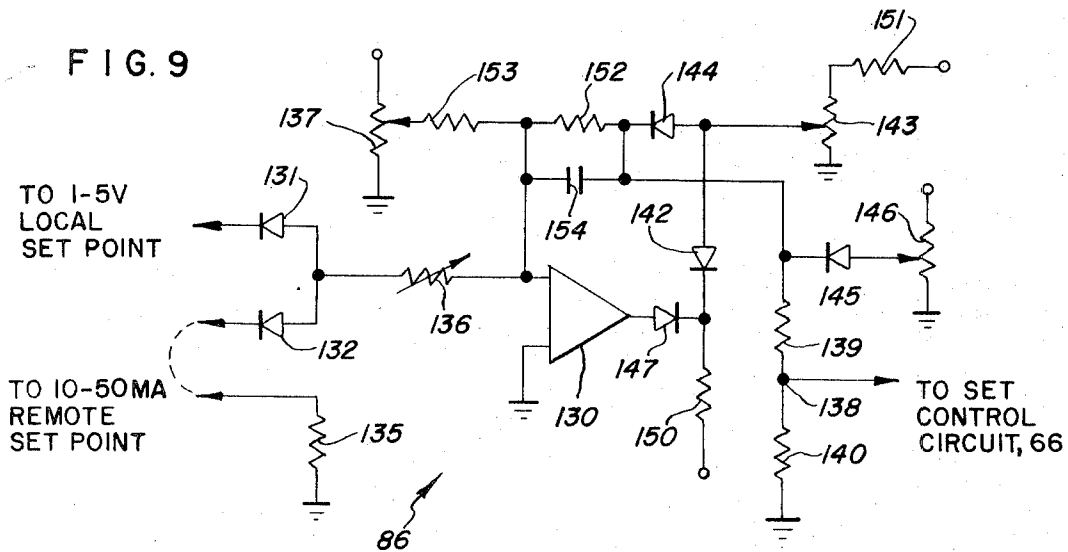


FIG. 10

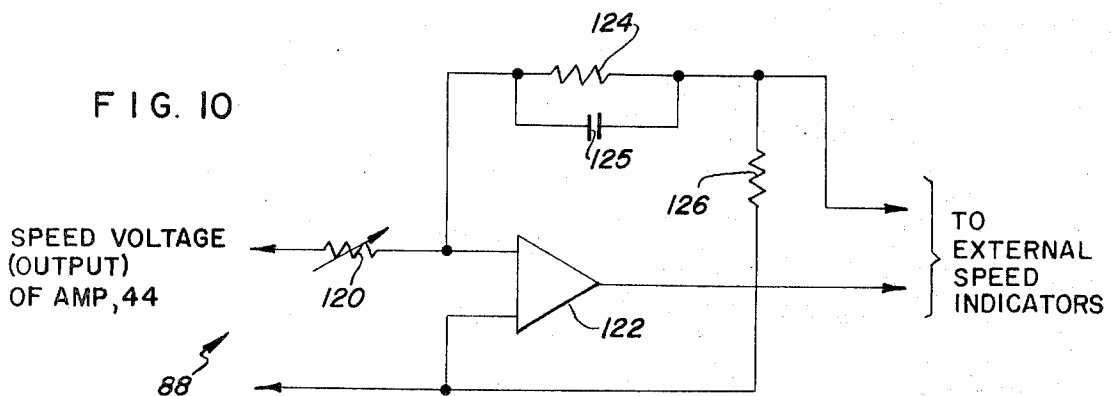
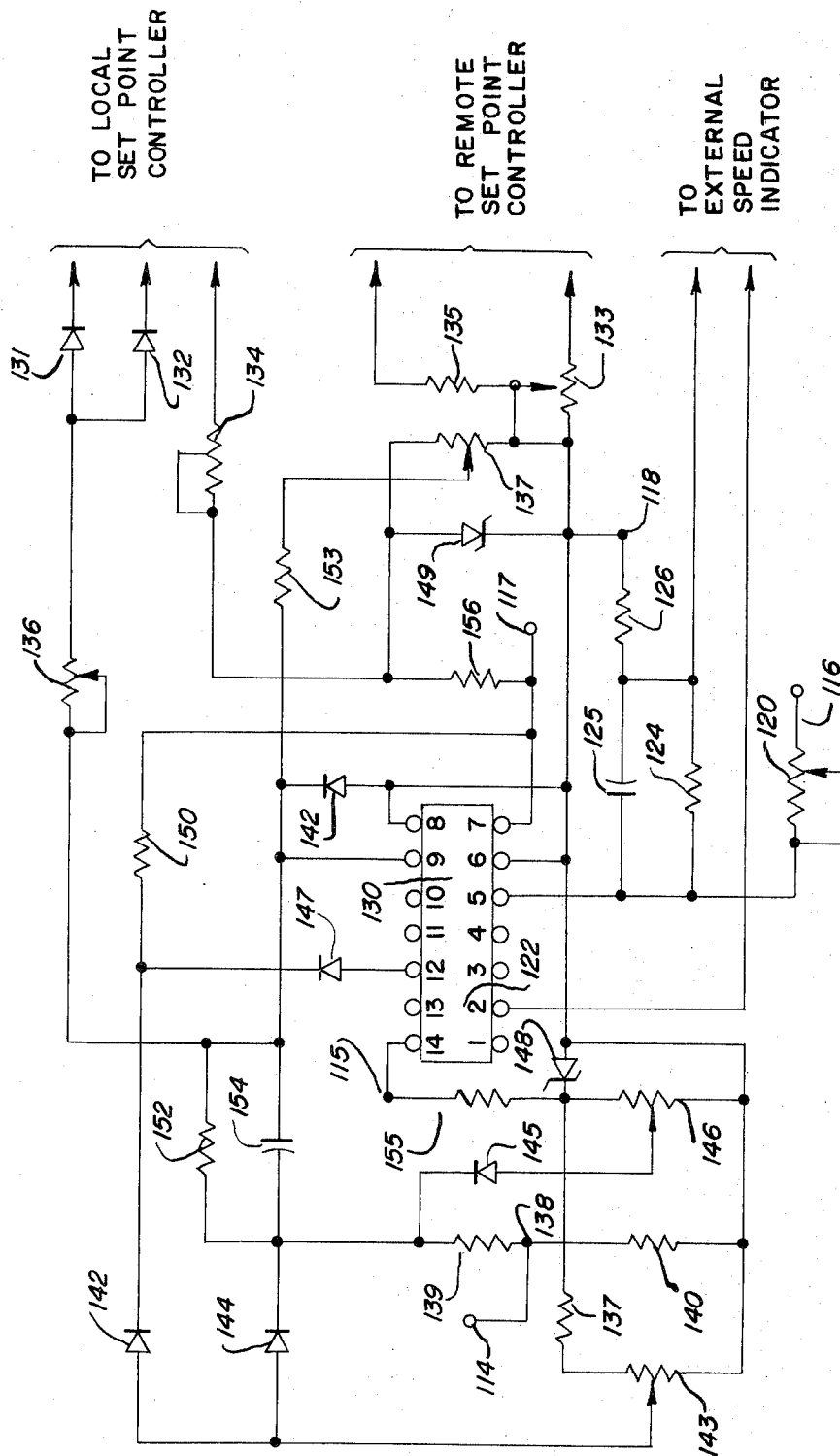


FIG. 8



ELECTRONIC SPEED GOVERNOR FOR A TURBINE

BACKGROUND OF THE INVENTION

The present invention relates to a control device for electronically controlling the speed of a turbine and more particularly, for an improved electronic speed governor for a turbine wherein the electronic elements of the speed governor are self-contained within a housing of a pneumatic transducer.

In recent years, the trend has been to use electrical, rather than mechanical devices for controlling the speed of a turbine. Two such electrical devices are disclosed in U.S. Pat. No. 3,578,871, issued to Tetsuzo Sakamoto on May 18, 1971, and in U.S. Pat. No. 3,340,883, issued to J. R. Peternel on Sept. 12, 1967.

Although the electronic devices disclosed in the above two identified United States patents have served the purpose, they have not provided entirely satisfactory under all conditions of service in that the electronic circuitry of the speed governor was housed externally of the electro-mechanical transducer which was used to directly control the speed of the turbine and was thus subjected to a corrosive environment and could possibly overheat. Applicant's invention overcomes these difficulties.

SUMMARY OF THE INVENTION

The general purpose of this invention is to provide an improved electronic speed governor for a turbine which embraces all of the advantages of similarly employed speed governors, which is economical to produce and which is not susceptible to corrosive elements or overheating.

To attain this, the present invention contemplates and utilizes a digital signal generating means associated with the turbine to produce an electrical signal which is a function of the rotational speed of the turbine. A first platform is located within the housing of a current to air or a pneumatic transducer. Located on the first platform is a means for converting the digital signal into a D. C. voltage velocity signal which is proportional to the speed of the turbine. A reference generating circuit is also located on the first platform for generating a preselectable reference voltage signal indicative of a desired speed of the turbine. A comparator circuit located on the first platform compares the velocity signal with the reference voltage signal and generates an error signal indicative of the difference between the voltage velocity signal and the reference voltage signal. Lastly, a control amplifier located on the first platform generates a control signal, responsive to the error signal, to the transducer whereby the transducer in response to the control signal generates a pneumatic signal which controls the speed of the turbine.

An object of the present invention is to provide an improved electronic speed governor where the entire circuitry of the speed governor is contained within the housing of an electro-pneumatic transducer.

Another object is to provide an electronic speed governor which is relatively protected from steam deposits and other corrosive affects.

A further object is the provision of an electronic speed governor for a turbine which is extremely simple

to install and which is compact and mountable at the turbine itself.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of the electronic speed governor.

FIG. 2 is a perspective diagram of an electro-pneumatic or current to air transducer with the top portion of the housing removed showing the electronic speed governor circuit of the present invention.

FIG. 3 is a schematic diagram of the electronic speed governor which constitutes a preferred embodiment of the invention.

FIG. 4 is a simplified schematic diagram of the multi-vibrator circuit shown in FIG. 1.

FIG. 5 is a simplified schematic diagram of the filter circuit shown in FIG. 1.

FIG. 6 is a simplified schematic diagram showing the summing junction, the control amplifier, and the current amplifier of FIG. 1.

FIG. 7 is a simplified schematic diagram of the power supply circuit utilized in the preferred embodiment of the invention.

FIG. 8 is a schematic diagram of additional circuitry which may be used in combination with the electronic speed governor shown in FIG. 3.

FIG. 9 is a simplified schematic view of a portion of the circuit shown in FIG. 8.

FIG. 10 is a simplified schematic view of a portion of the circuit shown in FIG. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1, an electronic speed governor circuit 10 which is used to control the speed of a turbine 12 by regulating a turbine control valve 16 through the use of air pressure from a current to air transducer 90. The electronic speed governor circuit 10 is designed to be mounted at the turbine 12 through the uniqueness of its integral packaging within the housing of the current to air transducer 90 used to supply the air pressure to the control valve 16.

A speed detector 18 is provided to sense the speed of the turbine shaft 14. One conventional speed detector 18 comprises a wheel 20 having a plurality of teeth 22 which is mounted on the turbine shaft. A magnetic pick-up head 24 is provided which produces a plurality of pulses the frequency of which is directly related to the speed of the turbine shaft 14. These pulses form a digital signal whose frequency is a function of the rotational speed of the turbine shaft. The digital pulses are transmitted to a mono-stable or "one shot" multi-vibrator 30. The multi-vibrator 30 and filter 42 convert the pulses into a D. C. voltage which is proportional to the speed of the turbine. The filter circuit 42 also provides buffering and scaling of the voltage velocity signal. The voltage velocity signal is then transmitted to a summing junction 52. Also present at the input of the summing junction 52 is a reference voltage signal

which is generated by a set point control circuit 66. The reference voltage signal generated by the set point control circuit 66 is preselectable and is indicative of the desired speed of the turbine.

Both the reference voltage signal from the set point control circuit 66 and the D. C. voltage velocity signal from the filter 42 are compared at the summing junction 52 and are transmitted to a control amplifier 70. If a difference exists, an error signal is produced at the output of the control amplifier 70. Thus, the actual velocity of the turbine is constantly being compared to the desired velocity as determined by the set point control circuit 66. The control amplifier 70 functions as an operational integrator that integrates the error signal and thus provides a smoothly modulated control voltage which is then transmitted to a current amplifier 80 where the voltage is converted into a current which is then used to drive a current to air transducer 90. The current to air transducer 90 is a conventional pneumatic transducer wherein a pneumatic output is obtained from a current input. The pneumatic output from the current to air transducer 90 is transmitted via a conduit 94 to the turbine control valve 16 and thus adjusts the speed of the turbine 12 in proportion to the amount of current from the current amplifier 80 which in turn is responsive to the error signal generated from the summing junction 52.

In the preferred embodiment of the invention, each of the components shown in FIG. 1 which comprise the electronic speed governor circuit 10 with the exception of the speed detector 18, are located within the housing 91 of the current to air transducer 90. This can be seen in FIG. 2. By placing these components within the housing, the components are continuously cooled and purged due to the continuous air bleeds through the transducer housing 91. This increases the component life in corrosive atmospheres and as such has been proven to be a great advantage over those systems wherein electronic components are external to the housing of the current to air transducer. In the preferred embodiment of the invention, the current to air transducer comprises a Fisher Model No. 546 transducer manufactured by the Fisher Governor Company. It will be recognized, however, that other similar transducers may be utilized.

Referring to FIG. 2, the current to air transducer 90 comprises a housing 91 within which is placed a first platform 96. Located on the first platform 96 are the solid state elements which comprise the one shot multi-vibrator 30, the filter 42, the summing junction 52, the control amplifier 70, the current amplifier 80 and the set point control circuit 66. As will be explained in detail below, a second platform 98 may also be provided either above or below the first platform 96. The purpose of the second platform 98 is to house additional elements which may optionally be utilized with the electronic speed governor circuit 10. These elements are shown in FIGS. 8-10 and will be explained below.

The current to air transducer 90 is a conventional transducer with the exception of the platforms 96 and 98 which have been added. The current to air transducer 90 converts a current input which in the preferred embodiment of the invention comes from the control amplifier 80 located within the housing 91 and produces a proportional pneumatic output through an outlet pneumatic tube 94. In addition, a source of air

supply 92 is also provided for the transducer. The transducer 90 in the preferred embodiment may be mounted in the vicinity of the turbine which is to be controlled. Only two external wires are necessary to connect the current to air transducer 90 to the entire system. One such lead is designated by the numeral 25 and connects the speed detector 18 to the one shot multi-vibrator 30 located within the housing 91 of the current to air transducer 90. A second lead 27 connects the circuitry of the electronic speed governor 10 to a source of D. C. voltage. In the preferred embodiment, this is a 48 volt source. The 48 volts may be obtained through the use of a voltage regulator from a normally available 129 volt D. C. source located at the turbine.

Referring now to FIGS. 3-7, the detailed circuitry of the electronic governor circuit 10 will be explained. FIG. 3 shows the over-all schematic diagram of the electronic speed governor circuit 10 which constitutes the preferred embodiment of the invention. FIGS. 4-7 show simplified diagrammatic schematic views corresponding to some of the block diagrams shown in FIG. 1. Referring to FIGS. 1, 3 and 4, the monostable multi-vibrator 30 comprises a conventional multi-vibrator which is triggered by the positive half cycle of the input pulses from the speed detector 18. These pulses are transmitted to the multi-vibrator 30 via the leads 25. The multi-vibrator 30 comprises two transistors 31 and 32 which are triggered by the positive half cycle input pulses from the speed detector 18. A pair of diodes 33 and 34 protect the transistor 31 from damage during the negative half cycle. Triggering will not take place until the input voltage exceeds the forward biasing voltage of the diode 34 and the transistor 31 which in the preferred embodiment is 1.2 volts. This provides immunity to noise, transients, etc. The output of the multi-vibrator 30 appears at the collector of the transistor 32 and is a positive going square wave whose amplitude is controlled by a zener diode 35. The period of the square wave is determined by the time constant of the resistor 37 and the capacitor 36. The capacitor 36 may be a stable silva-mica type capacitor which is selected based upon the RPM's of the turbine shaft and the number of teeth 22 on the pick-up wheel 20. Because the area under each pulse is fixed and the frequency of pulses is determined by the turbine speed, filtering of this square wave will produce a D. C. voltage which is proportional to the speed or velocity of the turbine and thus forms an analog voltage signal.

The filter circuit 42 is shown in schematic form in FIGS. 3 and 5. Filtering of the square wave input from the one shot multi-vibrator circuit 30 is accomplished by the RC network comprising resistors 45 and 46 and a capacitor 47 as well as an amplifier 44 which provides a capacitor feedback through the capacitor 48 and thus provides reduced gain at higher frequencies. The amplifier 44 forms in the preferred embodiment a portion of an integrated circuit chip. It will be recognized, however, that any suitable amplifier may be utilized. The amplifier 44 also provides buffering and scaling of the speed voltage for application to the summing junction 52. Lastly, the amplifier 44 also inverts the speed voltage signal to produce a negative signal which is compared with a positive signal generated by the point set control circuit 66.

The signal generated by the set point control circuit 66 is representative of the desired speed of the turbine

and is referred to as the reference velocity voltage signal. The set point control circuit 66 is shown in greater detail in FIG. 3. The reference voltage representative of the desired velocity of the turbine is set by varying the wiper associated with the resistor 69.

The negative speed signal, or in other words, the D. C. voltage signal indicative of the actual speed of the turbine, is applied through a resistor 50 to a summing junction 52 shown in FIGS. 3 and 6. At the summing junction 52, this signal is summed with the positive signal delivered through a resistor 49 from a set point control circuit 66. The set point control circuit 66 is supplied with a highly stable positive voltage from a temperature compensated zener diode 67 via a resistor 68. If the turbine is running at the set speed, the voltage produced at the summing junction 52 will be zero. Any deviation from the desired speed will tend to produce an error voltage at the summing junction 52. This error voltage will be negative if the speed is too high and positive if the speed is too low. The summing junction 52 is the input to the control amplifier 70.

The control amplifier 70 is a conventional amplifier and in the preferred embodiment is shown in FIG. 3, constitutes a portion of an integrated circuit chip common with the amplifier 44. Feedback from the amplifier 70 is provided over the feedback path 72 via the capacitor 73. This feedback is also summed at the summing junction 52. The amplifier 70 therefore has a proportional signal plus an integral feedback signal at the output current stage of a transistor 82. The voltage drop across the resistor 76 in the emitter circuit of the transistor 82 is used as a measure of the current output and will produce in the preferred embodiment 1 volt at 10 milliamps minimum output and 5 volts at 50 milliamps maximum output. This voltage is applied across the gain control resistor 74 where all or part of it is sent back via the resistor 75 in the capacitor 73 to the summing junction 52. The resistor 75 in series with the capacitor 73 controls the "reset" action of the controller by controlling the charging rate of the capacitor 73. The resistor 75 also affects the gain of the amplifier 70. The error signal generated by the amplifier 70 is an integral function of the error signal as well as a proportional function of the error signal. This signal then is transmitted to the control current amplifier 80 which comprises a transistor 82 and the associated biasing circuitry. The output from the transistor 82 converts the error voltage into a current signal which is proportional to the error voltage. This current or control signal then is transmitted via the lead 26 to the current to air transducer 90. The current to air transducer 90 then emits a controlled air pressure via the conduit 94 (FIG. 2) which in turn regulates the valve 16 associated with the turbine 12 thereby controlling the speed of the turbine 12.

In practice, the voltage at the summing junction will always be zero since the amplifier 70 will change its output to maintain the voltage at zero. The changing output thereby manipulates the valve 16 at the turbine until the error is once again zero at which point the output will cease to change.

The power supply circuit 102 for the electronic speed control circuit 10 is shown more clearly in FIG. 7. Power is supplied by an internal system located within the housing 91 of the current to air transducer 90. A D. C. source, conventionally 129 volts, is present at the turbine and through appropriate voltage reducing cir-

cuitry, is converted into a 48 volt supply (not shown). The 48 volts is then applied through the resistor 103 and the zener diodes 104 and 105. A diode 106 prevents damage by reversing the supply voltage and a zener diode 107 provides a nine volt reference supply.

As mentioned previously, all of the components shown in FIG. 3 may be placed in modular form, on the platform 96 located within the housing 91 of the current to air transducer 90. By placing these components on the platform 96 within the housing 91, the constant air bleed of the current to air transducer 90 will purge the electronic component of all corrosive elements and will tend to cool them thereby extending their life and extending the life of the speed governor.

Referring now to FIGS. 8-10, certain optional features are shown which may be added to the previously described electronic speed governor circuit 10. These additional options may be individually added, or all of them may be added. One of these features provides for a remote speed read-out of the actual speed of the turbine 12. The second feature allows for a remote control setting of the speed of the turbine. As mentioned previously, a voltage is present in FIG. 3 which is representative of the turbine speed. To obtain a read-out, it is only necessary to condition this voltage to some useable level. It is apparent that a positive voltage can be inserted in lieu of the voltage across the resistor 69 in order to vary the speed of the turbine. If this voltage were derived from some standard source, such as a controller, then it must be altered to equal this voltage speed present at the speed desired. This would then enable a remote speed control.

Referring to FIGS. 8 and 9, the remote speed set control will be explained. FIG. 9 shows a remote set point control circuit 86, which comprises an amplifier 130. The amplifier 130 accepts an input from a pair of diodes 131 and 132. These diodes form a high signal selector between the two inputs. In this instance, only the highest voltage will be the input to the amplifier. This is done so that if both local and remote set points are used, only the one calling for the highest speed will be selected. The local set point is developed by a single turn control resistor which will be mounted externally to the housing of the transducer 90 and will provide -1 to -5 volts to the amplifier 131. This voltage is applied from the resistors 133 and 134 (FIG. 8).

A similar -1 to -5 volts is developed by dropping the ten to fifty milliamps remote set signal across resistor 135. This voltage is jumpered externally to the diode 132 as shown by the dotted line in FIG. 9. The amplifier 130 has gained an offset adjustment through the use of the resistors 136 and 137 which allow the incoming -1 to -5 volts to be converted to any desired positive voltage span. This span will correspond to the speed voltage span present at the output of the amplifier 44 (FIGS. 3 and 5) over the desired variable speed range. The output of the amplifier 130 is effectively the junction 138 of the resistor 139 and 140 which form an output voltage divider. Diodes 141 and 142 limit the possible output from the amplifier 130 to the voltage set by the resistor 143. This prevents a remote set point current higher than fifty milliamps calling for a speed higher than the normal maximum speed. The value of the resistor 143 is adjusted to achieve this limit. The diodes 144 and 145 form a high selector which prevents the output from falling below a desired level. This in-

sures that the remote set point control 86 cannot slow the turbine down below the normal minimum which is set by the resistor 146. If the remote speed control circuit 86 is utilized, the resistor 60 (FIG. 3) of the local set point control circuit 66 is not utilized and is omitted. The utilization of the remote set point control circuit 86 allows the speed of the turbine to be controlled remotely from the turbine but it is to be recognized that if this remote feature is not desired, speed control may be obtained by merely using the set point control circuit 66 located at the housing of the transducer 90.

Referring to FIGS. 8 and 10, the remote seed read-out circuit will be described. The remote speed read-out circuit 88 allows for a means of reading the voltage at the output of the amplifier 44 (FIGS. 3 and 5), which is representative of the speed of the turbine. This voltage is applied via the resistor 120 to an amplifier 122. The amplifier 122 forms a current amplifier having the gain set by the resistor 120. Adjustment of the resistor 120 allows calibration to any speed desired. Because the output of the amplifier 44 is controlled, any number of read-out indicators may be connected in series, thus giving a reading of the actual turbine speed.

It will be noted, in FIGS. 3 and 8, that several connection points 114 through 118 are provided. These connection points schematically depict the interconnection between the circuitry of FIG. 3 and the optional circuitry shown in FIG. 8. In the preferred embodiment of the invention, the circuitry of FIG. 8 is placed on a second platform 98 located within the housing of the current to air transducer 90. This platform may be physically above or below the first platform 96 described previously. However, if it is desired, components shown in FIG. 8 may also be applied to the platform 96 rather than introducing a second platform 98.

It will be recognized that the schematic diagrams shown in FIGS. 3 and 8 represent one illustrative embodiment of the invention. The various circuit elements are tabulated below as to value or type number. It will be recognized, however, that these values are exemplary and are merely illustrative of the invention, and various modifications may be made without departing from the spirit and the scope of the invention. All capacitor values are in micro-farads except as otherwise noted. All resistor values are in ohms except as otherwise noted.

ELEMENT NUMBER	VALUE OR TYPE NUMBER
32, 34	Motorola MPS-6515
82	2N1487
32, 33	1N457
106	1N4003
104	1N4744A
35, 67	1N939B
107	1N4736A
105	1N5352
36	5% silva mica selected for frequency
48	.01
51	.001
108, 111	100
109	22
47	.47
48	2.0
69, 74	5K
75	5.0M
44 and 70 combined	Motorola M1458L
38, 39	2.0K
37, 46	20K
40, 45, 47, 68	10K
49, 50	402K

-Continued

	ELEMENT NUMBER	VALUE OR TYPE NUMBER
5	110	806
	103	400
	76	100
	90	Fisher 546 10-50 Ma input 3-15 PSIG output
	122 and 130 combined	Motorola MC1458L
	131, 132, 141, 142,	1N457
10	144, 145, 147	
	148, 149	1N939B
	152, 140, 124, 153	49.9K
	139	100K
	155, 156	806K
	151, 126	5.11K
	150	10K
15	135	100
	120	50K
	137	20K
	136	500K
	133	2K
	134	5K
	146, 143	10K
20	154	.47
	125	.01

Obviously, many modifications and variations of the present invention are possible in light of the above teachings without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. An electronic speed governor for a turbine wherein the speed of the turbine is controllable by a pneumatically controlled valve, comprising:
 - digital signal generating means for producing an electrical signal which is a function of the rotational speed of said turbine;
 - means for converting said digital signal into a D. C. voltage velocity signal which is proportional to the speed of the turbine;
 - reference generating means for generating a preselectable reference voltage signal indicative of a desired speed of said turbine;
 - comparison means for comparing said velocity signal to said reference voltage signal and for generating an error signal indicative of the difference between said voltage velocity signal and said reference voltage signal;
 - control signal generating means responsive to said error signal for generating a control signal; and
 - a transducer means having a housing wherein said transducer means generates a pneumatic signal to said controlled valve in response to said control signal thereby controlling the speed of said turbine and wherein said converting means, said reference generating means, said comparison means, and said control signal means are located within said transducer housing whereby said air within said transducer housing prevents corrosion and reduces heating of said electronic elements.
2. The electronic speed governor of claim 1 wherein said control signal comprises a time integral function of said error signal.
3. The electronic speed governor of claim 1 wherein said control signal comprises a proportional function of said error signal.
4. The electronic speed governor of claim 1 wherein said control signal comprises a proportional function plus a time integral function of said error signal.
5. The electronic speed governor of claim 1 further comprising an indicator means, a portion of which is

located within said transducer housing, for providing an instantaneous readout of said turbine speed.

6. The electronic speed governor of claim 1 wherein said reference voltage signal generating means comprises a means for remotely selecting said reference voltage signal. 5

7. An improved electronic speed governor for a turbine wherein the speed of the turbine is controlled by the output from a pneumatic transducer and wherein said pneumatic transducer includes a hollow housing, the improvement comprising: 10

digital signal generating means associated with said turbine for producing an electrical signal which is a function of the rotational speed of said turbine;

a first platform means located within said transducer housing; 15

a means located on said first platform means for converting said digital signal into a D. C. voltage velocity signal which is proportional to the speed of the turbine; 20

reference generating means located on said first platform means for generating a preselectable reference voltage signal indicative of a desired speed of said turbine; 25

comparison means located on said first platform means for comparing said velocity signal to said

reference voltage signal and generating an error signal indicative of the difference between said voltage velocity signal and said reference voltage signal; and

control signal generating means located on said first platform means and responsive to said error signal for generating a control signal to said transducer means whereby said transducer means in response to said control signal generates a pneumatic signal which controls the speed of said turbine.

8. The improvement of claim 7 further comprising an indicator means for providing an instantaneous readout of said turbine speed.

9. The improvement of claim 7 wherein said reference generating means comprises a means for remotely selecting said reference voltage signal. 15

10. The improvement of claim 8 further comprising a second platform means located within said housing wherein a portion of said indicator means is located on said second platform means. 20

11. The improvement of claim 9 further comprising a second platform means located within said housing wherein a portion of said means for remotely selecting said reference velocity voltage is located on said second platform means. 25

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