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MEANS FOR AUGMENTING ENERGY IN AN AIR LINE

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FIG. 1

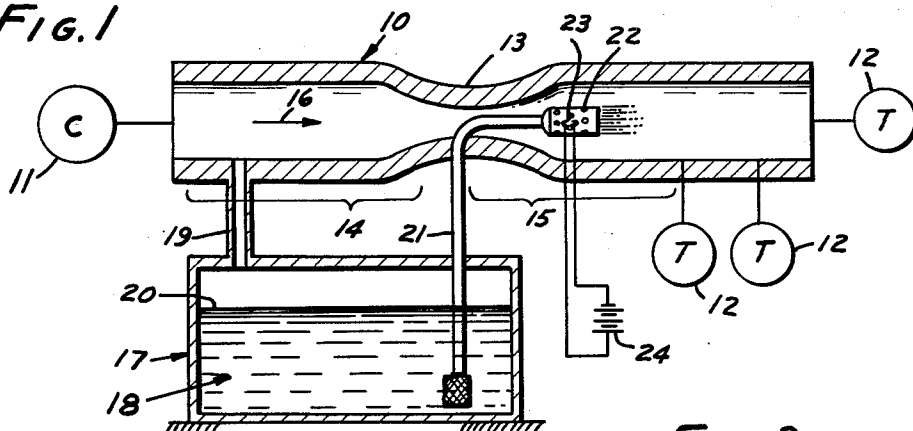


FIG. 2

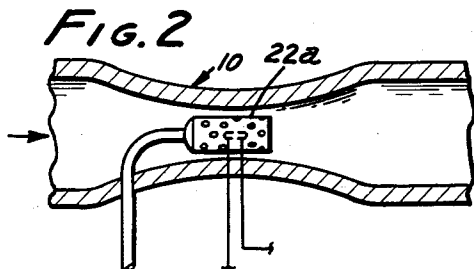


FIG. 3

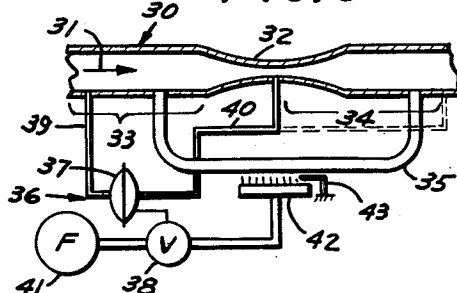


FIG. 4

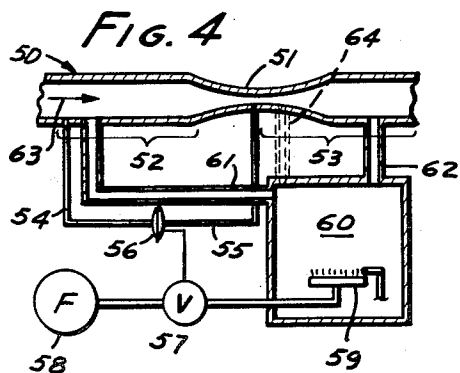


FIG. 5

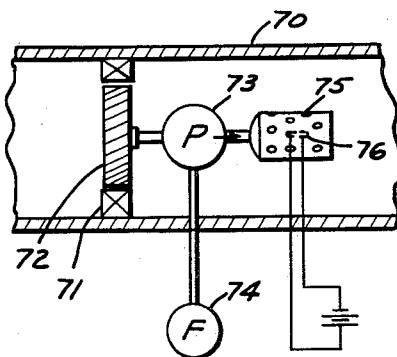
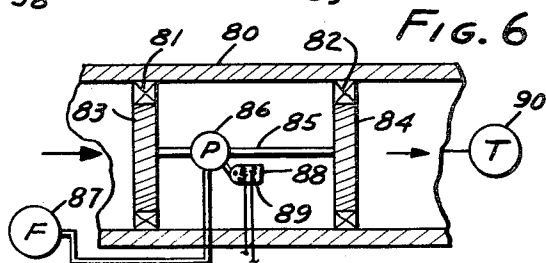


FIG. 6



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3,173,254 MEANS FOR AUGMENTING ENERGY IN AN AIR LINE

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This invention relates to devices for augmenting the energy in a compressed air line.

Particularly in the construction industry where large quantities of compressed air are used to operate tools such as jack hammers and the like, there is usually a central compressor which feeds the tools through long lines and manifolds. Considerable energy is lost in these lines and manifolds, so that, particularly on cold mornings, a normal plant installation may not be ample to supply needed power. Accordingly, larger compressor capacities are usually provided than would be necessary for less extensively distributed systems, or for systems insulated from the cold. Any compressed air-operated tool relies on the expansive properties of the compressed air, which inherently involves a refrigerating effect on the exhaust side. This refrigerating effect is even more pronounced when very cold compressed air is used, and sometimes chills the tools to the point of immobilization.

Adding energy to the air near the point of use, such as by heating the tool, is one solution at least to the problems created by cold. However, such an approach has proved to be impractical because of the weight added by the heater, and also because the tool has to be moved around and is often far from a central source of power for the heater. Attempts to directly heat the air in the air line have also proved impractical in the past, because a steady source of heat was usually provided for an air line in which the air flow rate varied as tools were started up and shut down in various numbers and combinations. Such a heating technique is good enough as long as all of the tools remain in operation, because then the temperature of the air remains within a reasonable working range. However, if all of the tools are shut down at once for any length of time, and the heating continues, the hose is apt to be melted down, or the air may be heated to such a high temperature that the tools are heated by it and become so hot that the operators cannot hold onto them.

Surprisingly great increases in tool efficiency are observable when even small temperature rises are provided. A rise from 30° F. to merely 50° F. provides a marked and noticeable increase in smoothness of tool operation and efficiency as to power consumption. Furthermore, increased efficiencies can be anticipated by augmenting the mass flow through the tool, as well as by raising the temperature.

It is an object of this invention to provide a means for augmenting the energy of the air in a compressed air line in such a manner that the air remains within a selected temperature range regardless of the rate of flow of air therein, thereby overcoming some of the defects in the prior art.

It is a preferred but optional object of this invention to augment them as flow in the air line by burning fuel therein, thereby also heating the air at the same time.

Apparatus according to this invention includes a fuel source, and a burner connected to the fuel source which is adapted to burn fuel supplied therefrom. Proportioning means, which are responsive to air flow in the line, render the flow of fluid to the burner substantially proportional to air flow in the line. The burner is so disposed and arranged that air in the line is heated by the burned fuel, and the caloric input to the air is thereby rendered proportional to the air flow through the line. When the

air flow is shut down, the supply of fuel to the burner is shut off, and any risk of burning up the lines or of overheating the tools is avoided.

According to a preferred but optional feature of the invention, the fuel is burned in the air line and the mass of the combustion products is thereby added to the compressed air, thereby further augmenting the energy in the air line.

According to still another preferred but optional feature of the invention, the proportioning means includes a venturi section in the air line which forms a differential pressure proportional to the air flow in the line, the differential pressure supplying control means for determining the rate of fuel flow, and thereby the caloric input.

According to still another preferred but optional feature of the invention, the proportioning means includes a motor driven by air in the line, said motor driving a pump which is disposed between the fuel source in the burner, the rate of fuel flow caused by the pump being proportional to the motor speed and thereby to the flow rate in the line.

According to still another preferred but optional feature of the invention, the proportioning means includes a venturi section having regions of relatively higher and lower pressure (when air flows therethrough) and in which the fuel source is a closed tank, the differential pressure developed in the venturi section being used as power to pump the fuel to the burner at a rate proportional to the differential pressure, and thereby to the air flow rate.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings in which:

FIG. 1 is a cross-section partly in schematic notation of the presently preferred embodiment of the invention;

FIG. 2 is a cross-section showing an alternate embodiment for a portion of FIG. 1; and

FIGS. 3-6 are cross-sections partly in schematic notation showing still other embodiments of the invention.

FIG. 1 shows the manifold 10 of an air line connected at one end to a compressor 11 and at the other end to a variety of tools 12 which may be jack hammers or the like. The manifold includes a venturi section 13 having (when air flows through it) a region 14 of relatively higher pressure and a region 15 of relatively lower pressure, related to air flow in the direction of arrow 16. It will be recognized that when all tools are shut off and there is no air flow, then pressure throughout the manifold will become the same, but that in the operation of this device, when one of the tools is in operation and flow occurs, then pressure in region 14 will be higher than in regions downstream, and that the difference is proportional to flow rate, although not necessarily linearly proportional. The properties of venturies are well known, and it will be recognized that the region of low pressure includes the section from the throat of the venturi downstream, all of which section is included in the term "region of relatively lower pressure."

A fuel source 17 comprising an enclosed tank containing fuel 18, which may be such as kerosene, fuel oil or the like, has a fluid connection 19 between that portion of the fuel source above the fuel level 20 and the region of higher pressure, while a second fluid conduit 21 connects the inside of the tank beneath the fluid level to the region of relatively lower pressure. Fluid conduit 21 leads to a burner 22, which may be a conventional blow torch arrangement for vaporizing the fuel, mixing it with air in the fuel line, and burning it. Combustion is initiated by a glow point 23 fired by battery 24 or some other voltage source.

In FIG. 2, manifold 10 is shown with a burner 22a disposed in the throat of the venturi section, instead of

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downstream, it being understood that the numerical value of the differential pressure for the same flow will be different from that which arises in FIG. 1, but that the relationship in the sense of the existence of a proportional differential pressure will be the same.

FIG. 3 shows still another embodiment of the invention, in which a manifold 30 is connected to a compressor and tools (not shown), and in which fluid flow occurs in the direction of arrow 31. The manifold includes a venturi section 32 having a region 33 of higher pressure and a region 34 of relatively lower pressure (when air flows) as in FIG. 1. A shunt conduit 35 interconnects regions 33 and 34. It bypasses a portion of the air around the venturi, the quantity bypassed being a function of flow rate.

A differential pressure valve control 36 includes a diaphragm control 37 effective to control the opening of a valve 38. Diaphragm control 37 moves valve 38 to its closed position when there is no differential pressure across it. As the differential pressure increases across the diaphragm control, valve 38 is increasingly opened. The diaphragm control is connected by fluid conduits 39, 40 to regions 33 and 34, respectively. Valve 38 is connected to a fuel source 41, and controls fuel flow to a burner 42, which burner has a pilot light 43 adjacent to it. The burner is adjacent to and in heat-transfer relationship with shunt conduit 35 so that it heats air bypassed therethrough. It will be recognized that instead of bypassing a portion of the flow, it is equally possible to directly heat the manifold, but ordinarily more heat needs to be supplied to the larger wall of the manifold than to a small bypass conduit, so that bypassing is more economical as to fuel consumption, and there is less "residual" heat in the pipe to superheat the air when flow stops. Therefore, a small shunt conduit is preferable.

FIG. 4 shows a variation of the scheme of FIG. 3, wherein a manifold 50 includes a venturi section 51 with regions 52 and 53 of relatively higher and lower pressures as in FIG. 1. Fluid conduits 54, 55 connect to opposite sides of a diaphragm control 56 identical to diaphragm control 37. The diaphragm control controls a valve 57 identical to valve 38. Valve 57 is connected to fuel source 58, and controls flow of fluid to burner 59, the same as valve 38 in FIG. 3. A combustion chamber 60 is connected by fluid conduits 61, 62 to regions 52 and 53, respectively, so that the combustion chamber and conduits 61 and 62 form a shunt conduit with the air line in which air tends to flow in the direction indicated by arrow 63. Dashed lines 64 illustrate an optional connection for fluid conduit 62.

The burner is placed inside the combustion chamber and operates at the same time as burner 42 in FIG. 3. However, instead of heating the air in the line through a heat transfer relationship, the products of combustion are directly discharged into the air line, which serves further to augment the energy in the air line. The arrangement of FIG. 3 will be used when products of combustion cannot be tolerated in the air line for some reason, such as incompatibility with materials of which the lines or tools are made.

FIG. 5 shows another technique for adding heat to an air line in proportion to the flow of air therethrough. A manifold 70 has a set of internal bearings 71 which support a turbine motor 72 inside the manifold. The turbine motor drives a pump 73, the pump serving to withdraw fuel from a fuel source 74 and pump it to a burner 75 identical to burner 22 in FIG. 1. This burner includes a glow point 76, the same as in FIG. 1. The turbine motor will, of course, turn at a rate proportional to the air flow, and the pump will therefore pump a proportional quantity of fuel.

FIG. 6 illustrates an improvement over the embodiment of FIG. 5. In this embodiment, a manifold 80 has two sets of bearings 81, 82 which journal a compressor wheel 83 and a turbine wheel 84. A shaft 85 is connected to

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them both and drives a pump 86, which pumps fuel from a fuel source 87 to a burner 88 identical to burner 22. It includes a glow point 89, as in FIG. 1. Tools 90 are driven by fluid from the manifold.

The operations of the various embodiments should be evident from the foregoing. In FIG. 1, when there is no flow, there is no differential pressure between conduits 19 and 21 and, therefore, no pressure for supplying fuel to the burner. When air begins to flow, there arises a differential pressure which pressurizes the top surface of the fuel and forces fuel through fluid conduit 21 to the burner in which it is burned. The higher the rate of air flow (within operating limits) through the venturi section, the greater the differential pressure, and the greater the resulting rate of flow of fuel. Therefore, the amount of fuel burned in the burner is directly proportional to the rate of flow of fuel so that a sensibly constant temperature is maintained in the air flowing through the air line. The differential pressure acts as a control means for fuel flow, as well as providing power for it. It will be recognized that the elevation of the fuel tank relative to the burner will need to be such that the differential pressure is sufficient to cause fuel flow at the desired conditions, but this is merely a matter of raising or lowering the fuel tank. FIG. 2 illustrates that the technique of FIG. 1, and that of any of the other schemes is attainable by placing the downstream elements anywhere at or downstream from the throat of the venturi so long as a differential pressure exists between that region and the upstream part of the venturi.

In FIG. 3, when there is no fuel flow, there is an equal pressure in conduits 39 and 40, and diaphragm control 37 shuts off valve 38. When air flow starts, a differential pressure arises which causes the diaphragm control to open valve 38 in an amount proportional to the differential pressure, and this amount of fuel is burned in the burner, the caloric input thereby being rendered substantially proportional to the air flow. The dashed lines in FIG. 3 illustrate that conduit 40 need not be connected at the throat, but instead may be placed at any downstream region which has a lower pressure than region 33.

The operation of the device of FIG. 4 is essentially the same as that of FIG. 3, with the exception that the products of combustion are added directly to the air in the air line. When there is no air flow through the manifold, then the pressures in fluid conduits 61 and 62 are equal and the diaphragm control closes valve 57. This shuts off fuel flow to burner 59. When flow begins through the manifold, there arises a differential pressure across the diaphragm control, and valve 57 opens proportionally to the magnitude of the differential pressure, thereby introducing to the burner for combustion there an amount of fuel sufficient to render the caloric input directly proportional to the air flow.

In FIG. 5, the turbine motor is run by air flow. When there is no flow to the tools, the turbine wheel will not turn and no fuel will be pumped to the burner. The greater the air flow, the faster the turbine motor will run, and the faster the fuel will be pumped from the fuel source to the burner, thereby rendering the caloric input substantially proportional to the air flow. It is evident that the motor need not be physically placed inside the manifold, but that, instead, it could be placed in a bypass conduit. Also the differential pressure could be utilized with a control, such as control 56, to regulate the speed of a motor pump combination, which could be powered by a bleed from the manifold.

In FIG. 6, the device is run both by air flow and by combustion of fuel. When the tools are all shut down, neither the turbine wheel nor the compressor wheel will turn, and no fuel will be pumped. When a tool is turned on, fluid will start to flow, and a differential pressure will arise across the two wheels, turning them. This starts the pump, and fuel is pumped to the burner. The burned fuel, in turn, spins the turbine wheel as well as the com-

pressor wheel. This action is limited by back pressure on the downstream side of the turbine wheel, because when all tools are turned off and the pressure is equalized across the two wheels, the only way for the turbine to be turned is by further compressing the air on the downstream side, but this requires new oxygen for combustion, and it does not exist. Therefore, combustion ceases and the wheels stop. A fuel cutoff valve can be provided to prevent oversupply of fuel at the cutoff condition. Thus, this device is flow sensitive, and the additional mass and caloric input is proportional to the air flow demanded by the tools.

It will be recognized that the particular valves actually used to proportionalize the fuel flow may be adjusted to meet the varying conditions of fuel source pressure and of the burner's efficiency in burning the fuel supplied thereto. Also, it may be formed unnecessary or undesirable to burn fuel at all for very low flow rates. The term "proportional" as used herein does not require strict linear, or continuous, proportionality, or even fuel flow at all air flow rates. It does require caloric supply sufficient to maintain the air temperature during flow condition within a suitable range. Therefore the term "proportional" relates to temperature maintenance at normal flow rates. In every embodiment shown herein, there are means whereby the caloric input is made reasonably proportional to the rate of flow. In some instances, banks of burners may be used, burners being individually turned on one by one so that one or more are burning in some range of flow rates. This, too, is within the meaning of "proportional." In the practice of this invention, temperatures are satisfactory if they are held in quite a wide range, so that proportionality need not be linear and in many cases may not be desired to be linear. For example, on very cold days when few tools are working, it may be desired to have a relatively higher rate of heating at relatively low speeds to make up for thermal losses in the manifold. However, in every case, the caloric input will increase with the rate of air flow through the manifold, and, when the products of combustion are also discharged into the manifold, the mass flow is similarly proportionally augmented.

For convenience herein, the term "manifold" has been used, because this is the most convenient location for placing such a device. However, it is to be understood that the manifold is merely one location in a compressed air line at which such a device might be placed, and that this is not a restriction on the invention.

This invention thereby provides a means for reliably and safely raising the temperature of compressed air to overcome the disadvantages of the refrigerating effect of the air, particularly on cold mornings, and does so with simple and reliable mechanisms which are able to stand rough usage in the field. It also provides means for increasing the efficiency of tools by augmenting their energy source near the point of use.

This invention is not to be limited by the embodiments shown in the drawings and described in the description which are given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. In combination: a compressed air-operated tool; a compressed air supply line to which the tool is connected; a fuel source; a burner connected to the fuel source and adapted to burn fuel supplied therefrom; and proportioning means responsive to air flow in the line for rendering the flow of fuel to the burner proportional to air flow in the line, the burner being so disposed and arranged that air in the line is heated by the burned fuel, the rate of air flow being determined by the tool demand, whereby energy in the air line is augmented by energy from the burned fuel in proportion to the tool demand.

2. A combination according to claim 1 in which the proportioning means comprises a venturi section in the

line which forms a differential pressure proportional to air flow in the line, the differential pressure acting as control means for determining the rate of fuel flow.

3. A combination according to claim 1 in which the proportioning means comprises a venturi section in the line which forms a differential pressure proportional to air flow in the line, and a valve which opens adjustably in response to said differential pressure, said valve being located between the fuel source and the burner, the fuel flowing through said valve.

4. A combination according to claim 1 in which the proportioning means comprises a venturi section in the line which forms a differential pressure and supplies a higher pressure and a relatively lower pressure, the differential between the pressures being proportional to air flow in the line, the fuel source being a closed tank and having a fuel level, there being a fluid connection between the high pressure portion of the venturi section and the inside of the fuel tank above the fuel level, and a fluid connection between the lower pressure section and the inside of the fuel tank below the fuel level, the elevation of the fuel level being such that the differential pressure is able to act to pump fuel to the burner at a rate proportional to said differential.

5. A combination according to claim 1 in which the proportioning means includes a motor driven by air in the line, said motor driving a pump which discharges fuel to be burned from the fuel source to the burner, the rate of fuel flow as pumped by the pump being proportional to the motor speed.

6. A combination according to claim 5 in which the motor is a turbine disposed directly in the line.

7. A combination according to claim 5 in which the motor includes a turbine and a compressor disposed directly in the line, the compressor and turbine being interconnected, with the turbine downstream, the burner being disposed between the turbine and compressor.

8. In combination, a compressed air-operated tool; a compressed air supply line to which the tool is connected; a fuel source; a burner disposed in the line and adapted to burn fuel therein which is supplied from the fuel source; and proportioning means responsive to air flow in the line for rendering the flow of fuel to the burner proportional to air flow in the line, the rate of air flow being determined by the tool demand, whereby energy in the air line is augmented by energy from the burned fuel in proportion to the tool demand.

9. A combination according to claim 8 in which the proportioning means comprises a venturi section in the line which forms a differential pressure proportional to air flow in the line, the differential pressure applying a control means for determining the rate of fuel flow.

10. A combination according to claim 8 in which the line includes a venturi section having a higher pressure region and a relatively lower pressure region, and a shunt conduit interconnecting these regions, the burner being disposed in said shunt conduit.

11. A combination according to claim 8 in which the proportioning means comprises a venturi section in the line which forms a differential pressure and supplies a higher pressure and a relatively lower pressure, the differential between the pressures being proportional to air flow in the line, the fuel source being a closed tank and having a fuel level, there being a fluid connection between the high pressure portion of the venturi section and the inside of the fuel tank above the fuel level, and a fluid connection between the lower pressure section and the inside of the fuel tank below the fuel level, the elevation of the fuel level being such that the differential pressure is able to act to pump fuel to the burner at a rate proportional to said differential.

12. A combination according to claim 8 in which the proportioning means comprises a motor driven by air in the line, said motor driving a pump which is disposed between the fuel source and the burner, the rate of fuel

flow as pumped by the pump being proportional to the motor speed.

13. A combination according to claim 8 in which the motor includes a turbine and a compressor disposed directly in the line, the compressor and turbine being interconnected, with the turbine downstream, the burner being disposed between the turbine and compressor.

14. In combination: a compressed air-operated tool; a compressed air supply line to which the tool is connected; a fuel source; a burner connected to the fuel source and adapted to burn fuel supplied therefrom, said burner being in heat-exchange relationship with the line for heating the air therein; and proportioning means responsive to air flow in the line for rendering the flow of fuel to the burner proportional to air flow in the line, the rate of air flow being determined by the tool demand, whereby energy in the air line is augmented by energy from the burned fuel in proportion to the tool demand.

15. A combination according to claim 14 in which the line includes a venturi section having a higher pressure

region and a relatively lower pressure region, and a shunt conduit interconnecting these regions, the burner being disposed in said shunt conduit.

16. A combination according to claim 14 in which the line includes a shunt conduit through which a portion of the air flows, and in which the proportioning means includes a venturi section in the line having a higher pressure region and a relatively lower pressure region a differential valve which is adjustably open in response to the differential pressure, said valve controlling supply of fuel to the burner.

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