

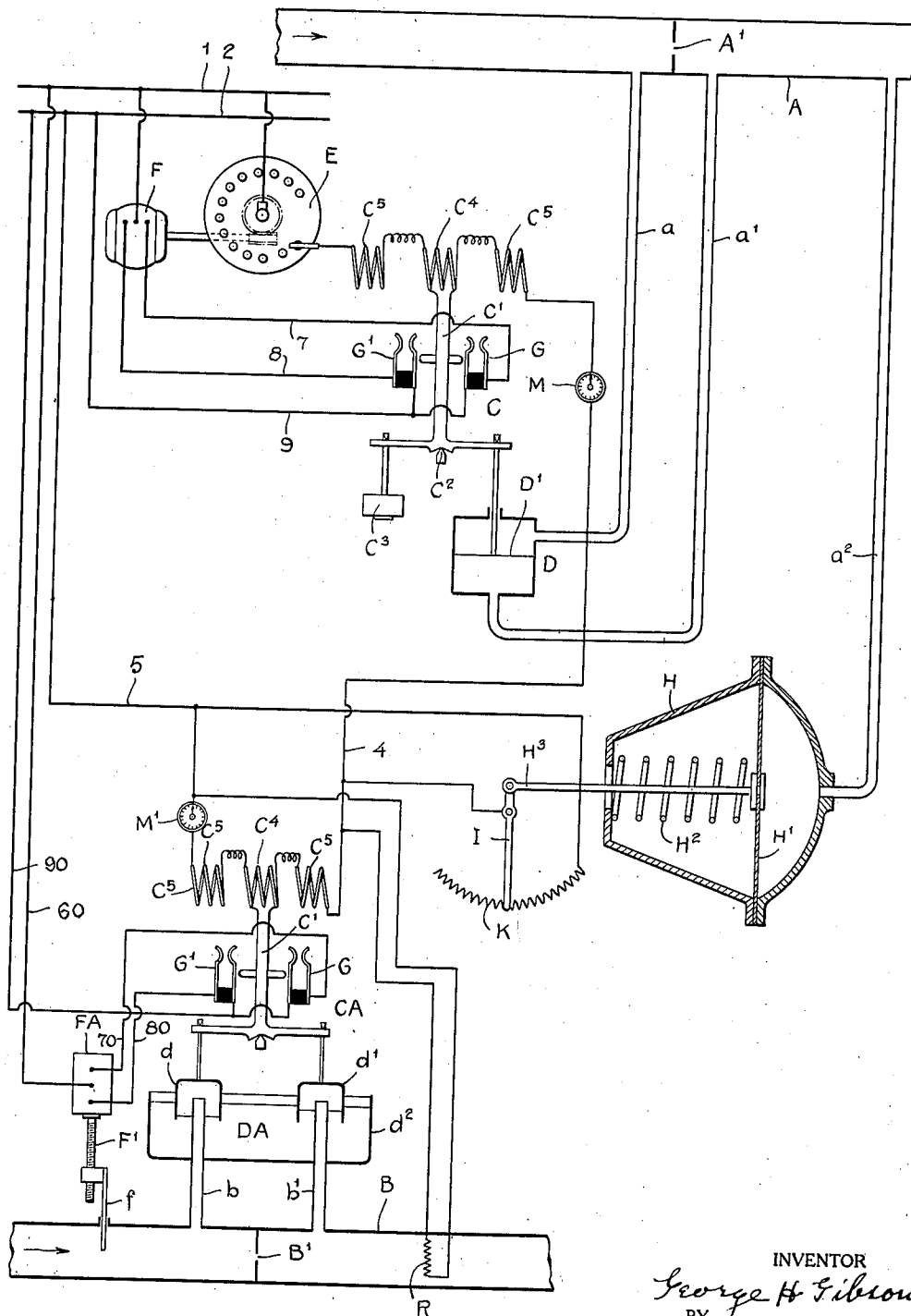
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FLOW CONTROLLING APPARATUS

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FLOW-CONTROLLING APPARATUS.

Original application filed June 3, 1920, Serial No. 349,303. Divided and this application filed August 10, 1923. Serial No. 656,765.

My present invention comprises improvements in apparatus for controlling fluid rates of flow, and was primarily devised, and is especially adapted for use in maintaining a predetermined ratio between the rate at which steam is withdrawn from a boiler and the rate at which air is supplied to the boiler furnace to support combustion therein.

The present invention consists essentially in improvements on apparatus heretofore devised by me, and the primary purpose of the present improvements is to provide for compensatory adjustments in response to such a variation in the physical condition of one of the flowing fluids as a change in the pressure of the steam or a change in the density of the air.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

The one figure of the drawing is a diagrammatic representation of apparatus for automatically measuring and maintaining a predetermined ratio between two fluid rates of flow. In the drawing, A represents a conduit through which one fluid flows, and B represents another conduit through which a second fluid flows, at a rate which depends upon the rate of flow through the conduit A. The conduit A may be the steam outlet pipe from a boiler, and the conduit B may supply air to the boiler furnace to support the combustion therein. Associated with the conduit A is an electromagnetic flow balance C, the purpose and effect of which is to maintain an electric control current proportional in strength to the rate of steam flow through conduit A. As shown, the balance C comprises a lever C', pivoted at C² and having three arms. One of these arms is horizontal and carries an adjustable counterweight C³. A second arm is vertical and carries an electric coil C⁴. The third arm is horizontal and opposed to the first mentioned arm and is connected to the

diaphragm D' of a differential pressure device D. The latter comprises a chamber divided into two compartments by the diaphragm D'. The diaphragm D' is subjected to a differential pressure which is a function of the rate of flow through the conduit A, and this differential tends to tilt the lever C' in the clock-wise direction, whereas the counterweight C³ tends to tilt the lever in the opposite direction. The means shown for impressing the desired differential pressure effect on the diaphragm D' comprises a restricted orifice A' in the conduit A, a pipe a, connecting the pipe A at the supply side of the orifice A' to the compartment of the device D above the diaphragm D', and a pipe a' connecting the pipe A at the discharge side of the orifice A' to the compartment of the device D below the diaphragm D'.

The coil C⁴ carried by the lever C' forms, in effect, the floating coil of a Kelvin balance, having two stationary coils C⁵. The coils C⁴ and C⁵ are connected in series, and an electric current is maintained there-through of the proper intensity to normally maintain the lever C' in its neutral position notwithstanding fluctuations in the differential pressure acting on the diaphragm D'. The means shown for this purpose comprise a source of electric energy as supply conductors 1 and 2 between which the coils C⁴ and C⁵ are connected in series with a rheostat E, and the coils C⁴ and C⁵ of a flow balance CA hereinafter referred to. The rheostat E is adjusted by a reversible electric motor F, having three terminals, one of which is connected to the supply conductor 1, while the other two are connected to switches G and G', respectively, by conductors 7 and 8 respectively. The switches G' and G² are also connected by a common conductor 9 to the supply conductor 2.

When the differential pressure on the diaphragm D' increases and the lever C' tilts in the clock-wise direction, it closes the normally open switch G and causes the motor F to turn in the direction required to adjust the rheostat E so as to decrease the resistance in series with the coils C⁴ and C⁵ of the balance C, and thereby increase the current through said coils and restore the lever to its neutral position in which the switches G and G' are both open. On a decrease in

the differential pressure acting on the diaphragm D' and a consequent tilting of the lever C' in the counter clock-wise direction, the switch G' is closed and the motor F then
 5 turns in the direction required to adjust the rheostat E so as to increase the resistance in series with the coils C⁴ and C⁵ of the balance C and thereby reduce the current
 10 through said coils and thus restore the balance lever C' to its neutral position.

The balance CA is similar in character to the balance C, and is acted upon by a differential pressure mechanism DA responsive to the rate of fluid flow through the conduit B. The differential pressure mechanism of
 15 the balance CA, as shown, comprises bells $\bar{d}$ and $\bar{d}'$, connected to the opposite horizontal arms of the lever C' of the balance CA. These bells dip into a sealing liquid in a receptacle $\bar{d}^2$ open at its top to the atmosphere.
 20 Pipes $\bar{b}$ and $\bar{b}'$ connected to the pipe B at opposite sides of the restricted orifice B' therein, open into the bells $\bar{d}$ and $\bar{d}'$ respectively, above the liquid level therein. As before stated, the coils C⁴ and C⁵ of the balances C and CA are connected in series, 4
 25 representing the conductor connecting the coils of the two balances, and 5 the conductor connecting the coils of the balance CA to the supply conductor 2. The balance CA, through switches G and G' controls a reversible motor FA just as the balance C controls the motor F as shown. One terminal
 30 of the motor FA is connected to the supply conductor 1, by a conductor 60, and the other two terminals of the motor FA are connected by conductors 70 and 80 to the switches G and G' respectively, of the balance CA, these switches G and G' being also connected
 35 to the supply conductor 2 by a conductor 90.

The motor FA operates a damper f controlling flow through the conduit B. As shown, the motor FA is provided with a threaded spindle F' in engagement with a
 45 nut carried by the damper, so that when the motor rotates in one direction the damper is adjusted in the closing direction, and when the motion of the motor is reversed, the damper is opened. The motor FA and
 50 the balance CA are arranged to cause the damper to close and throttle the flow through the conduit B when the lever C' of the balance CA tilts in the clock-wise direction, and on a reverse movement of the lever,
 55 the damper is opened thus increasing the flow through the conduit B.

The operation of the apparatus so far described tends to maintain a fluid rate of flow through conduit B, which is proportional to the fluid rate of flow through conduit A, in accordance with the invention disclosed and claimed by me in my co-pending application, Serial No. 121,547, filed Sept. 22, 1916, and patented May 5, 1925, Pat. No. 1,537,044.
 65 This mode of operation may be explained as

follows: The pressure differential acting on the diaphragm D' is approximately proportional to the square of the velocity of the flow through the conduit A, and this differential is balanced by the electromagnetic interaction of the coils C⁴ and C⁵, which interaction is proportional to the square of the strength of the electric current flowing through said coils. The current flowing through the coils C⁴ and C⁵ of the balance C is thus normally proportional to the rate of steam flow to the conduit A, and since the balance CA normally maintains a flow through the conduit B, proportional in strength to the electric current flowing through the coils of both balances, the flow through the conduit B is thus maintained proportional to the flow through conduit A.

The supply of air supporting combustion to the boiler furnace in constant proportion to the rate at which steam is withdrawn from the boiler, tends to maintain a constant steam pressure, but in practice it is ordinarily impossible to avoid some fluctuations in steam pressure and in accordance with the present invention I provide means for increasing and decreasing the air flow through the conduit B, relative to the steam flow through conduit A, as the steam pressure decreases and increases. For this purpose I connect a resistance K in a shunt about the windings C⁴ and C⁵ of the balance CA and adjust the amount of resistance K in this shunt, accordingly, as the static pressure in the conduit A falls below or rises above a predetermined value. To thus vary the amount of the resistance K in the shunt circuit, I employ a fluid pressure motor H having a diaphragm H' subjected at one side to the static pressure in the conduit A which is transmitted to the motor H by the pipe α^2 , and subjected at the other side to the opposing action of a spring H². The diaphragm H' has its stem H³ connected to a pivoted switch arm I. As the static pressure in the conduit A decreases, the arm I is adjusted to increase the amount of the resistance K in the shunt circuit. The effect of the shunt including the resistance K varied as above described, in response to variations in the static pressure in the conduit A, is to vary the ratio between the fluid rates of flow in the conduits A and B as the static pressure in the conduit A varies, so as to diminish or increase the supply of air to the boiler furnace as the steam pressure in the boiler rises above or falls below a predetermined normal pressure.

To automatically compensate for variations between the rate of flow through the conduit B and the resultant differential between the pressure transmitted to the balance CA which are produced by changes in air density resulting from changes in temperature of the air passing through the con-

duit B, a suitable resistance R is located in the conduit B, and is connected in shunt to the coils C⁴ and C⁵ of the balance CA.

The effect of a rise in temperature in the air passing through the conduit B, is to decrease the density of the air. A consequence of this density change is, that for a given differential of pressure impressed on the fluid pressure motor bell *d* and *d'*, the weight rate of flow will be decreased by a decrease in the air density. The shunt resistance R, if of such material that its electrical resistance will increase with the temperature of the air to which it is exposed, compensates more or less for the change of air density by diverting more of the balancing current away from the coils C⁴ and C⁵ of the balance CA when the air is relatively cool, than when it is relatively hot. By choosing for the resistance body R, a material the resistance of which changes with its temperature at the proper rate, and by properly proportioning this resistance with respect to the resistance of coils C⁴ and C⁵, the compensation thus obtained may be made almost mathematically exact for ordinary ranges of temperature variations. The principles by which the material for said resistance body R is chosen and this resistance is proportioned with respect to the coils C⁴ and C⁵ are fully explained in my co-pending application Serial #247,858, filed August 1, 1918, and patented Feb. 10, 1925, Pat. No. 1,525,807. It is sufficient to say herein that the desired result will be obtained in the present case, if the air density is expressed by the equation

$$d = \frac{C}{\sqrt{1+Bt}}$$

wherein *d* is the density at the temperature *t*, and C and B are constants, and if the resistance at any temperature *t*, of the resistance body R is expressed by the equation $R=R_0(1+Dt)$, wherein R represents the resistance at any temperature *t*, and R₀ and D are constants. With these assumptions, the desired compensation will be obtained when R₀ is small with respect to the resistance of coils C⁴ and C⁵, and B is twice as large as D. M and M' are ammeters showing the electric currents flowing through the coils of the balances C and CA respectively.

This application is a division of my application, Serial #349,303 filed June 3, 1920, and patented March 30, 1926, Pat. No. 1,578,279, in which I have illustrated an embodiment of the invention claimed herein, in which the flow balances employed and the manner in which they are connected differ specifically in form from the apparatus illustrated herein.

While in accordance with the statutes, I have illustrated and described the best form of embodiment of my invention now known

to me, it will be apparent to those skilled in the art that changes may be made, in addition to those specifically suggested above, without departing from the spirit of my invention as set forth, in the appended claims, and that certain features of my invention may be used to advantage in such cases without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In apparatus for maintaining a definite ratio between the strength of an electric current and a fluid rate of flow, the combination with a differential pressure motor actuated by the flowing fluid, of an electrodynamic motor actuated by said current and opposing the action of the first mentioned motor, and means responsive to a physical condition of the fluid flowing for modifying the said ratio.

2. In apparatus for maintaining a definite ratio between the strength of an electric current and a fluid rate of flow, the combination with a differential pressure motor actuated by the flowing fluid, of an electrodynamic motor actuated by said current and opposing the action of the first mentioned motor, and means responsive to a physical condition of the fluid flowing for modifying the force exerted by said electrodynamic motor.

3. In apparatus for maintaining a definite ratio between the strength of an electric current and a fluid rate of flow, the combination with a differential pressure motor actuated by the flowing fluid of an electrodynamic motor actuated by said current and opposing the action of the first mentioned motor, and means responsive to changes in a physical condition of the fluid flowing for diverting more or less of said current through a shunt about said electrodynamic motor.

4. Means for automatically proportioning the rate of flow of one fluid stream to another comprising in combination, a balancing device for each stream including a fluid pressure motor responsive to the rate of flow of the corresponding stream and an opposing electro-magnetic motor, means for connecting the two electro-magnetic motors in series in the same energizing circuit, means actuated by each balance for regulating the ratio between the rate of flow of the stream to which the balance pertains and the strength of the electric current passing through the electric motor of the balance, and means for compensating for a change in the density of the fluid flowing through one of said conduits, consequent upon changes in the fluid temperature comprising a shunt about one of said electro-magnetic motors including a resistance having a positive tem-

perature co-efficient and subjected to the temperature of said fluid.

5 5. Means for automatically proportioning the rate of flow of one fluid stream to another comprising in combination, a balancing device for each stream including a fluid pressure motor responsive to the rate of flow of the corresponding stream and an opposing electro-magnetic motor, means connect-
 10 ing the two electro-magnetic motors in series in the same energizing circuit, current regulating means actuated by one of said balances for adjusting the current in said circuit as required to maintain a predeter-
 15 mined ratio between the strength of said current and the rate of flow of the stream to which that balance pertains, means actuated by the second balance for varying the rate of flow of the stream to which the last
 20 mentioned balance pertains to thereby maintain a predetermined ratio between that rate of flow and the strength of said current, a shunt about the electro-magnetic motor of said second balance including a variable
 25 resistance and means responsive to the static pressure of the stream to which the said one balance pertains for adjusting said resistance.

30 6. Means for automatically proportioning the rate of flow of one fluid stream to another comprising in combination a balancing device for each stream including a fluid pressure stream and an opposing electro-

magnetic motor; means connecting the two electro-magnetic motors in series in the same
 35 energizing circuit, current regulating means actuated by one of said balances for adjusting the current in said circuit, as required to maintain a predetermined ratio between the
 40 strength of said current and the rate of flow of the stream to which that balance pertains, means actuated by the second balance for varying the rate of flow of the stream to which the last mentioned balance pertains to
 45 thereby maintain a predetermined ratio between that rate of flow and the strength of said current, a shunt about one of said electro-magnetic motors including a variable resistance and means responsive to the static
 50 pressure of one of said streams for adjusting said resistance.

7. In apparatus for maintaining a definite ratio between the strength of an electric current and a fluid rate of flow, the combination
 55 with a differential pressure motor actuated by the flowing fluid, of an electro-dynamic motor actuated by said current and opposing the action of the first mentioned motor, and means responsive to a physical condition of the fluid flowing for modifying the action
 60 of one of said motors upon the other.

Signed at Philadelphia in the county of Philadelphia and State of Pennsylvania this seventh day of August, A. D. 1923.

GEORGE H. GIBSON.