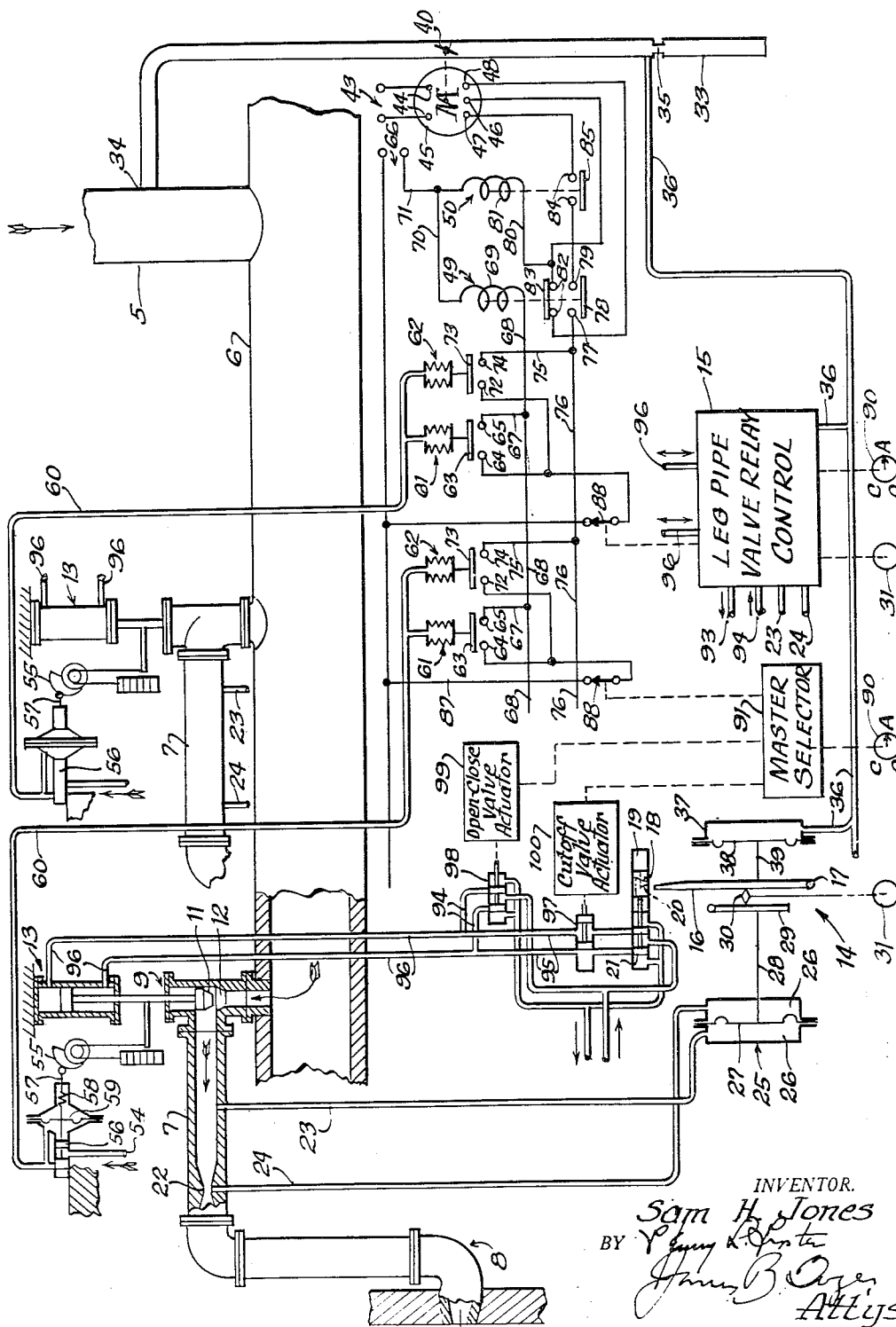


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BLAST FURNACE WIND DISTRIBUTION CONTROL

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BLAST FURNACE WIND DISTRIBUTION CONTROL
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The present invention relates to blast furnaces and particularly to control of the various flows of blast air to the different tuyeres.

It has become conventional practice to supply blast air at a constant volume rate that is calculated from various factors relating to the particular furnace and particular charge, and distribution of the blast air to the different tuyeres desirably is maintained in preselected ratios. Various causes tend to disturb these ratios and the primary object of the present invention is provision of a novel system that operates more effectively than do systems previously proposed for accomplishing the same general purpose. Such systems, for example, are disclosed by U. S. Patents No. 1,726,298 and No. 2,083,046.

The conventional practice of supplying blast air at a volume rate that is maintained constant in spite of variation in the resistance to air blast delivery, the so-called "burden" of the furnace, involves variation in the power expended in delivering the blast air. Obviously the individual valves of the different leg pipes that deliver the air to the different tuyeres present a power consumption-increasing source of resistance. To avoid introduction of unnecessary resistance, and resulting unnecessary power expenditure, it is desirable that all leg pipe valves be maintained as wide open as possible, while still maintaining the proper ratios between the volume rates of air delivery to the different tuyeres. In the event that the total demand of the leg pipe valves, as measured by the degrees to which all of them are opened, exceeds the constant volume rate at which the blast air is supplied, the required ratios among volume rates of delivery to the different tuyeres will not be maintained. This is simply because there is not sufficient air for all tuyeres and their rates of delivery then are determined independently of their valve settings by flow rate-affecting factors that are individual to the various leg pipes and tuyeres, such as relative distances between the hot blast main and the locations of connection of the different leg pipes to the bustle pipe, and the local furnace charge conditions at the delivery regions of the different tuyeres. Furthermore, while changes in the furnace burden, which depends on the condition of the charge as a whole and which may change considerably during progress of furnace operation, or a selected change in volume rate of total blast air delivery, tend to affect air flows to the different tuyeres in generally similar manner, they may upset the correct tuyere delivery ratios due to such individually differing factors as those mentioned above.

Another problem arising in blast furnace operation is that presented from time to time by partial blocking of tuyeres by the furnace charge. As set forth in Patent No. 2,083,046, this condition, once initiated, tends to intensify itself by cooling of the charge in the region of the blocked tuyere, but may be overcome by forcing air through the blocked tuyere at the normal or an increased rate. This forcing may require closing adjustment of the valves of the leg pipes supplying the other tuyeres to provide the bustle pipe pressure necessary to the forcing and prevent bypassing to unblocked tuyeres of air not accepted by the blocked tuyere, and its distribution among the former in accordance with the selected ratios for which their relays are set.

In a way that somewhat resembles that of the system disclosed by Patent No. 2,083,046, the system of the present

invention accomplishes these results by imposing on each leg pipe valve relay a master signal that serves as a standard for adjustment of the valve of that leg pipe in accordance with the condition of the tuyere of that leg pipe, and which master signal is varied in magnitude in response to the positions of all of the leg pipe valves to provide for an increase in bustle pipe pressure if a tuyere is so blocked as to require it. However, in the present system the master and leg pipe signals are developed by and control operation of novel apparatus functioning in accordance with a novel theory and a novel and markedly improved mode of operation.

In brief, the novel theory upon which the present invention is based is development of a master signal that represents both the volume rate of blast supply and the furnace burden, thereby simulating the volume flow rate through a leg pipe and tuyere that are in normal conditions, and serving as a very accurate standard to which the actual air flows through the different leg pipes are compared for development of corrective signals that adjust the leg pipe valves to effect correction of a faulty flow.

An essential feature of the invention is that the master signal is developed from the blast supply by metering the volume rate of flow of a discharge from the hot blast main or bustle pipe. The discharge path is so arranged that it presents flow resistance that varies with the furnace burden. By controlling the rate of the master signal developing discharge in response to the positions of the various leg pipe valves, the system acts to maintain all leg pipe valves as open as is consistent with maintenance of the proper flow ratios, and it also responds to blocked tuyeres to open the valves controlling them, close other valves sufficiently to maintain the required flow ratios and, if necessary, raise the bustle pipe pressure. An extremely important operation characteristic of the system is that in the event of a total demand of all leg pipe valves exceeding the constant volume rate of blast supply, an automatic closing adjustment of all leg pipe valves will occur, reducing the demand until it matches the pre-set volume rate of supply and the proper ratios are established.

In the specific form of the invention herein disclosed, the master signal is developed from a special pilot flow discharged direct to atmosphere from the bustle pipe or blast main, preferably the latter since it is not subject to localized pressure variation as the bustle pipe may be. The pilot flow is discharged through a bleeder line presenting resistance to flow that simulates the furnace burden, and that automatically is varied to maintain that simulation as the burden varies, and preferably in response to leg pipe valve positions to obtain the desirable operating characteristics set forth above.

An important novel feature of the present system is that, in accordance with the theory of the system outlined above, and regardless of the particular type of discharge flow selected for master signal development, the master and individual leg pipe signals respectively are of magnitudes having proportional relations to volume rates of air flow, and as hereinafter disclosed, conveniently may be developed by differential pressure type flowmeters.

Another important novel feature of the system, and one that is not confined to a system wherein the master and leg pipe signals are developed by flow metering, is the arrangement and resulting mode of operation of the section of the system that regulates the master signal magnitude in response to the settings of the leg pipe valves. The cycling variation of the master signal and resulting cycling opening and closing of leg pipe valves disclosed by Patent No. 2,083,046, which are resorted to for accomplishing forced draft clearing of blocked tuyeres, is avoided, and consequently in the instant system the

leg pipe valves are maintained constantly in as wide open conditions as permitted by the three controlling factors, total volume rate of blast delivery, furnace burden, and selected ratios of blast delivery to the different tuyeres.

The master signal automatically is so controlled as to provide the following scheme of leg pipe valve control. A range of positions within which the leg pipe valves are to operate under normal conditions is selected, the upper limit of which preferably is at or near the limit of opening of those valves, and which extends to a pre-selected degree of closing. A master signal is developed, which is combined at each leg pipe valve relay with a signal that represents flow rate through that leg pipe, to provide a resultant relay signal which is used to adjust the valve of that pipe to properly proportion the flow through it to the magnitude of the master signal. In a condition wherein all leg pipe valves are closed to degrees below the lower operating range limit, the master signal is so regulated as to constantly be varied in a sense to impose on each leg pipe valve relay a signal calling for continuing opening adjustment of the valve that it controls. Resulting opening adjustment of all of the valves continues until at least one of them has reached the lower limit of the operating range, at which time the variation of the master signal is stopped. In this condition at least one, and possibly more, of the pipe valves will have reached the lower limit of the operating range. After termination of the valve-opening variation of the master signal, any further opening of any valve is in response only to deficiency in the air flow through the leg pipe controlled by that valve. In the event that any one valve reaches the upper limit of the operating range, the master signal control automatically starts to vary the master signal in a sense to initiate closing operation of all leg pipe valves. However, in case of a severe air flow deficiency through the leg pipe controlled by the wide open valve, the opening leg pipe signal applied to the relay controlling that valve will override the closing master signal, and the valve of the starved leg pipe will remain open while all other valves are increasingly closed. As distinguished from the above-mentioned cyclical variation of the prior art, this valve-closing variation of the master signal is not continued until the lower limit of the operating range has been reached by all valves, but is terminated as soon as the valves have been sufficiently closed to eliminate the deficiency through the leg pipe controlled by the valve that started the closing operation, which is signalled by departure of that valve from the limit position. Furthermore, all valves but the starved one may be closed to greater degrees than the lower limit condition so long as that starved valve remains in the operating range.

Thus it will be seen that the operation characteristic of the system embraces a lower non-operating valve-position range, occupation of which by all valves serves to vary the master signal in a sense resulting in adjustment of all valves increasingly toward open and continuing until at least one of them is in the operating range, and a second, or operating range of valve positions occupation of which by any valve precludes variation of the master signal in the sense to cause further valve opening, but wherein any valve may be further opened in response to deficiency in flow rate through the leg pipe controlled by it and an upper open limit of the operating range, reaching of which by any other valve serves to readjust the master signal to the degree that is necessary to remove the valve from the limit position and place it at the upper limit of the operating range, in which condition it again becomes subject to readjustment by variation of the flow rate through the leg pipe that it controls.

The accompanying drawing is a schematic diagram of a portion of a system arranged according to the invention and showing schematically and in detail a relay and regulator system for controlling one leg pipe valve,

the portion of the system for developing the master signal, the motor switching relays that control the motor and valve for regulating the master signal magnitude, and two of the switching relay sections that operate the motor switching relays in response to the leg pipe valve positions. An important feature of novelty of the system is that the master signal is developed by discharging a bleeder pilot flow of air from the blast source through a resistance that simulates the furnace burden.

Describing the drawing in detail, a hot blast main is designated 5, is the supply source and is assumed to be supplied with hot blast air at a constant volume rate. Main 5 delivers to a bustle pipe 6, which in conventional fashion is assumed to encircle a blast furnace and with which plural leg pipes 7 are connected for supplying individual tuyeres such as that indicated at 8, and providing plural discharge paths from main 5 and bustle pipe 6. In the drawing only two leg pipes and one tuyere are shown, it being understood that as many as required for the furnace are connected to the bustle pipe 6. One of the leg pipes 7 is provided with a flow rate regulating valve assembly that is shown in section at 9, and the other with a similar valve assembly 10 shown in elevation, each such valve conveniently being a plug valve with a body 11, that is movable toward and away from closed relation to seat 12, and that is operated by a piston and cylinder assembly 13.

The cylinder and piston assemblies 13 are the power output units of first and second relay devices, generally designated 14 and 15; such as of the hydraulic jet pipe and auxiliary piston type shown at 14, comprising a jet pipe 16 that is pivoted for swinging about a fixed axis 17, and that is supplied with pressurized fluid, such as oil. The jet pipe discharges from an orifice in its tip a stream of this oil in the direction of an auxiliary piston 18 that is movable in a cylinder structure 19. At the side of the piston facing the jet pipe is a receiver structure provided with a pair of receiver ports 20 that are narrowly spaced in the direction of piston travel, which also is the direction of movement of the jet pipe orifice as the jet pipe swings about axis 17. The receiver ports 20 are cross-connected by passages through the auxiliary piston 18 with cylinder spaces at opposite ends of the piston, so that upon unbalance of pressure at the piston ends, caused by departure of the jet pipe from equal registration with the two ports 20, the piston will be moved by the pressure differential in the direction of displacement, that movement continuing until the ports 20 are again in equal registration with the jet pipe orifice. By this structural arrangement the piston 18 follows movement of the jet pipe. The piston 18 is connected to a control valve 21 of spool type that is movable in opposite directions from a neutral position respectively to connect the different ends of the cylinder of assembly 13 with a source of pressurized fluid and with exhaust in reversed senses respectively to open and close the connected valve body 11.

The jet pipe has exerted upon it a positioning signal force that is proportional to the flow rate of air through the leg pipe 7, the valve body 11 of which it controls through the piston and cylinder assembly 13. To this end each of the leg pipes is provided with a conventional type of volume flow rate measuring device, preferably of the differential pressure type including flow restrictive means and pressure signal pipes for detecting pressures in regions of different pressures developed by the flow restrictive means. Such an assembly is shown as comprising a venturi type flow restriction 22, having an upstream pressure signal pipe 23 tapped into it at a location spaced toward the leg pipe valve and bustle pipe from its point of maximum restriction, and a downstream signal pressure pipe 24 tapped into it at the narrowest part of its throat, these locations being regions of different pressures developed by the flow restriction. The pipes 23 and 24 are connected with inputs of a

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force balance device that opposes one to the other to develop a force signal of a magnitude proportional to their differential and that is also proportional to the volume rate of fluid flow through venturi 22, as is well known. The device in question is shown as a diaphragm assembly 25, having a pair of closed chambers 26 respectively connected with the different signal pipes 23, 24 and separated by a flexible diaphragm 27 to which a signal link 28 is connected. The force exerted through link 28 by diaphragm 27 is exerted on jet pipe 16 and tends to position it. The senses of signal application, that is of the pressures of the different regions of the venturi 22 to the diaphragm 27, and of application of their resultant force, are such as to tend to swing jet pipe 16 in directions to open and close valve body 11 respectively in response to decrease and increase of rate of air flow through the leg pipe.

It will be seen that the relay mechanism so far described and which is provided at each leg pipe for operating the valve body 11 of that pipe, constitutes a flow rate regulator, operation of which tends to maintain the volume rate of flow through that leg pipe constant by adjusting the valve body 11 to correct variation in that flow rate. Each of the relay assemblies is provided with a so-called "ratio regulator" by means of which setting of the relay for different volume rates may be accomplished. The ratio regulators of the different leg pipe relays afford means for selectively varying the ratios of volume rates of flow through the various leg pipes that are to be maintained by the system. Each such ratio regulator includes a lever 29 that is angularly positioned by movement of the motor output link 28 and a slider 30 that is movable, as by a handwheel 31, between and along lever 29 and jet pipe 16 to vary the point of application to the latter of the signal from diaphragm 27 transmitted by link 28 and lever 29, thereby to vary degree of response movements of the jet pipe to changes of force exerted by the diaphragm.

As has been suggested above, such factors as distance of a particular leg pipe connection with the bustle pipe from the delivery location of main 5 may affect delivery through that leg pipe, and this characteristic exists even though the leg pipe in question be provided with a constant flow regulator of the type just described. For example, the volume rate of air that is drawn off by other leg pipes may so reduce the air supply to the one in question that it will not receive the proper proportional flow regardless of the setting of its valve by the relay.

To obviate this difficulty, the relays such as 14 and 15 are provided with a common master or pilot signal additional to the signal developed by the venturi 22, which latter signal represents the flow rate through the individual pipe. This pilot signal, which is applied in common to the relays of all leg pipe valves, represents volume rate of a discharge from main 5. In the specific form shown it is developed by a pilot line 33 that has an inlet in communication with the hot blast main and bustle pipe, as by connection at 34 to the former, and that has structure presenting to air flow through that line a resistance that is preselected and preferably adjustable. Conveniently this pilot bleeder line 33 discharges to atmosphere which is assumed to exert substantially constant back pressure, and it is provided with flow restrictive means, which may be a control valve alone, but which preferably includes structure providing an orifice 35 for development of a differential pressure signal. The upstream pressure, which is transmitted by a signal pressure pipe 36 connected to line 33 at the upstream side of orifice 35 is opposed, at each of the individual leg pipe relays to the upstream pressure developed by the venturi 22 of each of the different leg pipes. Conveniently, this is accomplished by connection of signal line 36 with a second expansive chamber force device 37, also shown as of diaphragm type and with a flexible diaphragm 38. The pressures of the regions upstream and downstream of

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orifice 35, the latter of which is atmospheric in the arrangement shown, are exerted oppositely on diaphragm 38. Therefore device 37 actually is a flow rate measuring device of the same pressure differential type as device 25. The resultant force developed by diaphragm 38 is transmitted as a positioning signal to jet pipe 16 by a link 39. Senses of introduction of pressures to devices 25, 37, and of connection of the diaphragms 27, 38 to jet pipe 16 are such that the upstream and downstream pressures developed at the restrictions 22, 35 are opposed, so that the leg pipe and bleeder line flow rate signals are summarized by opposition. Thereby the volume rate of flow through the leg pipe is proportioned to the bleeder line flow rate, and varies in response to its variation, and all leg pipe flow rates, by being varied in proportion to the bleeder flow, are maintained in the ratios selected by setting of their respective ratio regulators 29.

In further consideration of this characteristic, the senses of application of the various signal pressures and their effects on the relay and the valves thereby operated may be considered. The upstream leg pipe pressure is applied to diaphragm 27 in a sense to swing the jet pipe 16 rightward or clockwise as seen in the drawing. This tends to operate the auxiliary piston and valve body 21 rightward, thereby to admit operating fluid to the upper end of the cylinder of assembly 13 and connect the lower end of that cylinder with exhaust, and thereby move valve body 11 downward toward closed position and tending to reduce flow rate through the leg pipe and the differential between the upstream and downstream pressures developed by venturi 22 and the former of which is opposed to the upstream pressure by diaphragm 27. The signal pressure delivered through pipe 36 tends to swing the jet pipe 16 leftward or counter-clockwise, as seen in Fig. 1. This tends to aid the downstream pressure delivered to diaphragm 27 by pipe 24, and atmospheric pressure exerted on diaphragm 38 aids and opposes the upstream and downstream pressures of venturi 22.

The above arrangements assure the proper distribution of air flows among the leg pipes so long as the total of the leg pipe valve demands are within the volume flow rate of blast supply through main 5.

Assurance of maintenance of the leg pipe valves in as nearly wide open condition as permitted by the blast supply, burden, and individual tuyere conditions, and assurance of a maintained flow rate to a partly blocked tuyere are provided as follows: Bleeder line 33 is provided with a valve 40 that is connected in series in line 33 with orifice 35, and upstream, toward main 5, from the orifice and the tap point of signal pipe 36. This valve 40 permits selection of a particular degree of resistance to air flow through the pilot bleeder line 33. It may be regarded as effectively being a resistance to flow that is parallel to the total furnace resistance, and its adjustment permits variation of the bleeder line resistance to simulate the resistance of a specific furnace condition or a particular furnace burden and effect of such resistance or burden on air flow to a normally operating tuyere. Adjustment of this valve 40 towards more open or more closed positions serves respectively to increase and decrease the magnitude of the signal delivered to all of the relay signal devices 37 through pipe 36, which in turn tends respectively to adjust all leg pipe valves toward open or closed positions. Setting of valve 40 to simulate a particular furnace burden, therefore, serves as a means of adjustment of all leg pipe valves to positions that are proper for that burden and affording a standard for regulation of each leg pipe flow.

The valve 40 is subjected to automatic adjustment operation to maintain it in correspondence with the furnace burden condition, to maintain the leg pipe valves as wide open as possible with maintenance of proper operation and to provide the proper relative adjustments of the leg pipe valves in case of blocking or impairment of air flow through any of them.

Electrical power for operating valve 40 is supplied from a source 43 to the energizing winding terminals 44 of a reversible electric motor 45 operatively connected with the valve. This motor has two reversing circuits, the individual closing of which respectively serve to run the motor in opposite directions, thereby operating to adjust valve 40 respectively toward open and closed conditions. The reversing circuits of motor 45 are provided with a common terminal 46 that may be connected to one of the other terminals 47 or 48 of the respective circuits to close that circuit. Opening of both circuits results in non-running condition of the motor.

Switching of the motor terminals is accomplished by means of two valve position-responsive relays 49, 50. The solenoids of these relays are so connected in an energization circuit controlled by the leg pipe valves that while all valves are in relatively closed conditions lying below the lower limit of the selected operating range, terminals 46, 48 are connected, through relay 49, to operate motor 45 in a direction to open valve 40. Opening of valve 40 increases the differential pressure between the upstream region of orifice 35 and atmosphere, increases the magnitude of force developed by relay regulator motor 37 and operates all of the leg pipe valve relays to effect opening adjustments of the valve bodies 11 of all leg pipe valves.

Further, relay 49 is so controlled that upon arrival of any valve body 11 at the degree of opening corresponding to the lower limit of the operating range, motor operation is terminated, and a circuit for operating the motor in the reverse direction is conditioned for closing by relay 50. Upon arrival of any one of the leg pipe valve bodies 11 at the preselected wide-open limit, relay 50 is actuated to energize the circuit that operates the motor in valve-closing direction. This may be accomplished by a wide variety of remote control systems, and is shown in a preferred form as including a variable pressure system for each leg pipe valve, which systems operate pressure responsive switch means that control relays 49, 50.

The variable pressure system of each leg pipe control assembly is supplied with operating fluid under pressure by a pipe 54. It will be seen that each leg pipe valve is connected with a cam 55 that is rotated in opposite directions in response to opening and closing movements of the valve assembly. This cam positions the valve 56 of a fluid pressure system through a link 57 and spring 58. A diaphragm 59 is connected with spring 58 and the expansible chamber of which it forms a wall is connected with a controlled pressure line 60 to exert upon 59 a force that opposes that of spring 58, thereby to maintain a proportional relation of the pressure in line 60 to the angular position of cam 55 and the position of valve body 11. The magnitude of pressure in line 60 controls low and high pressure-responsive switching relays 61, 62, which are connected as shown to control energization of the solenoids of relays 49, 50 in such relation to the switch wiring of the latter relays as to produce the scheme of motor operation described above. It may be assumed that the low pressure switch 61 responds to a pressure of forty pounds per square inch, corresponding to a selected low limit in the operating range of leg pipe valve positions, to move its contactor 63 into circuit-closing relationship with a pair of contacts 64, 65, the former of which is connected to one side of an electrical source 66 for the solenoids of relays 49, 50. When the pressure of line 60 drops below this limit, switch 63, 64, 65 is opened. Terminal 65 is connected by a line 67 with a line 68 that is a common valve position-controlled line connected with the pressure switch relays 61 of all of the leg pipe valve mechanisms, and it leads to one terminal of the solenoid winding 69 of relay 49. The other terminal of that solenoid is connected by lines 70, 71 with the second side of power supply 66.

The switch of the high pressure, or leg pipe valve opening limit switching relay 62, includes a contact 72 that is connected with the first side of supply 66 by the same wiring that so connects contact 64, a contactor 73 and a controlled contact 74 that is connected with power contact 72 when pressure in line 60 reaches the selected limit, say forty-five pounds. Contact 74 is connected by a line 75 with a second common control line 76 that also is connected with the high pressure switch of each of the leg pipe valve assemblies. This line 76 is connected to a contact 77 of relay 49. During de-energized condition of solenoid 69 contact 77 is disconnected, but upon energization of that solenoid it is connected by contactor 78 with a controlled contact 79. The latter is connected by a line 80 with one terminal of the solenoid 81 of relay 50, the second terminal of which is connected with the second side of power supply 66 by line 71. It will be seen that energization of the solenoid of relay 50 is dependent upon energization of solenoid 69 of relay 49.

Relay 49 includes a second switch assembly including a pair of contacts 82 which are connected together by a contactor 83 while solenoid 69 is de-energized and disconnected while it is energized. Closing of this latter switch serves to short-circuit the terminals 46, 48 of motor 45, thereby operating motor 45 in the direction to open valve 40. Relay 50 includes a similar switch having contacts 84 and a contactor 85 that connects them when the solenoid 81 is energized to interconnect motor terminals 46, 47 to run the motor in the direction to close valve 40.

The operation of the pressure and motor switching relays, and the resulting control of motor 45 and valve 40, upon blocking of any tuyere is as follows. Reduction of air flow through the leg pipe tends to equalize the magnitudes of the upstream and downstream pressures developed by venturi 22, reducing the differential across diaphragm 27 and permitting the force exerted by diaphragm 18 to override it. The resulting operation of relay 14 is to start opening valve 9. Assuming that the system has been operating normally, the low pressure switching relay of at least one leg pipe valve system will be closed, and in any event the one controlling the blocked tuyere is either already closed or will become closed as valve opening progresses. Therefore, solenoid 69 of relay 49 will be energized, conditioning the circuit of solenoid 81 of relay 50 for energization and insuring that the bleeder valve opening circuit 48, 82, 83, 82, 46 is open. Subsequent continuing opening of the leg pipe valve controlling the blocked tuyere to the limit position will result in closing of the high pressure switch 62, energizing solenoid 81 and closing the bleeder valve closing circuit 47, 84, 85, 84, 46 starting motor 45 in the direction to close valve 40. Closing valve 40 decreases volume rate of pilot flow through orifice 35, thereby decreasing the magnitude of differential pressure across it, and the resultant force exerted on diaphragm 38 of each of the relays controlling the unblocked tuyeres, and operating the relays to effect closing adjustment of the valves that they control. The master pressure signal reduction, however, will not affect the regulation of the relay controlling the blocked tuyere, since that pressure and the resultant force are aided by the downstream pressure exerted on diaphragm 27 through pipe 24, which in the blocked leg pipe is relatively large. The closing adjustment of the unblocked lines will continue so long as one line is sufficiently blocked to be maintained fully open since, so long as one low pressure switch 61 is closed the bleeder valve-opening circuit 48, 82, 83, 82, 46 remains open, and so long as one high pressure switch remains closed the bleeder valve-closing circuit 47, 84, 85, 84, 46 remains closed. As clearing of the blocked tuyere progresses air flow through it will increase, until the signal force balance is such as to begin closing adjustment of the leg pipe valve controlling it. At commencement of

this closing, the high pressure switch 62 will open, terminating energization of solenoid 50 and closing adjustment of valve 40. Thereafter, closing of the leg pipe valve of the previously blocked tuyere will continue until it reaches the degree of closing corresponding to the selected limit, at which time pressure switch 61 will open, de-energizing solenoid 69, and starting motor 45 in the direction to open valve 40. Thereafter the system will operate by variation of the master signal and operation of leg pipe relays until it is in normal condition.

In the event that supply through main 5 is insufficient to supply all of the leg pipe flows called for by the conditions in which their valves are set, pressure at 34 will decrease, with a consequent decrease in volume rate of discharge through line 33 and orifice 35. This will decrease the magnitude of the master signal component tending to maintain the leg pipe valves open, and consequently the leg pipe valves all will be adjusted to the more closed conditions called for by the actual blast supply and necessary to maintenance of the selected leg pipe flow ratios.

Opposite operation occurs in the event that blast supply exceeds the valve demand, which condition is reflected by an increase in master signal magnitude and results in opening adjustment of the leg pipe valves.

Actually, with the possible exception of some abnormal situation, conditions will not occur wherein the blast supply is deficient or in excess of the valve demand, since the system responds in the ways described immediately above to any trend toward them rather than delaying response until they actually exist.

It will be noted that in line 87 that connects terminals 64 of the pressure-responsive switching relay 61 and terminal 72 of relay 62 is connected a make and break switch 88. Opening of this switch in the relay circuit of any leg pipe valve control system disables that entire circuit from control of motor 45, thereby making operation of the motor by that leg pipe valve impossible regardless of its position and the resulting magnitude of pressure in its signal line 60, but at the same time not disabling control by the circuits of the other leg pipe systems.

Such disabling is made necessary by provision of each of the individual leg pipe control assemblies with a manually actuated control by means of which the simple adjustment of a control member between three positions can effect either automatic positioning regulation of the leg pipe valve by operation of the system as described above, or its adjustment to a fully open or fully closed position. This is permitted by auxiliary relay mechanisms that operate in response to positioning of the manual control members.

A control assembly is shown by means of which selection can be made between this manual open-closed operation or automatic regulation. Full disclosure of the mechanical and structural details of a suitable arrangement is made by U. S. Patent No. 2,635,584, dated April 21, 1953. In brief, the arrangement includes a control member such as hand wheel 90, rotation of which among three positions selects between automatic control of the leg pipe valve or its opening or its closing. In the system in question hand wheel 90 constitutes the actuating element of a master relay control 91. The system includes two channels, which respectively include pairs of controlled lines 94, 94 and 95, 95. The master relay control is so arranged that it selects the one or the other of the two channels that is effective to control the sense of selective connection of the cylinder lines 96 with supply line 92 and exhaust line 93, thereby to select the ends of cylinder 13 that are connected with supply and exhaust.

To accomplish this result the one of the channels that includes the lines 95 is the automatic control channel that is operated by the jet pipe 16, and valve 21 accomplishes the selective senses of connection of lines 95, 95, and the cylinder lines 96, 96 with supply and exhaust in response to the position of the jet pipe 16. This channel includes

a cutoff valve 97 that is selectively positionable either to block or unblock both lines 95.

The other channel includes a blocking and control valve 98 that is movable from a neutral position wherein it blocks both control lines 94, in opposite directions respectively to connect lines 94 with supply line 92 and exhaust line 93 in reversed senses. The movable body of valve 98 is connected to an actuator 99 that is controlled by the master relay control to position valve 98 in its neutral position while control wheel 90 is in a position corresponding to automatic operation and to move the valve body in one direction or the other upon movement of the wheel 90 to a position corresponding to opening or closing operation of the leg pipe valve.

An actuator 100 is provided for the cutoff valve 97 of the other channel and this is controlled by master relay control 91 in such fashion that the cutoff valve blocks lines 95 while the hand wheel 90 is in the position calling for opening operation or that calling for closing operation of the leg pipe valve and valve 98 is appropriately positioned to accomplish that operation. While the wheel 90 is in the position corresponding to automatic operation, master relay control 91 operates actuator 100 to move valve 97 to unblock lines 95, and actuator 99 positions valve 98 to block both lines 94.

Switch 88 is so actuated by hand wheel 90 that it is closed while the wheel occupies the position corresponding to automatic valve control and is open to disable the leg pipe valve position-responsive pressure switch relay control of bleeder valve 40 while hand wheel 90 is in positions calling for either opening or closing of the leg pipe valve.

From the foregoing, the principles and modes of operation that characterize the invention will be apparent, and it is to be understood that many changes in the details of arrangement of the system and its elements herein disclosed may be resorted to within the scope of the invention as defined by the appended claims.

I claim:

1. Control means for a blast furnace wind distribution system which system includes plural leg pipes for respectively supplying blast air to different tuyeres and each provided with a valve having a body that is adjustable in position to vary an internal pressure condition of that leg pipe, an individual relay for adjusting the position of each said valve body, individual means connected with each said leg pipe for developing a leg pipe signal of magnitude corresponding to volume rate of air flow through that leg pipe, means for developing a master signal and individual regulator means for each said relay comprising a device for comparing magnitudes of the leg pipe signal of that leg pipe and said master signal and adjusting the leg pipe valve body of that leg pipe upon departure of said signal magnitudes from a preselected ratio to restore that ratio by adjusting that valve body to vary said pressure condition; said control means comprising a system for controlling the magnitude of said master signal, and operating, while all of said leg pipe valves are more closed than to a preselected limit degree, to vary said master signal in the sense tending to operate said individual relays to adjust said valves toward more open conditions, operating when any of said valves is opened to a preselected limit condition of opening to vary said master signal in the opposite sense, and operating to maintain said master signal magnitude constant while all said valves are more closed than said limit condition of opening and at least one of them is more open than said limit degree, said system comprising means for varying the magnitude of said master signal and including a control member that is movable in opposite first and second directions respectively to vary magnitude of said master signal in the senses respectively tending to open and close said valves by operation of said individual relays, plural signal devices respectively connected with the different said valve bodies and operable by movements of the latter to vary

magnitudes of valve position signals that they respectively develop in correspondence to movements of said valve bodies, a first relay control device connected with all of said signal devices and operating, in response to magnitudes of the signals that they develop while more closed than said preselected limit degree, to move said member in said first direction and to terminate that movement when magnitude of any said valve body position signal corresponds to said limit degree, and a second relay control device connected with all of said signal devices and operating, in response to magnitude of any of said valve body position signals, corresponding to said limit condition of opening, to move said control member in the second said direction.

2. Control means according to claim 1, including an electric motor operable in opposite directions respectively to move said control member in opposite directions, and a pair of circuits connected with said motor and each effective while closed to run it in a different direction, and wherein said relay means includes a pair of solenoids, two switches operated by a first of said solenoids and one of which is opened and the other closed in reversed senses respectively by energization and de-energization of said first solenoid and one of which is connected in the one of said motor circuits that moves said control in the direction that is effective to operate said leg pipe valve relays to open those valves, an energization circuit for the second said solenoid including the second said switch, a third switch operated by the second of said solenoids and connected in the second said motor circuit, an energization circuit for said first solenoid including a fourth switch, relay means responsive to the positions of all said leg pipe valves and including an output member maintained in one position while all said valves are more closed than said limit degree and in another position while any one of them is more open than said degree, said output member being connected with said fourth switch for operating it by movement between said positions to energize and de-energize said first solenoid in a first sense to maintain said first switch closed and said second switch open while all said valves are more open than said limit degree and in a second sense to open said first switch and close said second switch while at least one leg pipe valve is more open than said limit degree, a fifth switch connected in said second solenoid energization circuit in series with said second switch, and relay means responsive to the positions of all said leg pipe valves for maintaining said fifth switch open while all of the leg pipes are more closed than a preselected limit open condition more open than said limit degree and to close and open said fifth switch respectively when any leg pipe valve is opened to or closed from said limit condition.

3. Control means for a blast furnace wind distribution system which system includes plural leg pipes for respectively supplying different tuyeres and each connected with a common source of blast supply and provided with a valve that is adjustable to vary the rate of flow through that leg pipe, and an individual relay for adjusting each said valve; said control means comprising an individual device for measuring the rate of air flow through each of the different leg pipes and developing a signal having a magnitude that is proportional to volume rate of that flow, a pilot bleeder line for discharging a pilot flow from said source, a device for measuring the volume rate of said pilot flow and developing a master signal having a magnitude that is proportional to it, individual regulator means for each said relay including a device for comparing magnitude of the leg pipe signal of the leg pipe controlled by that relay with that of said master signal and arranged to operate the valve of that leg pipe to maintain a preselected proportional relation between the volume rate of air flow therethrough and the magnitude of the master signal, a valve connected in said pilot bleeder line and that is adjustable to vary the volume rate of said pilot

flow, and means responsive to the rates of air flow through said leg pipes for automatically adjusting said pilot bleeder line valve to adjust magnitude of said master signal in response to departure of said flow rates from a preselected normal operating range.

4. Control means according to claim 3, wherein each of said flow rate measuring and signal devices comprises structure providing a flow-restrictive orifice in the path of the flow of which it measures the volume flow rate, a pair of signal pressure pipes communicating respectively with regions of different pressures, and means connected with said pipes and arranged to oppose forces of magnitudes proportional to those pressures to develop said signal as a resultant of said forces.

5. A system for maintaining selected ratios of volume rates of flow of blast air to multiple tuyeres of a blast furnace through plural leg pipes individually supplying the different tuyeres from a common blast main and each of which leg pipes has a valve that is adjustable to vary rate of air flow through it and a relay arranged for adjusting that valve to more open and closed conditions respectively in response to decrease and increase in that flow rate; said system comprising a bleeder line in communication with said blast main for discharging a pilot flow of air, means for measuring the volume flow rate of said pilot flow, developing a master signal of magnitude proportional to that rate and applying said signal to all of said leg pipe valve-controlling relays in a sense to adjust said leg pipe valves toward more open and closed conditions respectively in response to preselected opposite senses of variation of said pilot flow and master signal, a bleeder valve in said bleeder line that is adjustable to vary said pilot flow volume rate and said master signal and relay mechanism for adjusting said bleeder valve including first means responsive to the positions of all said leg pipe valves and that is effective only while all of them are more nearly closed than a partly closed condition preselected as an operating range limit, to adjust the bleeder valve and the pilot flow in senses to adjust all of the leg pipe valves toward more open conditions, second means responsive to the positions of all of said leg pipe valves and that is effective upon opening of any one of them to said preselected limit condition to terminate adjustment of said bleeder valve, and third means responsive to the positions of all said leg pipe valves and that is effective only while one of them is in a preselected second limit condition that is more nearly open than the first said limit condition to adjust said bleeder valve and pilot flow in senses to effect closing adjustment of all said leg pipe valves.

6. A system for maintaining selected ratios of volume rate of flow of blast air to multiple tuyeres of a blast furnace through plural leg pipes individually supplying the tuyeres from a common blast main and each of which leg pipes has a valve that is adjustable to vary rate of air flow through it and a relay arranged for adjusting that valve to more open and closed conditions respectively in response to decrease and increase in that flow rate; said system comprising a bleeder line in communication with said blast main for discharging a pilot flow of air, means for measuring the volume flow rate of said pilot flow, developing a master signal proportional to that rate and applying said signal to all of said leg pipe valve-controlling relays in a sense to adjust said leg pipe valves toward more open and closed conditions respectively in response to preselected opposite senses of variation of said pilot flow and master signal, a bleeder valve in said bleeder line that is adjustable to vary said pilot flow volume rate and said master signal, an electric motor operatively connected with said bleeder valve for adjusting it toward more open and more closed positions respectively by running in opposite directions and a pair of motor circuits respectively closable for operating the motor in opposite directions and maintaining said motor stopped while both are open, a first motor-control relay

having motive means having a movable output member and actuable in response to all said leg pipe valves to move that member to a first position when all said leg pipe valves are closed to positions corresponding to a preselected degree and to a second position when one of said leg pipe valves is open to that degree, a first motor switch connected in the one of said motor circuits that is closable to operate the motor in the direction to adjust said leg pipe valve and vary said master signal in senses to open said leg pipe valves, and said motor switch being connected with said output member for being closed and opened respectively as it is moved to its first and second positions, and a relay switch connected with said output member and that is opened and closed respectively as said output member is moved to its first and second positions, a second relay having a solenoid and a second motor switch that is connected in the second said motor circuit and that is closed and opened respectively in response to energization and deenergization of said solenoid, a third relay having motive means provided with a movable output element and responsive to the positions of all of said leg pipe valves for maintaining said element in a first position while all of said leg pipe valves are more closed than a preselected limit condition more widely open than said preselected degree and to move said element to a second position when any leg pipe valve is opened to said limit condition, a second relay switch operable by said output element and opened and closed respectively in the first and second positions thereof, and a circuit for energizing said solenoid and including said first and second switches in series connection.

7. The system of claim 6, wherein each of said leg pipe valve-adjusting relays includes a power unit having an output member connected with the leg pipe valve and oppositely movable to position it, and regulator means responsive to said leg pipe volume rate and master signal magnitudes and connected with said power unit for operating it to position its said output unit according to said magnitudes, and said system includes a manual control for each said leg pipe valve relay, including auxiliary relay means for disabling said regulator means from control of said power unit, auxiliary relay means for actuating said power unit to adjust the leg pipe connected with its output member in a selected direction, auxiliary relay means for disabling said relay circuit and comprising a third relay switch that is series connected therein, and a common manually operable control that is movable between two positions wherein respectively it renders all of said auxiliary means effective and ineffective.

8. A system for maintaining selected ratios of volume rates of flows of blast air to multiple tuyeres of a blast furnace through plural leg pipes individually supplying the different tuyeres from a common blast main and each of which leg pipes has a valve that is adjustable to vary rate of air flow through it, a reversible relay power unit connected with said valve for adjusting it, and a relay regulator having a control element movable in opposite directions and to various positions and arranged to operate said power unit to adjust said valve to a position corresponding to its own position; said system being provided with individual relay regulator means for each said leg pipe valve, comprising first and second differential pressure expansible chamber force balancing devices each having a movable output element connected with said regulator control element and each arranged to exert thereon a force that is proportional to the magnitude of difference between two pressures, a flow rate measuring device in each said leg pipe comprising structure providing a flow-restrictive orifice in said pipe and means for exerting on the movable output element of said first device a force proportional to the difference between regions of different pressures developed by air flow through that restriction, and in a sense to move said control element to effect opening of said leg pipe valve,

and said system also including a bleeder line in communication with said main for discharging a pilot flow of air, means for measuring the volume rate of said pilot flow comprising structure providing a flow-restrictive orifice in said bleeder line, means for exerting on the output element of said second device of each said leg pipe relay regulator a force that is proportional to differential in pressures developed by said bleeder line flow-restrictive orifice, and that is exerted on the regulator control elements of the respective relay regulators in senses to move them to effect opening and closing adjustment of all of the leg pipe valves respectively in response to increase and decrease in the volume rate of pilot flow, a bleeder valve in said bleeder line and adjustable to vary said pilot flow rate, and bleeder valve-controlling relay means responsive to the positions of all said leg pipe valve-controlling relays, and arranged to respond to their positioning of all said leg pipe valves in conditions more closed than a preselected condition to continually adjust said bleeder valve in a direction to increase said pilot flow, to respond to opening of any leg pipe valve to said condition to terminate said bleeder valve opening adjustment, and to respond to adjustment of any leg pipe valve to a preselected degree more open than said preselected condition to adjust said bleeder valve toward closed condition only while the latter said leg pipe valve is open to said preselected degree.

9. Control means for a blast furnace wind distribution system, said system comprising a blast supply main and piping structure that provides plural paths of discharge of blast air delivered through said main and including plural leg pipes for respectively supplying blast air to different tuyeres each provided with a valve that is adjustable to vary volume rate of air flow therethrough, and individual relays respectively operable to adjust the different said valves; said control means comprising individual flow metering devices each responsive to the volume rate of flow through a different one of said leg pipes to develop a leg pipe signal of magnitude that is proportional to that rate, an additional flow metering device responsive to volume rate of air flow through a selected one of said paths of discharge to develop a master signal having a magnitude proportional to volume rate of air flow through that path, individual regulators for controlling operation of the different said relays, including means, responsive to both the magnitude of said master signal and magnitude of the leg pipe signal developed from air flow through the leg pipe of which the valve is adjusted by the relay controlled by that regulator, to develop upon departure of the rate of the latter flow from a preselected proportional relation to said master signal magnitude an error signal of sense corresponding to sense of that departure, and each said relay being responsive to sense of error signal developed by its regulator to adjust the leg pipe valve in a sense to restore said proportional relation, and said control means also including means responsive to the positions of said leg pipe valves for varying the magnitude of said master signal, operating, only while all of said valves are closed to a degree greater than a preselected limit, continuously to vary said master signal in the sense to effect leg pipe valve-opening operation of said relays, and operating, only while one of said valves is opened to a preselected limit condition more open than said limit degree, to effect leg pipe valve-closing operation of said relays.

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