June 19, 1962 M. K. DREWRY 3,039,745

AIR HEATER

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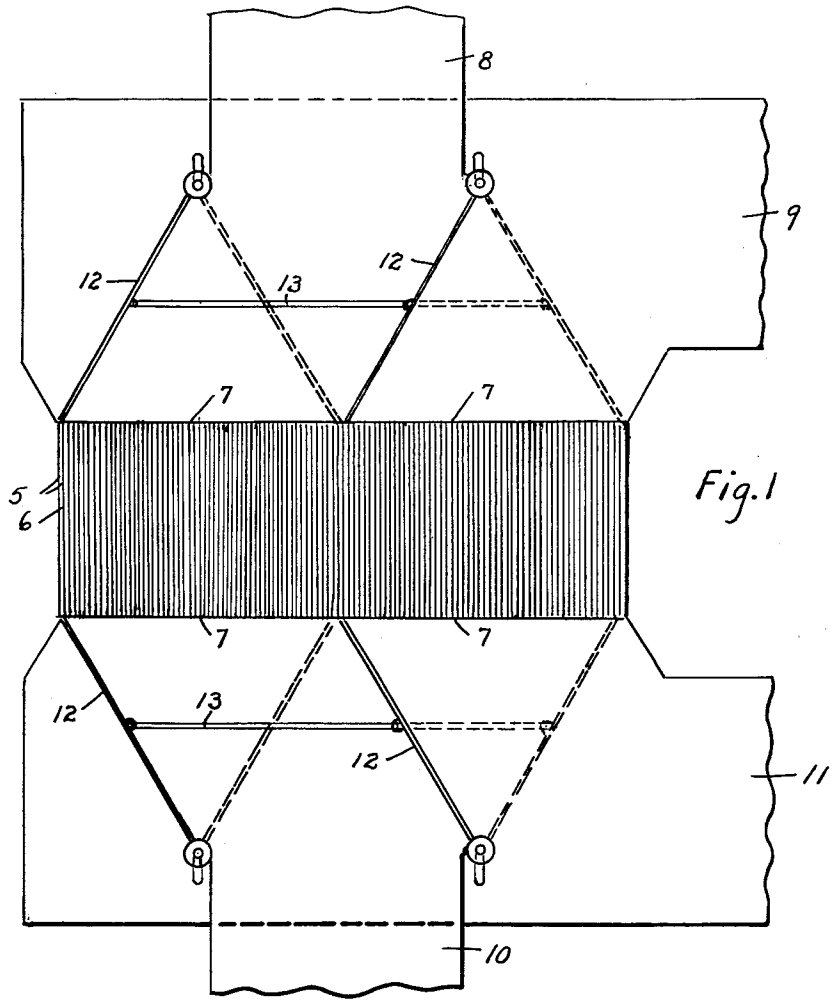
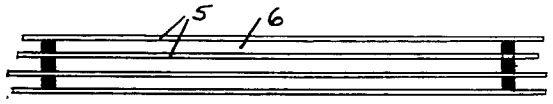


Fig. 1

Fig. 2



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AIR HEATER

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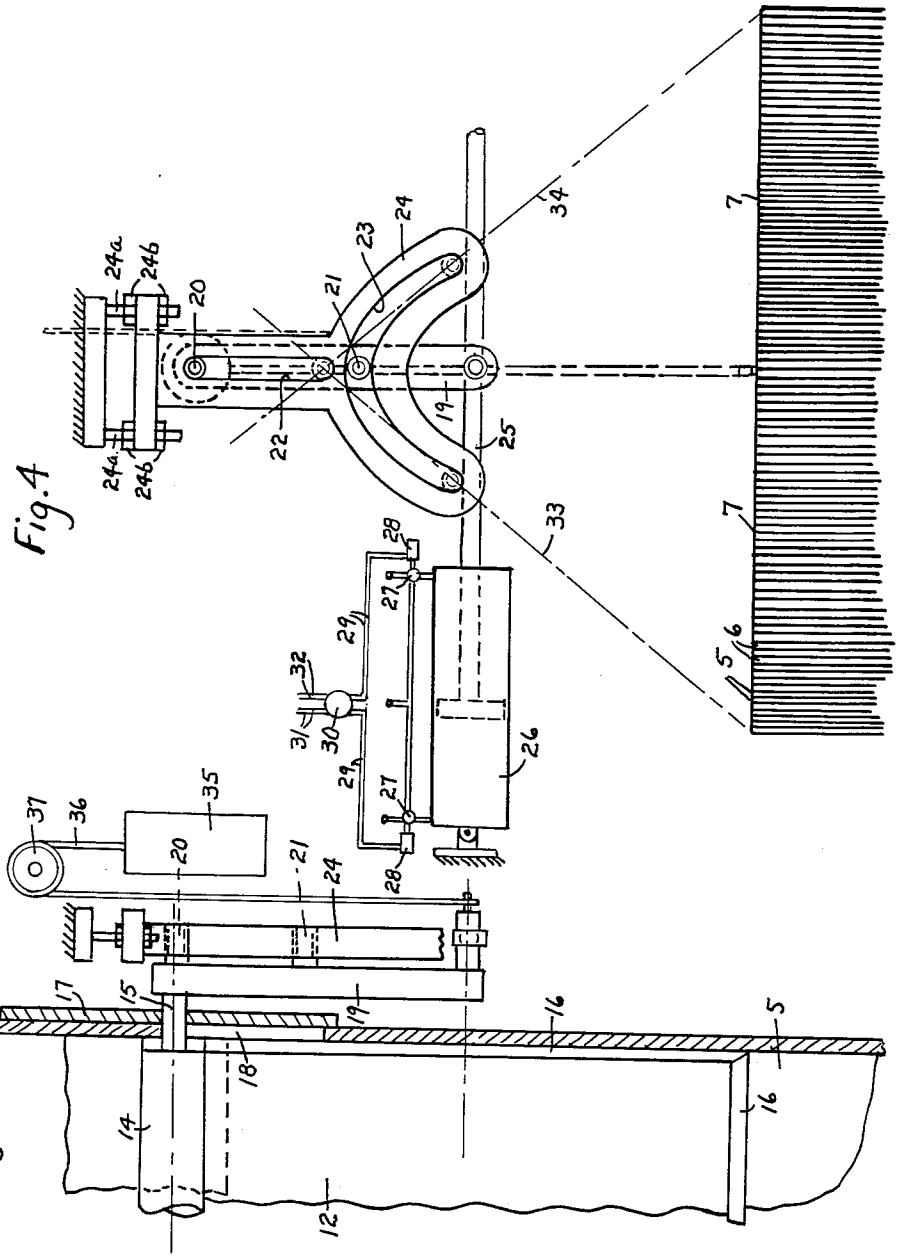


Fig. 4

Fig. 3

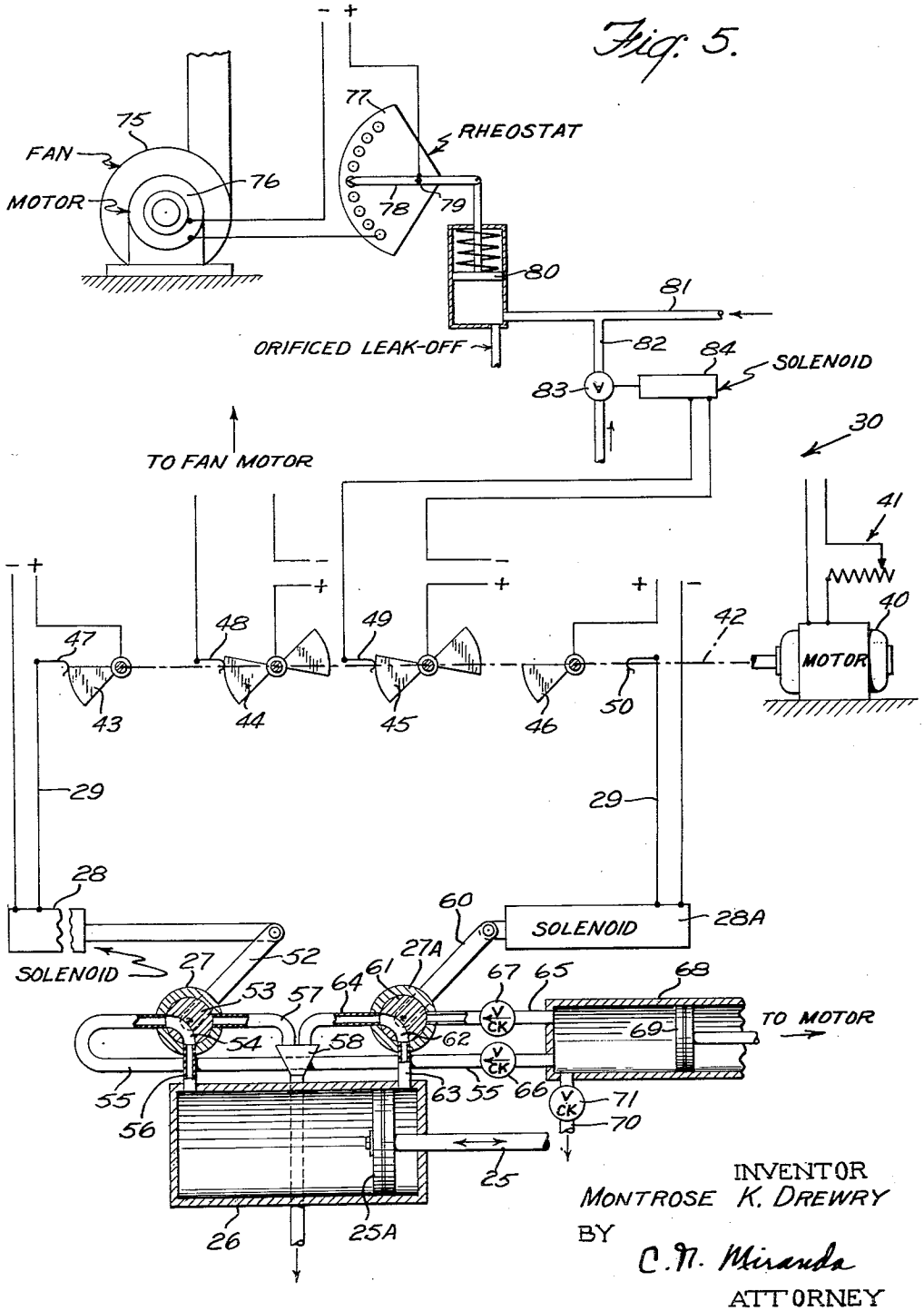
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AIR HEATER

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Fig. 5.



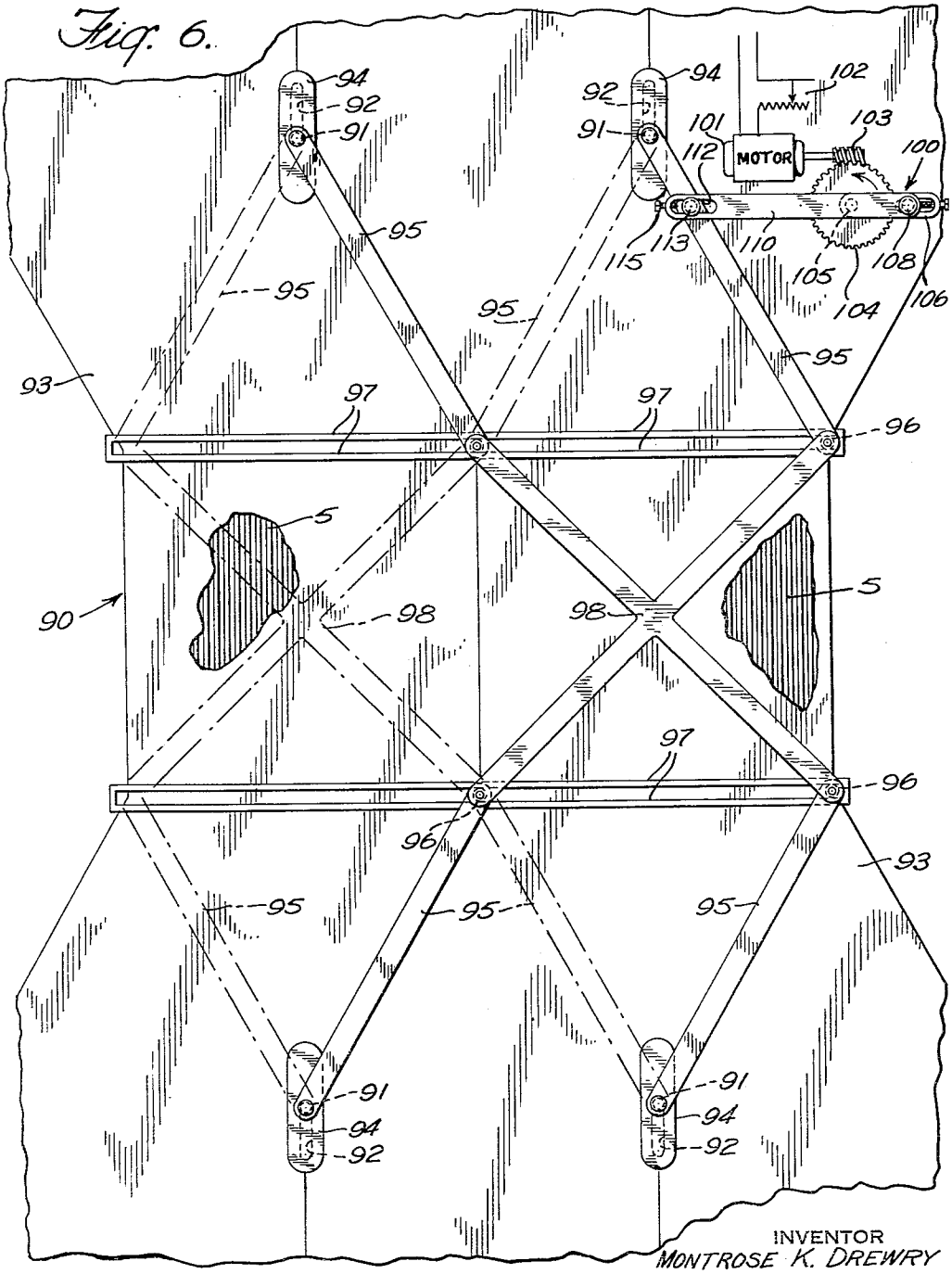
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Fig. 6.



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Fig. 7.

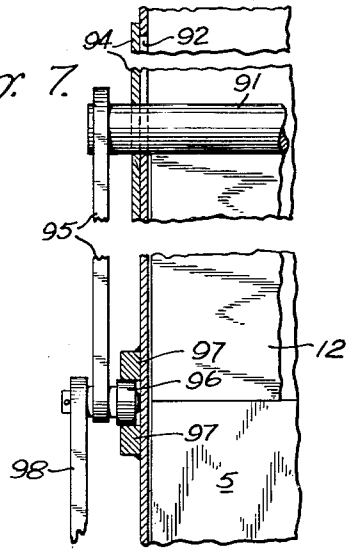


Fig. 9.

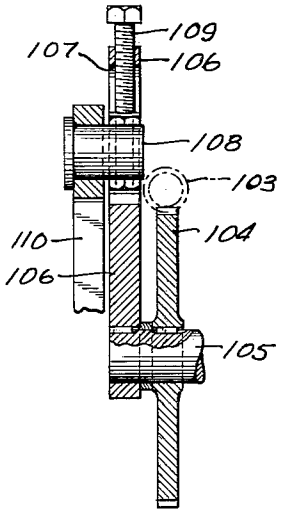
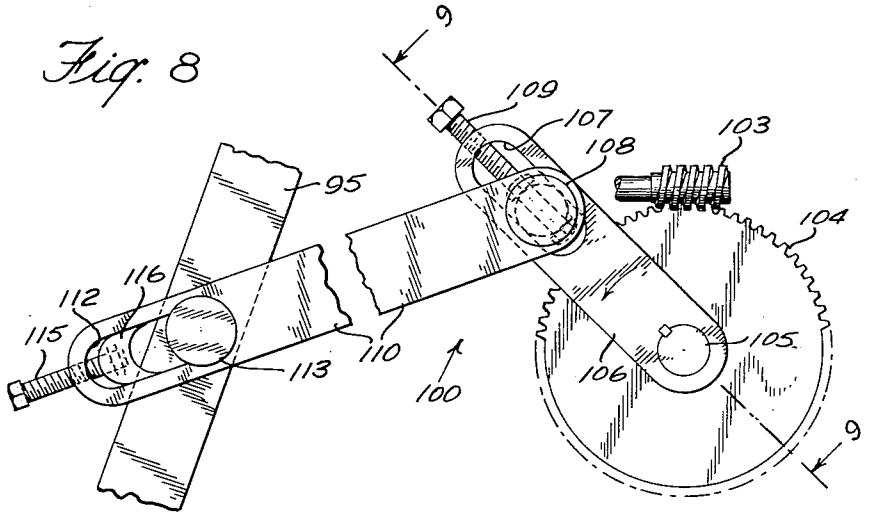


Fig. 8



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3,039,745

AIR HEATER

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Filed Jan. 2, 1959, Ser. No. 785,773
16 Claims. (Cl. 257—264)

The invention relates to air heaters and more particularly to regenerative type air preheaters for steam power plants in which the heat of the boiler flue-gases is used to heat air for combustion of boiler fuel and at the same time cool the flue-gases. This application is a continuation-in-part of applicant's copending U.S. patent application S.N. 511,685, filed May 27, 1955, and now abandoned. Such air heaters are usually located between the boiler unit and the chimney and reduce the amount of fuel required by the boiler unit since a substantial amount of what would otherwise be waste heat is recovered in the preheating of the combustion air.

As the demands for larger and larger steam power plants for generation of electricity increases with a consequent increase in the size of the boiler units, the size of the air heaters for these units increases proportionately and with it changes in air heater design to make larger heater units possible. Rotary regenerative air heaters presently in most common use have already reached very large size. Shipment and design problems act as deterrents to their further size increase. The object of the present invention is to provide a new and improved design of air heater which may be made in large sizes and may be readily shipped in knocked down condition.

A further object of the invention is to provide a new and improved method for operating air preheaters of the regenerative type so that only a relatively small amount of flue-gas contamination occurs, and the heater plates are more uniformly heated.

The above and other objects and advantages of the present invention will appear more fully hereinafter from a consideration of the detailed description which follows taken together with the accompanying drawings wherein two embodiments of the invention are illustrated.

In the drawings:

FIG. 1 is a vertical sectional view of diagrammatic form showing an air preheater unit embodying the invention;

FIG. 2 is a detailed plan view of a part of the heater plate structure;

FIG. 3 is a detailed vertical sectional view of the damper operating mechanism;

FIG. 4 is a front elevation view of the damper operating mechanism and its controls;

FIG. 5 is a diagrammatic illustration of the timer control for the dampers shown in FIG. 1 and the controls for the induced-draft and forced-draft fans;

FIG. 6 is a vertical diagrammatic illustration of an air preheater unit constituting a second embodiment of the present invention;

FIG. 7 is an enlarged detailed vertical sectional view of the damper linkage of FIG. 6;

FIG. 8 is an enlarged detailed elevational view of the actuating linkage for displacing the damper of FIG. 6; and

FIG. 9 is a sectional view of the linkage taken along line 9—9 of FIG. 8.

Referring to FIG. 1, the air preheater includes a heat transfer section including a plurality of metal heat transfer plates 5 disposed in parallel formation and suitably spaced from each other to provide channels or passages 6, the ends of these plates being indicated by the numeral 7. The plates are arranged to provide right and left sets of transfer units.

The heat transfer section is operatively connected at one end with a flue-gas source through a flue-gas inlet means 8 and an air outlet 9 and at its other end with a flue-gas outlet 10 and a source of air through an air inlet means 11. Dampers 12 that route the flue-gas and air alternately through the two sets of plates 5 are shown in full in one of their positions and in dotted in their alternate positions. There are two dampers 12 at each end of the heat transfer section, one controlling gas passage through one set of plates and the other controlling gas passage through the other set of plates. The dampers 12 at each end are operatively connected together by struts 13 that cause them to be balanced against the different draft and pressure forces of the flue-gas and air.

With the dampers 12 in the positions shown in solid lines, flue-gas passes downwardly through the passages 6 of the group of plates 5 on the left half of the transfer section. Air passes upwardly through the passages 6 of the right hand group of plates. Flue-gas and air cannot mix because all extremities of the dampers are sealed. The damper shafts are closely fitted or in contact with the flue-gas duct, and the plate ends of the dampers are closely fitted or in contact with the plates, which act to complete the separation of the flue-gas and air. Seals at upper and lower ends of the dampers, and at their horizontal ends, may be of the resilient type in that they will deflect upon meeting with projections and compensate for distortions. They may be designed for continuous contact or for continuously small clearance with or without the resilient property.

Upon the plates at the left becoming heated and the plates at the right becoming cooled, the dampers are changed from the full line positions of FIG. 1 to their dotted line positions, thus routing the flue-gas through the plates at the right and the air through those at the left. In this regard the alternating operation of the dampers is conventional. However, the scheduling of their time of dwell and their time of movement is novel and vital to the success of this type of preheater. Unlike previous designs, they neither oscillate continuously nor change positions rapidly. The time that they take to change to the alternate position is a vital part of this invention.

All regenerative air heaters have a common shortcoming, that of contamination of air with flue-gas, and of flue-gas with air. Interchanging usage of flow spaces between the plates by these two gases makes such contamination inevitable. One object of this invention is to provide a method of minimizing the effects of such contamination to the point that it is tolerable, without unduly impairing thermal performance of the air heater.

Flue-gas contamination of combustion air in substantial quantity, even for a few seconds, can markedly impair furnace combustion because flue-gas is actually a fire-extinguishing medium since it contains very little oxygen. Present-day firing methods cause the fuel to remain in the furnace only two to three seconds. With low oxygen in the combustion air extinguishing of the flames is conceivable. This could occur under conditions of rapid damper oscillation. For slightly less rapid damper movement, impairment of combustion, reflected in minor smoke formation, is a reasonable expectation.

Continuous back and forth oscillation of the dampers is objectionable because of the unequal heating and cooling of different parts of the transfer section, that is, the plates near the outsides of the heater under the air ducts will receive relatively short-time heating with flue-gas but long-time cooling with air, and the plates near the center will be heated by flue-gas over relatively long periods, but cooled practically not at all by air with resulting poor thermal performance and also clogging of the passages near the outside of the heater with fly-ash or other objectionable products because of the low temperature of these plates.

The above disadvantages of the prior methods can be overcome by changing the positions of the dampers every sixty second and effecting their change in about ten seconds. The ten seconds travel time for the particular design contemplated will result in a reduction of the oxygen rate to the furnace of approximately three percent, but inasmuch as in present practice a fifteen percent air excess is furnished to the furnace, this three percent lesser oxygen is of little importance. With ten seconds damper movement time and sixty second dwell before starting of the movement, exterior plates will experience almost eighty seconds of air cooling and sixty seconds of flue-gas heating. Plates near the center of the air heater will be heated almost eighty seconds and cooled about sixty seconds. Therefore, end plates will operate somewhat cooler than will the central ones, and intermediate plates will operate at intermediate temperatures. The above differences between the temperatures of the plates of the transfer section are not sufficient to interfere with the practical working of the air heater.

While the time figures given above are based upon a particular design, it will be apparent that the relation of time of movement and time of dwell may be varied to suit the variety of plate spacing, flow areas, plate heights, and other variables that may occur in actual practice. While for the specific example given the ratio of time of dwell to time of travel is six to one, the advantages of this invention may be realized where the ratio of time of dwell to time of travel is within the range of three to one, to twelve to one.

Although FIG. 1 shows two sets of plates and a single flue-gas duct, four or more sets of plates and two or more flue-gas ducts and accompanying air ducts may be used to advantage in some cases. Height requirements are reduced, and by staggering damper movement time, flue-gas contamination of combustion air can be reduced in half, for instance, by using twice as many sets of plates.

In order to obtain an efficient seal between the dampers **12** and the plates **5**, I have provided a novel damper mounting whereby the plate end of the damper travels horizontally over the plates while its upper or duct end travels vertically.

Referring to FIGS. 3 and 4, each damper includes a tube **14** which imparts stiffness to it and a damper shaft **15**. Sealing strips **16** are mounted on the sides and lower ends of the damper, and a sliding sealing plate **17** covers the shaft clearance slot **18** in the duct in which the damper is mounted.

To create the horizontal and vertical motions of the extremes of the damper, a cam-like assembly at each outboard end of the damper shaft is employed. This assembly includes an actuating arm or crank **19** on the shaft **15** and having two cam followers **20** and **21** which are restrained to move in guide means comprising slots **22** and **23**, respectively, of a fixed cam member **24**. The slot **22** is a straight vertically disposed slot. The slot **23** is formed as an arcuate slot. The actuating arm or crank **19** is operatively connected at its lower end to an actuator, here shown as the piston rod **25** of a piston **25A** working in a power cylinder **26** whose operating fluid, air or oil, is controlled by valves **27** and **27A** operated by conventional spring-biased solenoids **28** and **28A** respectively, having circuit connections **29** with a suitable timer **30** shown in greater detail in FIG. 5. The structure and operation of timer **30** in controlling dwell and travel periods of the dampers will be described in greater detail hereinbelow. The piston rod **25**, in FIG. 4, is shown as having an extension which connects with the damper for the other plate unit so that both dampers at one end of the transfer section are operated together. With the above construction as the piston rod **25** is reciprocated by the power fluid in the cylinder **26** the cranks **19** of the dampers connected therewith are swung back and forth. As the actuating arm or crank **19** makes its swinging movement, the follower **20** moves vertically

in the slot **22**, and the follower **21** moves along the arc of the slot **23** so that the damper is given a compound vertical and lateral swinging movement whereby its plate contacting end moves horizontally across the channels in the plates **5**.

In FIG. 4 the damper is shown in dotted in its vertical position. Extreme damper positions are shown by damper center lines **33** and **34** which also indicate positions of the cam followers **20** and **21** when the damper is at its extreme positions. A constant support, in the form of a counterweight **35** and a flexible connector **36** between this weight and the actuating arm or crank **19** at each end of the damper trained over a pulley **37** counterbalances the weight of the damper and its unsupported components to release weight forces from the cam system regardless of damper position. With the dampers balanced for draft and air pressure forces through the link **13** or the rod **25**, the actuating mechanism only needs to overcome friction of the parts, and therefore, requires only a small expenditure of power for operation.

The cam member **24** is shown as adjustably suspended on fixed studs **24***a* carrying adjustable nuts **24***b* to bring the plate ends of the dampers to a minimum or zero clearance position with the ends of the plates, such adjustments taking into account the expansion and contraction of the damper.

The dampers are balanced horizontally and vertically. The horizontal struts **13** cause exact and direct balancing of horizontal forces resulting from differences in flue-gas drafts and air pressures acting on the two sides of each damper. Since the directions of such different forces are opposed on the two adjacent dampers, connecting them with a strut causes horizontal balancing.

Suspending each damper at each end in horizontal alignment with its center of gravity results in avoiding all variable forces due to weight acting upon the mechanism that actuates the dampers. Actuating power is minimized, as is air leakage at the plates because of less damper distortion.

Vertical forces due to differences of flue-gas drafts and air pressures are resolved by acting through the actuating mechanism in opposite directions, thus accurately opposing each other. With all horizontal and vertical forces resolved to zero, the actuating mechanism only needs to overcome frictional forces.

The horizontal struts **13** could be omitted without losing the feature of horizontal balance, since the extension rods **25** also perform this function. However, the struts also aid in directly supporting the relatively large areas of the dampers subject to horizontal pressure differences, thus lightening their construction and that of the actuating mechanism. Vertical forces are substantially of less consequence in this regard for their center of application is significantly nearer the damper shaft. Section-moduli of cantilever beams need increase with the cube of the load overhang distance, which cube-relation emphasizes the lesser consequence of vertical forces as compared to horizontal forces.

Coming now to the controls for the dampers **12**, reference is made to FIG. 5 wherein timer **30** is shown as comprising a unidirectional electric motor **40** the speed of which may be adjusted by a variable resistance device, as for example a rheostat **41** in circuit therewith. Motor **40** is provided with a mechanical connection **42** (shown as a broken line) which drives a plurality of segmental-wheel switches **43**, **44**, **45** and **46** having associated contact members **47**, **48**, **49** and **50**, respectively. Switch **43** when engaged by contact member **47** is connected for energizing and actuating solenoid **28**, for example, the armature of which is moved to the right upon energization, as seen in FIG. 5 to overcome the force of the spring (not shown) normally urging the armature to the left when the solenoid is deenergized. Solenoid **28A** is connected for energization by contact member **50** and switch **46** to effect movement of the armature to the left as seen in

FIG. 5, to thereby overcome the force of the solenoid spring (not shown). Valve 27 is provided with an actuating arm 52 connected to the armature of solenoid 28 and the arm is secured for rotating a movable valve member 53 of valve 27. Valve member 53 has formed therein a fluid passage 54 which, in the position shown in FIG. 5, communicates a fluid supply conduit 55 and with a conduit 56 connected to cylinder 26. A drain conduit 57 also is connected to valve 27 and at its other end communicates with a drain 58. Valve 27A similarly includes an actuating arm 60 connected to the armature of solenoid 27A for rotating a valve member 61. A fluid passage 62 is formed in valve member 61, and in the position shown in FIG. 5 communicates a conduit 63, connected to cylinder 26 on the other side of piston 25A, with a drain conduit 64 connected to drain 58. A fluid supply conduit 65 is connected to valve 27A but is out of alignment with passage 62 when the solenoid 28A is deenergized. Fluid supply conduits 55 and 65 are provided with check valves 66 and 67, respectively, and the conduits are connected to a piston type pump 68 to receive fluid therefrom. Pump 68 inclues a plunger 69 which is driven by a variable speed motor (not shown) and the pump has a fluid inlet conduit 70 having a check valve 71 therein.

In the construction of the damper control described up to this point, it will be understood that with the switch member 43 engaged by contact member 47 and rotation of the member 43 in a clockwise direction fluid from pump 68 flows through supply conduit 55, passage 54 of valve 27 and conduit 56 into cylinder 26 to move piston 25A to the right as seen in FIG. 5 thereby effecting travel of dampers 12. The fluid on the other side of piston 25A discharges from cylinder 26 through conduit 63, passage 62 of valve 27A and drain conduit 64 to drain 58. Switch member 43 is so dimensioned that upon disengagement of the contact 47 from it, piston 25A and dampers 12 will have reached their extreme positions. At this point, solenoid 28 will become deenergized to return valve member 53 to a position closing off fluid supply conduit 55, and both valves 27 and 27A will be ineffective to conduct fluid into cylinder 26. At this time, switch member 46 still is disengaged from contact 50 and does not engage the latter until rotation for a predetermined angular distance whereupon the switch and contact will engage to energize solenoid 28A. The time interval between the disengagement of switch member 43 from contact 47 and the engagement of switch member 46 with contact 50 is the dwell period of the dampers 12 during which the latter remain stationary. Upon engagement of member 46 with contact 50 however, energization of solenoid 28A effects movement of valve member 61 to a position wherein passage 62 therein communicates supply conduit 65 with conduit 63 to provide for flow of fluid to cylinder 26 from pump 68. As a result, piston 25A moves to the left (FIG. 5) and the fluid in the cylinder on the other side of the piston discharges through conduit 56, passage 54 in valve member 53, and drain conduit 57 to drain 58. As in the case of switch member 43, switch 46 is so dimensioned that upon disengagement of the latter from contact 50, piston 25A and dampers 12 will have reached their extreme positions whereupon solenoid 28A will be deenergized to effect obstruction of flow of fluid to cylinder 26. An equal dwell period for the dampers 12 will exist before engagement of the switch member 43 with contact 47 to again effect movement of the dampers. Means (as for example, a pressure switch) (not shown) controls the motor (not shown) operating pump 68 in a manner such that operation of the latter is synchronized with the operation of the dampers and valves to restrain movement of the plunger 69 to the left during the dwell periods of the dampers by stopping and starting the pump motor at the appropriate times.

Regenerative air heaters of the type disclosed herein utilize induced-draft and forced-draft fans to maintain a constant supply of air to the heater. In the subject invention unusual conditions of operation of the heater may result in excessive reduction of oxygen flow to the furnace because of flue-gas contamination. This will occur particularly during the damper movement and accordingly it is an important feature of this invention to maintain the desired oxygen flow during damper travel by increasing the speed of the induced-draft and forced-draft fans to increase the air supply to the heater at such times. To this end, FIG. 5 of the drawings discloses timer operated means for varying the speed of the fans during operation of the heater. Since the controls for the induced-draft and forced-draft fans are identical it will be necessary only to describe the detailed controls for one fan, as for example, the induced-draft fan.

An induced-draft fan 75 is schematically illustrated in FIG. 5 and is driven by a variable speed motor 76 connected in circuit with a conventional rheostat 77 which varies the resistance in the motor circuit to regulate motor speed. Rheostat 77 is provided with an arm 78 pivoted at 79 by a spring opposed piston 80. A controlled airflow conduit 81 is connected to receive an amount of air under pressure from a combustion regulator (not shown) and to deliver said air to piston 80 to maintain arm 78 in the position shown in FIG. 5, which position is maintained during the dwell periods of the dampers 12. An orificed air supply conduit 82 communicates with conduit 81 and is provided with a control valve 83, diagrammatically shown, which is operable by a spring-biased solenoid 84. Solenoid 84 is connected in circuit with switch member 45 and contact 49 and as is evident from the drawing, engagement of the switch and contact causes energization of the solenoid. The timer operated controls of the forced-draft fan (not shown) are identical to the above described controls and the solenoid for the former controls would be operated from switch member 44 and contact 48 of timer 30.

Considering now the operation of the induced-draft fan 75, let it be assumed that the amount of compressed air or pneumatic signal through controlled air flow conduit 81 is constant and is of a value sufficient to provide a speed of motor 76 which effects the proper oxygen flow to the heater during the dwell periods of the dampers. When the dampers move however, an increased flow of air is required and to this end switch 45 moves into engagement with contact 49 to operate solenoid 84 which in turn actuates valve 83 to impress a pneumatic signal in conduit 83 on that in conduit 81. The increased resultant pneumatic signal further displaces piston 80 upwardly to move arm 78 and cuts out a predetermined resistance in the motor circuit to effect an increase in speed of the fan 75 and in the supply of air to the heater. The switch 45 is dimensioned to disengage itself from contact 49 when dampers 12 reach the end of their travel so that solenoid 84 is deenergized to actuate valve 83 to a closed position. Consequently, the added signal to piston 80 is cancelled so that fan 75 returns to its normal speed. Switch members 44 and 45 may be arranged slightly in advance of the switch members 43 and 46 with regard to time of contact to supply the finite time required for the fans to change speed from dwell position of the damper to travel of the latter.

As indicated hereinabove an important feature of the present invention is in the novel method of operating an air preheater to obviate among other things, the contamination of air with flue-gas and of flue-gas with air. To afford a clearer understanding of the subject novel method it is desirable to set forth the following example based upon a change of position of the dampers every sixty seconds and effecting their change in about ten seconds. In accordance with the foregoing assumption, the duration of contact of the switch members 43 and 46 with their respective contact members 47 and 50 will be ten seconds and the out of contact time interval thus is sixty seconds. Assuming that the structure of the air

heater disclosed in FIGS. 1 to 5 of the drawings commences operation with switch member 43 in engagement with contact 47, dampers 12 thus are operated in a direction left to right as seen in FIG. 1 and switches 44 and 45 engage their respective contacts 48 and 49 so that the induced-draft and forced-draft fans are operating at the required speeds to provide proper oxygen flow to the plates 5. Switch members 43, 44 and 45 at the end of ten seconds are disengaged from their respective contacts so that dampers 12 are brought to rest and the speed of the fans is returned to normal. After an interval of sixty seconds during which piston 69 returns to the position shown in FIG. 5, switch member 46 will reach a position to engage contact member 50 to energize solenoid 28A to thereby effect movement of the piston 25A and dampers 12 in the opposite direction. Concurrently, the oppositely disposed segments of switch members 44 and 45 will contact their respective contacts to increase the speed of the fans; it being noted that such switch members will engage their contacts a slight time interval before engagement of switch member 46 with contact 50 to provide the requisite time for the fan motors to be brought up to their increased speeds. At the end of ten seconds switch members 44, 45 and 46 will disengage from their contacts to terminate damper travel and return the fans to normal speed. Following an interval of sixty seconds the cycle will recommence as brought out above.

The above time cycle for dwell and travel of dampers 12 in one direction is seventy seconds and the ratio of dwell to travel time of the dampers therefore, is six to one. If it is desired to increase or decrease the dwell and travel time of the dampers it is merely necessary to vary the speed of timer motor 40 and the speed of the motor (not shown) which operates piston 69 of pump 68. For example, to increase dwell and travel time proportionally so that the time cycle is ninety seconds, the speed of timer motor 40 and of the motor (motor shown) operating pump 68 is reduced accordingly. Conversely, if reduction in dwell and travel time of the damper in the same proportion is required then the speed of the timer motor and pump motor is increased.

It was indicated previously that the variation in dwell time of the dampers to the travel time would be desirable at times and the same is accomplished by varying the speed of the timer motor and in some instances the pump motor. If for example, the dwell time were to be increased while the damper travel time were maintained constant, the speed of the timer motor 40 would be reduced and the pump motor speed maintained constant. However, the time of commencement of the stroke of piston 69 in either direction in cylinder 68 would have to be synchronized with respect to the engagement and disengagement of the switch members and contacts in timer 30. In similar manner, switch members 44 and 45 would be replaced with different segments having a shorter arcuate peripheral contact surface, otherwise the fans will be in above normal speed operation after the dampers have stopped moving and are at dwell. If the dwell time is to be decreased with travel time constant then the speed of timer motor 40 is increased and the speed of the pump motor (not shown) is maintained constant. However, switch members 43 and 46 are replaced by members having a longer arcuate peripheral contact surface so that energization and deenergization of solenoids 28 and 28A will not occur before the dampers have reached their extreme positions. Similarly, switch members 44 and 45 are replaced by members having a longer contact surface as to be synchronized for operation with damper travel. From the foregoing, it will be understood that the present invention provides for a change in the dwell time to a constant travel time.

A second embodiment of an air heater of the present invention is illustrated in FIGS. 6 to 9 wherein the air heater is generally designated by the numeral 90. Heater 90 comprises the same plate and casing construction as the embodiment of the heater shown in FIG. 1 and whenever such construction is identical the same reference characters shall be employed in the description of the heater of the second embodiment. The dampers 12 in heater 90 are provided with damper shafts 91 (FIG. 7) which extend through and move within vertical openings 92 in the heater casing 93 and such openings are covered by sealing plates 94. The projecting portion of shafts 91 have secured thereto damper actuating and supporting links 95 which are in alignment with their respective dampers and the links have connected at their other ends rollers 96 adapted for riding in tracks 97 on casing 93. Rollers 96 are in alignment with the ends of the dampers that contact or approach closely to the plate ends. A rigid cross-bar link frame 98 interconnects each of the damper links 95 (as seen in FIG. 6) and is effectively connected thereto by being secured to the shafts of the rollers 96. It will be apparent from the foregoing that movement of any one of the damper links 95 effects simultaneous movement of the other links through the interconnecting cross-bar frame 98.

In the arrangement shown in FIGS. 6 and 8 of the drawings an adjustable linkage 100 serves to transmit motion from a variable speed motor 101 in circuit with a rheostat 102 to one of the damper links 95. Motor 101 is provided with output means shown as a worm gear 103 on the motor shaft and the worm gear meshes with a gear 104 fixedly mounted on a shaft 105. Adjustable linkage 100 is more clearly shown in FIG. 8 and comprises a crank 106 and secured for rotation with shaft 105, having a slot 107 formed therein. An adjustable pin 108 is accommodated within slot 107 and the pin is adapted for movement within the slot by means of a threaded member 109 which has an unthreaded shank portion extending through pin 108. A connecting rod 110 is connected at one end to pin 108 and is provided at its other end with a slot 112 to accommodate a pin 113 secured to damper link 95, as seen in FIG. 7. Slot 112 is adjustable relative to pin 113 by a threaded member 115 having an end loosely mounted in a block 116 and upon rotation of threaded member 115 sliding movement of the block within slot 112 is effected. The adjustable linkage 100 in FIG. 8 is shown in the illustrated position to clearly disclose the mechanism during a dwell period of the dampers 12 before the linkage effects movement of the dampers right to left as seen in FIG. 6.

Considering now the operation of the heater 90 of the second embodiment as thus far described, motor 101 is operated at a predetermined speed to effect a rotation of crank 106 from the position shown in FIG. 6. Since the pin 113 is at the left end of slot 112 and against block 116 the dampers 12 will be subjected to a dwell period of certain number of seconds, connecting rod 110 pivots about pins 108 and 113. When pin 113 reaches and bears against the right end of slot 112 the dampers 12 commence to move right to left (looking at FIG. 6) until they reach the broken line position, and continued rotation of crank 106 is ineffective to move the damper because slot 112 moves relative to pin 113. Further rotation of crank 106 causes block 116 to engage pin 113 whereupon the dampers commence to move left to right. It will be apparent that the effective length of slot 112, as determined by the position of block 116 therein, effects a desired dwell period in which the dampers are stationary. Furthermore, both the dwell and travel time periods may be varied without modifying their ratio by changing the speed of motor 101 by means of rheostat 102.

Adjustable linkage 100 may be employed to change the period of dwell while maintaining the travel time constant. For example, if the dwell period of the dampers 12 in heater 90 is to be increased, threaded member 115 is rotated in the proper direction to move block 116 closer to the left end of slot 112. Since the

same amplitude of damper movement is to be retained the "throw" of the crank must be increased and this is accomplished by rotating threaded member **109** in a direction to move pin **108** away from shaft **105**. Thus, by increasing the effective length of slot **112** the time of dwell of dampers **12** upon rotation of gear **104** will be increased while the damper travel period remains the same. Conversely, if it is desired to reduce the dwell period of the dampers, threaded member **115** is rotated in a direction to move block **116** away from the left end of slot **112** and pin **108** displaced from its previous position and closer to shaft **105** by threaded member **109** to retain the same amplitude of damper movement.

It will be understood that the second embodiment of the present invention also contemplates the provision of means for increasing the speed of the induced-draft and forced-draft fans during damper travel and such means may comprise a control, as for example, disclosed in FIG. 5 wherein the switches may be actuated from shaft **105**. Since the controls illustrated in FIG. 5 have been fully described in cooperation with the means for effecting travel and dwell of the dampers **12** it is believed that the employment of same with the heater **90** is readily apparent to those skilled in the art and therefore further description and illustration of same employed with heater **90** is unnecessary.

The design of the present invention has definite advantages over the rotary type regenerative air preheaters because the fabrication and shipment problems for the heat transfer section are simplified, and much less power is required to operate the dampers as compared to driving the rotary units.

Prior designs using stationary heat transfer sections with oscillating dampers, it is believed, have not been commercially successful because of the difficulties encountered in using curved end transfer plates over which the damper swings, which difficulties have been avoided in the present invention by the horizontal travel of the plate ends of the damper over horizontally aligned plates so that there is no difference in the lengths of the passages in the plate section and hence no problems of variable velocity of gases in some of the passages as compared to others.

The general application of the novel method of the subject invention may be more ready appreciated by referring to the air heater disclosed in U.S. Patent No. 1,739,507, issued December 17, 1929. It will be apparent that the foregoing patented air heater although materially different from the air heater of the present invention provides structure by which the subject novel method may be performed without substantial modification thereof.

I desire it to be understood that this invention is not to be limited to any particular form or arrangement of parts except insofar as such limitations are included in the claims.

What is claimed is:

1. A method of operating an air preheater of the type having a movable damper controlling the alternate flow of flue-gas and air through a heat transfer section, the steps comprising, moving the damper in a predetermined unit of time, adjusting the period of dwell between damper movements in the ratios of a range of 3 to 12 of the damper movement time, maintaining the amount of air for passage through said heat transfer section at a predetermined value during said dwell periods, and increasing the amount of air for passage through said heat transfer section above said predetermined value during movement of said damper.

2. A method of operating an air preheater of the type having a movable damper controlling the alternate flow of flue-gas and air through a heat transfer section and induced draft and forced draft fans associated with said air preheater, the steps comprising, moving a damper in a predetermined unit of time, adjusting the period of dwell between damper movements in the ratios of a range of 3 to 12 of that of the damper movement time, maintaining the speed of said induced draft and said forced draft fans at predetermined values respectively during said dwell periods, and increasing the speed of said induced draft and said forced draft fans above said predetermined values during movement of said damper.

3. In an air preheater, the combination of a plurality of spaced plates forming a pair of heat transfer sections, a source of flue-gas, a source of air under pressure, means for conducting flue-gas from said flue-gas source to said heat transfer section, other means for conducting air from said source of air under pressure to said heat transfer section, sets of movable dampers controlling the alternate flow of said flue-gas and said air under pressure from said means and said other means to said transfer sections and working over the ends of said plates, the ends of said plates adjacent the dampers of each set being all in substantially the same horizontal plane, horizontal thrust balancing means between the dampers of each set, a relatively fixed cam engaged by parts of the outer end of each damper for imparting both vertical and lateral movements to said outer end to effect a substantial horizontal movement of the damper in a horizontal plane parallel to and directly over the ends of said plates, actuating means for each set of dampers, and means for adjusting said cams to bring the plate ends of said dampers to their operating positions with the ends of the plates.

4. In an air preheater of the class described having induced-draft and forced-draft fans, a plurality of spaced plates forming a heat transfer section, a source of flue-gas and a source of air under pressure, means for conducting flue-gas from said flue-gas source to said heat transfer section, other means for conducting air from said source of air under pressure to said heat transfer section, movable dampers controlling the alternate connection of said flue-gas conducting means and said air source conducting means with such transfer section, the movable dampers having ends adjacent the plates and ends remote from the plates, the ends of the plates adjacent the dampers being all in substantially the same plane, means for moving the dampers relative to the plates so as to alternately control the connection of said flue-gas conducting means and said air source conducting means with the heat transfer section, and control means connected to said moving means for rendering the moving means ineffective at the end of travel of the dampers in one direction to provide a dwell period for the dampers before movement of the latter in the opposite direction, said control means also being connected to said fans and operative to maintain a predetermined speed of said fans during dwell periods of said dampers and to effect an increased speed of said fans during movement of said dampers.

5. A method of operating an air preheater of the type having a movable damper controlling the alternate flow of flue-gas and air through a heat transfer section, the steps comprising, moving the damper in a predetermined unit of time of several seconds, adjusting the period of dwell between damper movements to six times the period of damper movement time, maintaining the amount of air for passage through said heat transfer section at a predetermined value during said dwell periods, and increasing the amount of air for passage through said heat transfer section above said predetermined value during movement of said damper.

6. A method of operating an air preheater of the type having a movable damper controlling the alternate flow of flue-gas and air through a heat transfer section and induced draft and force draft fans associated with said air preheater, the steps comprising, moving a damper in a predetermined unit of time of several seconds, adjusting the period of dwell between damper movements to six times the period of damper movement time, maintaining the speed of said induced draft and said forced draft fans at predetermined values respectively during said dwell periods, and increasing the speed of said induced draft and

said forced draft fans above said predetermined values during movement of said damper.

7. In an air preheater of the class described, a plurality of spaced plates forming a heat transfer section, a source of flue-gas, a source of air under pressure, means for conducting flue-gas from said flue-gas source to said heat transfer section, other means for conducting air from said source of air under pressure to said heat transfer section, movable dampers controlling alternate flow of said flue-gas and said air under pressure from said means and said other means to said heat transfer section, the dampers being vertically disposed for movement in substantially vertical and lateral directions, counterweight means connected to the dampers to counterbalance the weight of said dampers, the dampers having ends adjacent the plates and ends remote from the plates, the ends of the plates adjacent the dampers being all in substantially the same plane, means for moving said dampers relative to the plates, and means mounting the dampers and constraining movement of said adjacent damper ends in planes parallel to the plane of the plate ends and movement of said remote damper ends in a direction normal to the plane in which said adjacent damper ends travel.

8. In an air preheater of the class described, a plurality of spaced plates forming a heat transfer section, a source of flue-gas, a source of air under pressure, means for conducting flue-gas from said flue-gas source to said heat transfer section, other means for conducting air from said source of air under pressure to said heat transfer section, movable dampers controlling alternate flow of said flue-gas and said air under pressure from said means and said other means to said heat transfer section, said dampers having ends thereof adjacent to the plate ends and ends remote from the plate ends, the end of the dampers adjacent the plates being closely fitted and in sealing relationship with the end of the plates adjacent thereto, the ends of the plates adjacent the dampers being all in substantially the same plane, means for moving said dampers relative to the plates, and means mounting the dampers and constraining movement of said adjacent damper ends in planes parallel to the plane of the plate ends and movement of said remote damper ends in a direction normal to the plane in which said adjacent damper ends travel.

9. In an air preheater of the class described, a plurality of vertically disposed spaced plates forming a substantially horizontal heat transfer section, a source of flue-gas and a source of air under pressure, means for conducting flue-gas from said flue-gas source to said heat transfer section, other means for conducting air from said source of air under pressure to said heat transfer section, a pair of dampers connected for conjoined movement arranged above the heat transfer section and a pair of interconnected dampers arranged below said section, said dampers being operable for concurrent movement to control the alternate flow of said flue-gas and said air under pressure from said means and said other means to said transfer section, said dampers having ends thereof adjacent to the plate ends and ends remote from the plate ends, the end of the dampers adjacent the plates being closely fitted and in sealing relationship with the end of the plates adjacent thereto, the ends of the plates adjacent the dampers being all in substantially the same plane, an actuating arm secured to one damper of each pair of dampers and having follower means thereof, means for moving said actuating arms to operate said dampers, and guide means cooperating with said followers to constrain movement of said adjacent damper ends in planes parallel to the plane of the plate ends and movement of said remote damper ends in a direction normal to the plane in which said adjacent damper ends travel.

10. In air preheater of the class described, a plurality of vertically disposed spaced plates forming a substantially horizontal heat transfer section, a source of flue-gas and a source of air under pressure, means for conducting flue-gas from said flue-gas source to said heat transfer section, other means for conducting air from said source of air under pressure to said heat transfer section, a pair of dampers connected for conjoined movement arranged above the heat transfer section and a pair of interconnected dampers arranged below said section, said dampers being operable for concurrent movement to control the alternate flow of said flue-gas and said air under pressure from said means and said other means to said transfer section and having ends adjacent the plates and ends remote from the plates, the ends of the plates adjacent the dampers being all in substantially the same plane, an actuating arm secured to one damper of each pair of dampers and having follower means comprising a pair of followers thereof, means for moving said actuating arms to operate said dampers, and guide means having a vertical slot therein in which slot one of the followers travels and an arcuate slot therein in which the other follower travels to provide vertical and lateral movement of the dampers, while causing the adjacent damper ends to travel in a horizontal plane.

11. The air preheater of claim 10 wherein the moving means comprises a fluid pressure operated motor having solenoid operated valves to effect the reversal of direction of movement of the damper over the heat transfer section, and a timer connected for operating the solenoids to provide a predetermined time dwell period of the dampers and a predetermined travel time period for damper movement.

12. In an air preheater of the class described, a plurality of spaced plates forming a heat transfer section, a source of flue-gas, a source of air under pressure, means for conducting flue-gas from said flue-gas source to said heat transfer section, other means for conducting air from said source of air under pressure to said heat transfer section, movable dampers controlling alternate flow of said flue-gas and said air under pressure from said means and said other means to said heat transfer section, said dampers having ends thereof adjacent to the plate ends and ends remote from the plate ends, the end of the dampers adjacent the plates being closely fitted and in sealing relationship with the end of the plates adjacent thereto, the ends of the plates adjacent the dampers being all in substantially the same plane, an actuating and supporting link secured to each damper, means interconnecting each of said actuating and supporting links with the other to provide conjoined movement of the dampers upon movement of one of said actuating and supporting links, means for moving one of said actuating and supporting links, and means mounting the dampers and actuating and supporting links and constraining movement of said adjacent damper ends in planes parallel to the plane of the plate ends and movement of said remote damper ends in a direction normal to the plane in which said adjacent damper ends travel.

13. The air preheater of claim 12 comprising mounting means having vertical slots therein for receiving the ends of the dampers remote from the plate ends for sliding movement therein, said mounting means further including rollers secured to the actuating and supporting links adjacent the plate ends for rolling movement within track means arranged substantially in the plane of said plate ends for effecting vertical and lateral movement of said dampers.

14. The air preheater of claim 13 wherein the means for interconnecting the actuating and supporting links comprises a rigid cross-bar frame member having a connection to each of said arms adjacent the rollers thereof.

15. The air preheater of claim 12 wherein the moving means comprises a motor connected for operating said one actuating and supporting link through an adjustable linkage which comprises means for varying the dwell time period of the dampers with respect to the travel time period of the dampers.

16. The air preheater of claim 15 wherein said one actuating and supporting link includes a projection by

which the link and associated damper are movable, and the adjustable linkage comprises a crank connected for rotation by the motor and a connecting rod connected at one end to such one actuating and supporting link and at the other end to the crank, a slot formed in the connecting rod to accommodate said projection, means for changing the effective length of said slot, and means on said crank for varying the throw of the connecting rod and actuating and supporting linkage.

References Cited in the file of this patent

UNITED STATES PATENTS

746,805	Farmer	Dec. 15, 1903
1,138,994	Steele	May 11, 1915
1,985,269	Yerrick	Dec. 25, 1934

FOREIGN PATENTS

592,483	France	Jan. 9, 1925
613,822	France	Apr. 1, 1926