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J. A. RYDBERG
HEAT EXCHANGING APPARATUS, INCLUDING A COMBUSTION
CHAMBER AND A HEAT EXCHANGER

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3 Sheets-Sheet 1

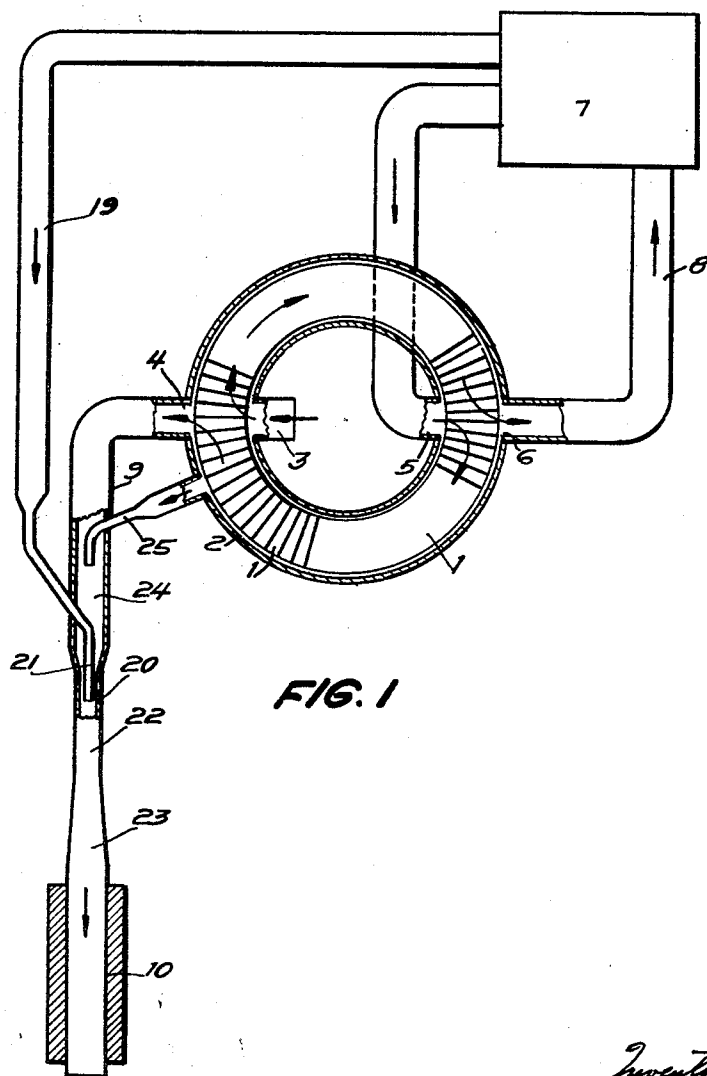


FIG. 1

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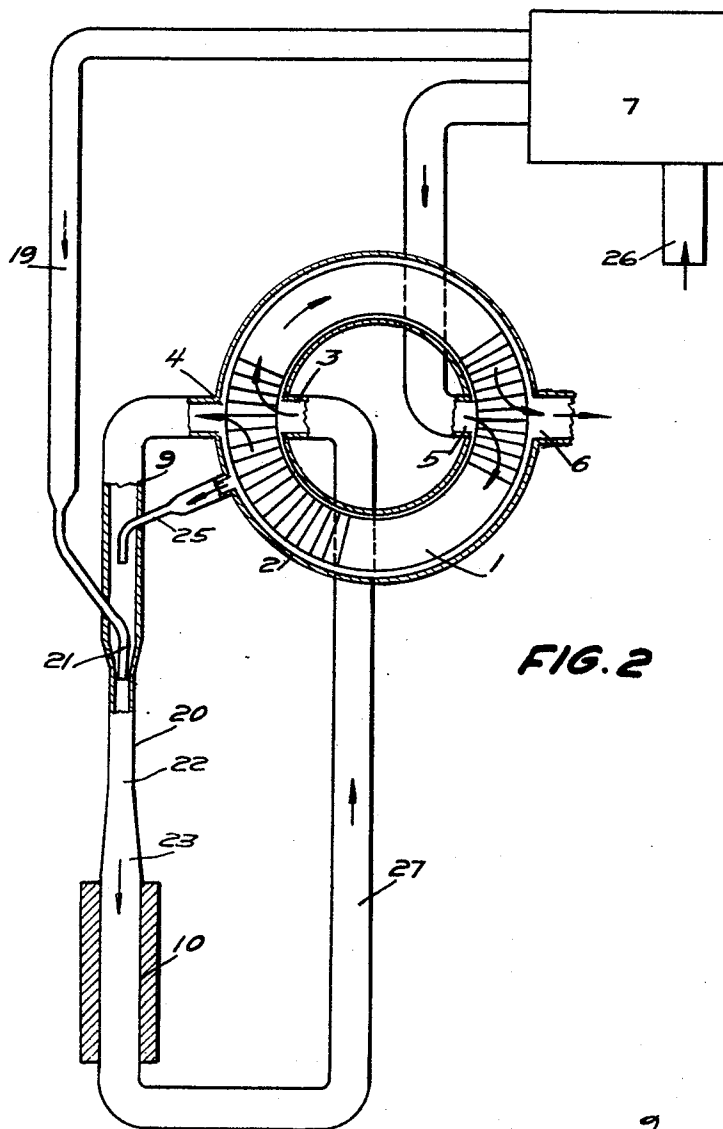
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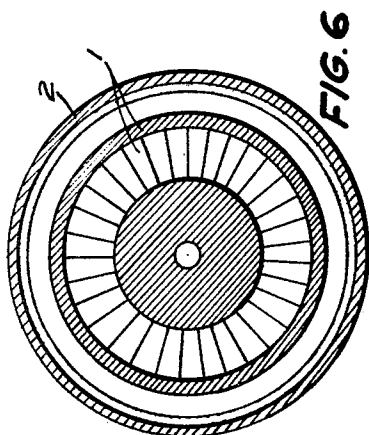
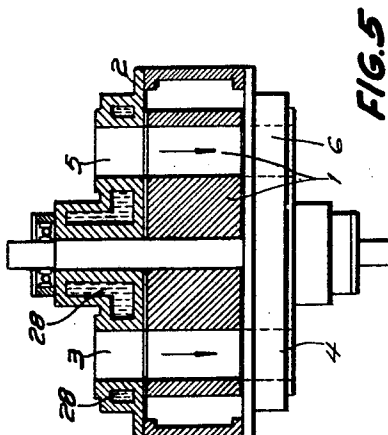
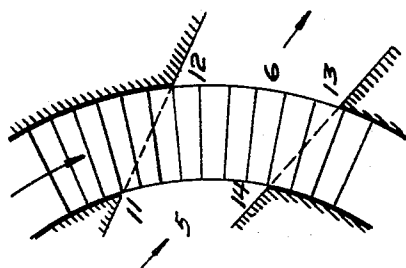
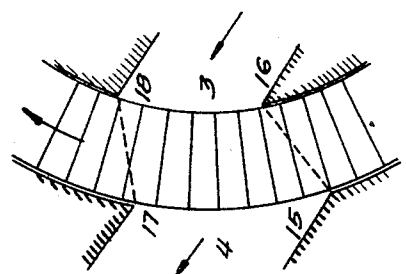
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HEAT EXCHANGING APPARATUS, INCLUDING A COMBUSTION
CHAMBER AND A HEAT EXCHANGER

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3 Sheets-Sheet 3



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HEAT EXCHANGING APPARATUS, INCLUDING A COMBUSTION CHAMBER AND A HEAT EXCHANGER

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4 Claims. (Cl. 263—19)

A cell wheel rotating in a shroud is used in gas turbines, heat pumps, etc., for taking gas from a lower pressure stage, compressing the gas, and at a higher pressure stage exchanging the same for gas in a different condition and of different quantity, the latter gas then being returned to the lower pressure stage while expanding, where it is discharged in exchange for the former gas. In a known device of this type, relating to a steam boiler, hot water boiler, furnace or other apparatus having a combustion chamber under pressure, a cell wheel is rotated in a shroud, the latter being provided with two pairs of openings. The cell wheel may be so designed that the gas is made to flow radially through the cells of the wheel, but they may also be arranged in such a manner that the gas flows through them axially or in some other way. Through one opening of one of the pairs of openings in the shroud, air flows into the cells, and the air thus displaces the gas previously contained in the cells so that the gas will flow out through the other opening of this pair of openings. When rotating, the cell wheel carries along the air which has entered the cells to one opening of the other pair of openings, where hot gases of combustion enter through a conduit from the combustion chamber, in which the fuel is burning. The gases of combustion coming from the latter opening displace the air, forcing it out through the other opening of the latter pair of openings, and take the place of the air in the cell wheel. The air then flows through a conduit to the combustion chamber, where it is used for combustion purposes. The hot gases entering the cell wheel are carried along by the same to the first mentioned pair of openings and are there discharged through a conduit to a heat-absorbing surface, which may consist of water-cooled walls.

The volume of air carried by the cell wheel to and into the combustion chamber is equal to the volume of gas carried away from the combustion chamber by the cell wheel. But as the gases leaving the combustion chamber have a higher temperature and thus at the same pressure a lower specific gravity than the air introduced, the pressure in the combustion chamber will rise until the specific gravity of the gas leaving and the air coming in is the same. At the temperature involved, a pressure of a few atmospheres above atmospheric pressure is thus obtained.

During the exchange of air for gases of combustion, which is effected in the cell wheel at the openings communicating with the combustion chamber, the air is being compressed to the pressure prevailing in the combustion chamber.

The gas leaving through the opening communicating with the heat-absorbing conduits has a comparatively high velocity as well as a pressure somewhat above atmospheric pressure. After the discharge, part of the velocity may also be transformed into pressure by means of a diffuser. The energy of the gas can be utilized for forcing the gas at high speed through the gas conduits forming the heat absorbing surface. Thus a high transfer of heat and for a certain heat effect an inexpensive heating surface is obtained. The device referred to has, however, not been used in practice for the purpose described here, mainly because the loss of energy is very great and the desired effect therefore is not attained; but it is known in principle and has come into use for other purposes in the case of heat pumps and gas turbines.

This invention is intended to improve the above de-

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scribed device. The invention thus relates to a steam boiler, hot water boiler, furnace or similar device, in which the combustion gases in the combustion chamber have a higher pressure than in the heat absorbing parts, the difference in pressure being obtained by means of a rotary pressure exchanger, the cells of which during rotation take in hot gas from the combustion chamber at high pressure, exchange this hot gas for the same volume of colder and heavier gas at lower pressure and return this colder gas to the high pressure stage where the gas content of further cells is exchanged for the hot gas taken up from the combustion chamber resulting in the transfer of a larger quantity of gas by weight from the lower pressure stage to the higher pressure stage than in the opposite direction in which apparatus the surplus of gas resulting in the combustion chamber from the rotary pressure exchanger transporting gas from the low to the high pressure stage is bypassed directly from the high pressure in the combustion chamber to the lower pressure in the heat absorbing parts of the apparatus. According to the invention, the apparatus is characterized in that the surplus of gas is utilized as a driving medium in a jet pump to draw along with it the hot gases coming from the rotary pressure exchanger and compress same, whereupon the combined quantity of gas at high velocity is forced through gas conduits in the heat-absorbing parts of the apparatus.

This apparatus can be provided with means for drawing off gas from the rotary pressure exchanger when the cells are moving from the high to the low pressure stage, so that this tapped gas by expansion to a low pressure stage, can be used for pre-compressing by means of a further jet pump the hot gas leaving the rotary pressure exchanger at the low pressure stage.

In one case as well as in the other the apparatus can be so constructed that there is a pressure in the combustion chamber that is higher than atmospheric pressure, and in the hot gas conduits atmospheric pressure or nearly atmospheric pressure. But alternatively it can also be arranged in such a manner that atmospheric pressure or nearly atmospheric pressure prevails in the combustion chamber, while the pressure in the hot gas conduits has a lower than atmospheric pressure.

It is suitable that those hot gases from the combustion chamber bypassing the rotary pressure exchanger have a higher temperature than the gases flowing through the rotary pressure exchanger.

For a better understanding of the invention and to show how it may be carried into effect the same will now be described with reference to the accompanying drawing, in which:

Fig. 1 shows one embodiment of the apparatus.

Fig. 2 shows a further embodiment of the apparatus.

Fig. 3 and Fig. 4 show details of a rotary pressure exchanger.

Fig. 5 shows an embodiment of a rotary pressure exchanger in cross-section along its shaft.

Fig. 6 shows the same rotary pressure exchanger in cross-section perpendicular to the shaft.

In the arrangement shown in Fig. 1, a cell wheel 1 of a rotary pressure exchanger rotates in a shroud 2, the latter being provided with openings 3, 4, 5 and 6. The cell wheel is, according to Fig. 1, so designed that the gas can flow radially through its cells. Through opening 3 in the shroud, air enters the cells, and the air thus displaces the gas which already is in the cells so that the gas flows out through opening 4. The cell wheel rotates in the direction of the arrow and carries along to opening 5 the air that entered the cells through opening 3. Through opening 5 hot gases of combustion enter from combustion chamber 7, in which fuel is burned. The combustion chamber may be water-cooled or followed by a heat absorbing surface in order to lower the temperature of the flue gases in a suitable manner. The gases of combustion coming from the opening 5 force the air out through opening 6 and replace the air in the cell wheel. The air flows through a duct 8 to the combustion chamber 7 where it is used for combustion. The hot gases entering the cell wheel at 5 are carried along by the cell wheel to opening 4 and leave

through a duct 9 to a heat-absorbing surface or heat exchanger 10, which may consist of water-cooled wall.

During the exchange of air for gases of combustion effected in the cell wheel at openings 5 and 6, the air is compressed to the pressure prevailing in the combustion chamber. Fig. 3 shows in detail how this compression can be effected. When the cells are opened toward the duct mouth 5 at edge 11, the gas under high pressure flows from 5 into the cells and compresses the air. A pressure wave is generated, which when the cell wheel rotates runs along the dotted line 11—12. When the pressure wave has arrived at the outer circumference of the wheel, the cells are opened at edge 12. After the pressure wave, which travels at a speed exceeding the velocity of sound, the gas flows in, but at a lower speed than the pressure wave. The speed of rotation of the cell wheel and the size of opening 6 are so adapted to the velocity of gas flow that, when the gas has passed through all the cells and forced out the air completely, the discharge side of the cells is closed by edge 13. Slightly before the discharge opening of the cells is closed by edge 13, the inlet is closed by edge 14. This results in a thinning wave running along line 14—13 and arriving at the discharge side of the cells just at the moment of closing the outlet. After the cell outlet has been closed at 13, the cell content is at rest at a pressure lower than the pressure in the combustion chamber. Alternatively it may be assumed that edge 13 closes sooner than edge 14. In that case a compression wave is obtained, which compresses the gas in the cells. It does not matter at all which procedure is chosen; the main point is that the energy of motion of the gas is utilized before the cells are closed entirely. During the exchange of gas, the air is partially compressed to the pressure prevailing in the combustion chamber, and partly the air obtains the energy of motion required for overcoming the resistance in duct 8 and in the combustion chamber.

After the gas has been entirely entrapped in the cells, nothing will happen before the cells arrive at openings 3 and 4. The process at these openings will be inferred from Fig. 4. When the cells pass edge 15, they are opened toward the lower pressure in opening 4, a thinning wave runs through the cells along line 15—16, and the gas flows out into opening 4. When edge 16 is passed, the cell content has begun to move; therefore the gas begins to leave the cells and is replaced by air from opening 3. The pressure in opening 4 is somewhat higher than in opening 3, which gradually retards movement of the gas. At edge 17 the cells have been entirely filled with air and their outlet end is closed. When the air current is suddenly held up, a pressure wave is generated, which runs backwardly along line 17—18. At 18 the whole cell content has been compressed to a pressure somewhat exceeding atmospheric pressure. Edge 18 closes the inlet side of the cells, and the cells move on toward openings 5 and 6, repeating the process.

Not all the hot gases, however, pass from combustion chamber 7 through the cell wheel 1 in the arrangement shown, but part of the gases flow through a duct 19 to a jet pump 20, consisting of a nozzle 21, through which the last mentioned gases expand with an increase in velocity to a pressure in the vicinity of atmospheric pressure, a mixing part 22 and a diffuser 23. The jet pump draws through duct 24 the hot gases leaving the cell wheel through opening 4. In the mixing part 22 the gases coming from the cell wheel and directly from the combustion chamber are mixed, and the velocity is mainly transformed then into pressure in diffuser 23. The gases are then forced at great velocity through conduit 10, which provides the heat absorbing surfaces or heat exchanger.

The arrangement according to Fig. 1 represents a number of advantages as compared with that described at the outset, which is known in principle. In the previous device, where all gases of combustion are passing through the cell wheel, the overpressure in the combustion chamber is comparatively high. At a temperature of 1000° C. in the gases leaving the combustion chamber the overpressure will for example be between 3 and 4 atmospheres. This high overpressure is unfavourable in regard to leakage. In the arrangement shown in Fig. 1, on the other hand, the overpressure in the combustion chamber can be varied. The more favour-

able operating result is obtained at an overpressure of about 1 atmosphere.

In the previous arrangement, the gases when passing through the plant will pass compression or expansion waves four times in succession. At a pressure ratio of 1:4 the loss of energy in each pressure wave is about 20%. In addition to this, considerable losses of energy must be taken into account at the inlet and outlet of the cell wheel, in the necessary diffusers, etc. The efficiency obtainable with the previously used process therefore is low. It is probably below 40%.

The process according to Fig. 1 will give better results merely because the pressure in the combustion chamber is lower. The pressure ratio in the compression and expansion waves will thus be reduced, which strongly reduces the losses in the same. But the principal gain is due to the fact that only a smaller portion of the gases passes through the cell wheel. The remainder flows through duct 19 and expands in the jet pump directly to high velocity. Although it must be admitted that jet pumps in most cases also are working with low efficiency, conditions are favourable in this special case for a jet pump, because a comparatively high velocity can be assumed for the driven medium coming through duct 24. If it is assumed that the driving and driven quantities of gas are equal and that the ratio between the velocities of the driving and driven gas is 2, which approximately corresponds to actual conditions, the efficiency of the jet pump, excluding diffuser losses, will be more than 70%. It can thus be expected that the arrangement as per Fig. 1 gives a much better efficiency than is possible according to the first-mentioned design. If only a minor part of the gas passes through the cell wheel, it is also possible to reduce the demands in regard to construction. One has no longer to depend upon the compression and expansion waves running in a correct manner. It becomes evident that it is even possible to disregard these processes altogether, and that good results are obtained also if the cell wheel merely acts as a simple gas sluice, which sluices hot gas from the higher pressure stage to the lower and the same volume of cold gas in the opposite direction.

The use of a jet pump according to Fig. 1 presents, however, other advantages. The cell wheel will not endure too high temperatures, and it is therefore not practicable to let gases flow directly from a large combustion chamber to the cell wheel; a certain amount of cooling down of the gases is necessary before introduction into the wheel. In the arrangement as per Fig. 1 only a smaller part of the gases has to be cooled down for reasons mentioned. The fact that gases can be allowed to pass through the jet pump at a higher temperature than through the cell wheel is another great advantage, since the total amount of energy gained, i. e. the overpressure of the hot gases before they are bypassed to the heat absorbing surfaces 10, increases rapidly if the temperature is increased.

Constructional and other difficulties may be met with when it comes to utilizing the velocity of the gases leaving the cell wheel through opening 4. However, the energy in the gas from arriving cells may be utilized by letting out gas while equalizing the pressure from the cells through a duct 25 and blowing out this gas into duct 24 in a jet pump arrangement which draws in the gas discharged at 4 and gives it a certain velocity before entering jet pump 20.

The apparatus as shown in Fig. 2 operates in principle in the same manner as the arrangement shown in Fig. 1, with a high pressure in the combustion chamber and a low pressure in the hot gas conduits forming the heat absorbing surface; but while in the arrangement according to Fig. 1 the outlet of the hot gas conduits communicates with the outside air, in this case the combustion chamber 7 is in direct connection with the atmosphere. In the arrangement shown in Fig. 2 there is thus atmospheric pressure in combustion chamber 7 and a vacuum in the heat exchanger 10.

The arrangement functions as follows: The air for combustion is taken into the combustion chamber through intake 26. From the combustion chamber, part of the combustion gases go to the cell wheel 1, into which the gas enters through opening 5. This forces out gases previously contained in the cell wheel through opening 6 into the atmosphere. The gas then goes along with rotating cell wheel to opening 4, where the gas flows out with ex-

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pansion to the lower pressure prevailing in the heat absorbing conduits. Another portion of the hot gases flows from combustion chamber 7 through duct 19 to jet pump 20. With the aid of the increase of pressure obtained in the jet pump 20 the gas is forced at high velocity through the conduit 10 forming the heat absorbing surface, where the gas is cooled to a low temperature, for instance 150° C. The gas then flows through a duct 27 and opening 3 to the cell wheel, where it replaces the gas leaving the cell wheel at 4. The cooled combustion gases are then carried along by the cell wheel to position 5—6, where gas at a higher pressure enters and compresses the gas to atmospheric pressure and forces it out through the opening 6 into the atmosphere.

The actual difference between the arrangements as per Fig. 1 and Fig. 2 is that the air entering at 3 in the former arrangement is replaced in the latter arrangement by cooled combustion gas. If in the arrangement according to Fig. 2 the combustion gases in the conduits of the heat absorbing surface could be cooled down to the temperature of the outside air, both arrangements would give the same effect. Since the temperature of the gases entering the cell wheel through opening 3 exceeds the temperature of the outside air, the useful temperature effect will be somewhat lower in the arrangement according to Fig. 2 than in the one as per Fig. 1. With reasonable and usable values for the gas temperatures it is possible to attain an arrangement according to Fig. 1 a pressure available for the conduits of the heat absorbing surface amounting to a 3000 mm. water column, whereas in the case of the arrangement as per Fig. 2 the corresponding pressure amounts to 1000 mm. water-column.

In the practical development of the apparatus, the jet pump, the ducts and conduits, the shroud around the cell wheel, etc., can be air- or water-cooled. The cell wheel can be made of fire-proof material. The cell wheel, or at least its shaft, can also be cooled by air or water flowing therethrough.

Figs. 5 and 6 show a type of design of the cell wheel arrangement. In this, 1 is the rotating cell wheel, 2 is the shroud with the inlet and outlet openings 3, 4, 5 and 6; 28 are hollows in the shroud filled with circulating cooling water.

What is claimed is:

1. Apparatus of the character described comprising the combination with a fuel burning combustion chamber producing combustion gases at a first pressure level and a rotary pressure exchanger receiving said gases at said first pressure level and discharging the same for passage in heat exchange relation with heat absorbing surfaces at a second and lower pressure level while receiving the same volume of a second, colder and heavier gas at said second pressure level and discharging the latter gas at said first pressure level whereby a greater weight of gas is transferred per unit of time from said second level to said first level than from said first level to said second level, of a jet pump receiving gas from said pressure exchanger at said second level, a duct connecting said combustion chamber and said pump whereby excess gas at said first level is conducted to said pump and provides power for increasing the velocity of gas flowing from said pressure exchanger through said pump to said heat absorbing surfaces whereby the co-efficient of heat transfer of said heat absorbing surfaces is increased.

2. Apparatus of the character described comprising the combination with a fuel burning combustion chamber producing combustion gases at a first pressure level and a rotary pressure exchanger receiving said gases at said first pressure level and discharging the same for passage in heat exchange relation with heat absorbing surfaces at a second and lower pressure level while receiving the same volume of a second, colder and heavier gas at said second

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pressure level and discharging the latter gas at said first pressure level whereby a greater weight of gas is transferred per unit of time from said second level to said first level than from said first level to said second level, of a pump receiving gas from said pressure exchanger at said second level, a duct connecting said combustion chamber and said pump whereby excess gas at said first level is conducted to said pump and provides power for increasing the velocity of gas flowing from said pressure exchanger through said pump to said heat absorbing surfaces whereby the co-efficient of heat transfer of said heat absorbing surfaces is increased.

3. Apparatus of the character described comprising the combination with a fuel burning combustion chamber producing combustion gases at a first pressure level and a rotary pressure exchanger receiving said gases at said first pressure level and discharging the same for passage in heat exchange relation with heat absorbing surfaces at a second and lower pressure level while receiving the same volume of a second, colder and heavier gas at said second pressure level and discharging the latter gas at said first pressure level whereby a greater weight of gas is transferred per unit of time from said second level to said first level than from said first level to said second level, of a first jet pump receiving gas from said pressure exchanger at said second level and discharging the same to a second jet pump and to said heat absorbing surfaces, a duct connecting a high pressure portion of said pressure exchanger with said first jet pump whereby power is provided for compressing the gas in said first jet pump, a duct connecting said combustion chamber and said second jet pump whereby excess gas at said first level is conducted to said second jet pump and provides power for increasing the velocity of gas flowing from said pressure exchanger through said second jet pump to said heat absorbing surfaces whereby the co-efficient of heat transfer of said heat absorbing surfaces is increased.

4. Apparatus of the character described comprising the combination with a fuel burning combustion chamber producing combustion gases at a first pressure level and a rotary pressure exchanger receiving said gases at said first pressure level and discharging the same for passage in heat exchange relation with heat absorbing surfaces at a second and lower pressure level while receiving the same volume of a second, colder and heavier gas at said second pressure level and discharging the latter gas at said first pressure level whereby a greater weight of gas is transferred per unit of time from said second level to said first level than from said first level to said second level, of a first pump receiving gas from said pressure exchanger at said second level and discharging the same to a second pump and to said heat absorbing surfaces, a duct connecting a high pressure portion of said pressure exchanger with said first pump whereby power is provided for compressing the gas in said first pump, a duct connecting said combustion chamber and said second pump whereby excess gas at said first level is conducted to said second pump and provides power for increasing the velocity of gas flowing from said pressure exchanger through said second pump to said heat absorbing surfaces whereby the co-efficient of heat transfer of said heat absorbing surfaces is increased.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,399,394	Seippel	Apr. 30, 1946

FOREIGN PATENTS

Number	Country	Date
8,273	Great Britain	Apr. 5, 1906