

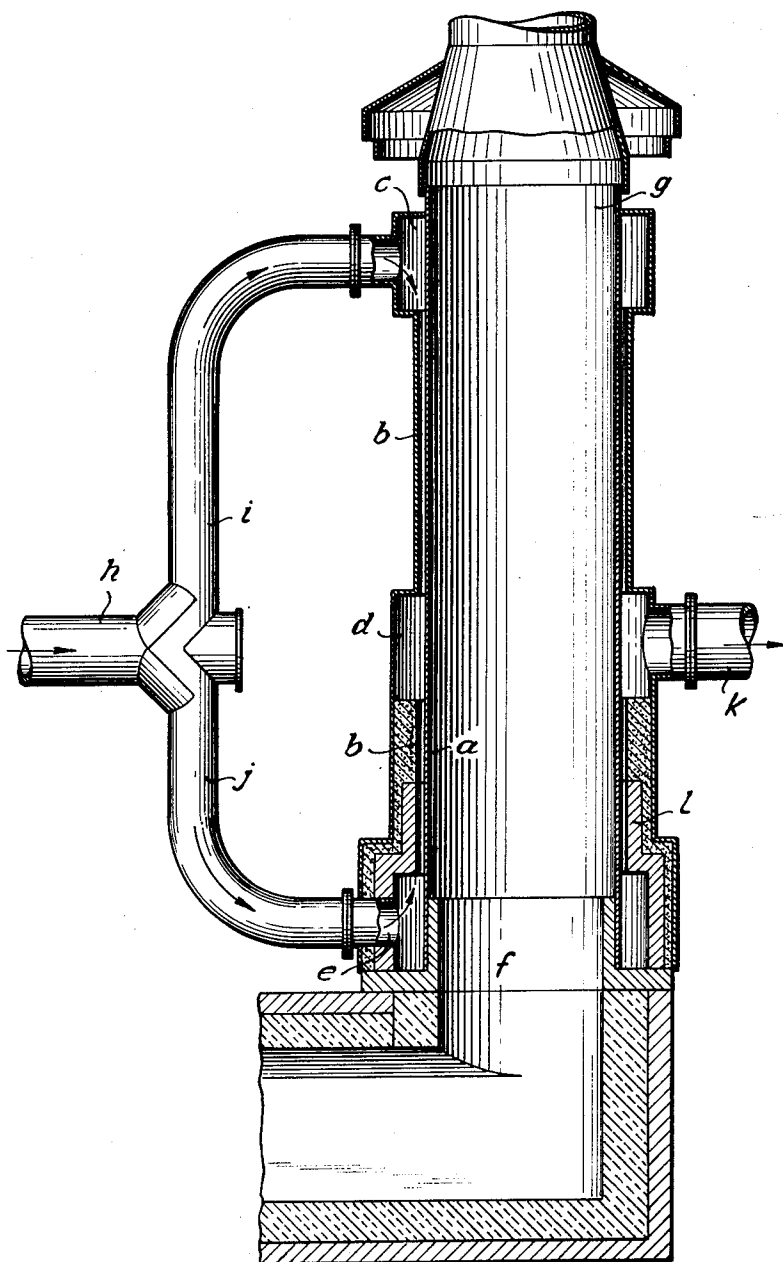
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RADIATION RECUPERATORS

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RADIATION RECUPERATORS

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The present invention relates to recuperators and more particularly to radiation recuperators in which the hot gases give up their heat primarily through infra-red rays to the gas which is to be heated.

Such recuperators are used in the form of convection recuperators advantageously in those instances where a high efficiency is not of primary importance and where there is no necessity for heating large amounts of gas, because of the fact that such recuperators are not undesirably influenced by overheating and by the presence of dust and the like in the hot gases which give up their heat. Also, such recuperators have no pressure loss at the part which handles the hot gases from which heat is derived.

However, the above advantages are obtained only as long as the recuperator operates substantially at its rated load. When such a recuperator operates at considerably less than its rated load then the ratio of heat transfer from the hot to the cool gases becomes so poor that such recuperators are of no use. The extent of gas radiation is independent of the speed of movement of the gas, while the rate of heat transfer to the cool gases decreases with the 0.8 power of the speed of movement of the cool gases. Where α is the rate of heat transfer of the hot gases which give up their heat and α' is the rate of heat transfer of the cool gases which are to be heated, and t and t' are respectively the temperatures of the hot and cool gases, then the wall temperature t_s of the recuperator according to "Der industrielle Wärmeübergang" 4th ed., 1953, Gl. 4, by A. Schack, is as follows:

$$t_s = \frac{\alpha t + \alpha' t'}{\alpha + \alpha'}$$

From this equation it follows that in extreme cases where the rate of heat transfer of the cool gases becomes zero the wall temperature t_s becomes the same as the temperature t of the hot gases. Inasmuch as it is customary in radiation recuperators to supply at the entrance end of the recuperator hot gases at a temperature of 1100–1200° C., it is apparent that the wall temperature of the recuperator will become equal to this latter temperature, and the recuperator will quickly fail to be of any further use.

In modern high temperature furnaces, particularly pit furnaces for heating ingots and the like, the temperature is controlled in such a way that the amount of gas of the furnace is reduced as the temperature of the furnace increases so that when the desired furnace temperature is reached the amount of gas used in the furnace is 10% of the amount normally used, such a reduced amount of gas being used during the time that the workpieces such as ingots reach an equilibrium temperature.

During such a period of operation the temperature of the hot gases which enter the regulator are particularly high and the rate of heat transfer from the hot gases to the inner wall of the recuperator resulting almost entirely from radiation is also particularly high, while at this same time the cool gases which are to be heated by con-

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vection while engaging the outer surface of the wall whose interior is heated by radiation of the hot gases are heated at a rate of heat transfer which is 10^{0.8} or 16% of the normal value because of the reduced heating taking place in the furnace. These conditions lead to the above-mentioned extreme values. The gas, such as air, which is heated by convection while engaging a wall the inner surface of which is heated by radiation from gases discharging from a furnace is fed to the furnace, the recuperator being used to preheat the air used to maintain combustion in the furnace.

One of the objects of the present invention is to overcome the above drawbacks by providing a recuperator which can operate under conditions as set forth above without any danger of breakdown of the recuperator.

Another object of the present invention is to provide a recuperator capable of overcoming the above drawbacks and at the same time capable of operating without sacrificing efficiency of operation.

A further object of the present invention is to provide a recuperator of relatively simple construction capable of accomplishing the above objects.

With the above objects in view the present invention includes in a recuperator a pair of recuperator portions having, respectively, inner tubular portions connected in series for conducting hot gases therethrough. The recuperator includes outer tubular portions respectively surrounding the inner tubular portions and connected in parallel with each other so that the gases which are to be heated and which move through the annular spaces between the inner and outer tubular members move concurrently with and partly in countercurrent to the hot gases. Concurrent movement of the gas to be heated with respect to the hot gases is provided at the region where the hot gases enter the recuperator.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

Referring now to the drawing, the recuperator of the invention includes an inner tubular member *a* having a lower portion which forms an inner tubular member of one recuperator portion and an upper portion which forms an inner tubular member of another recuperator portion. These tubular members of the two recuperator portions are connected in series, and in fact as shown in the drawing the inner tubular member *a* which forms the inner tubular portions of both recuperator portions is in the form of a single continuous cylindrical tube of sheet metal.

A lower outer tubular portion *b* surrounds and is spaced from the lower portion of the inner tube *a* and defines an elongated annular passage therewith, and an upper tubular portion *b* surrounds and is spaced from the upper portion of the inner tube *a* and defines a second elongated annular passage therewith.

The cool gases which are to be heated so as to be preheated before being delivered to the furnace enter through a conduit *h* to the branches *i* and *j* leading from the conduit *h* respectively to a pair of end rings *c* and *e* which surround and are spaced from the ends of the tubular member *a*. At the entrance end *f* of the tubular member *a* a conduit leading from the furnace delivers hot gases to the inner tubular member *a*, and at the discharge end *g* of the tubular member *a* the hot gases are conducted away through any suitable conduits. Thus, the ring *e* which communicates with the entrance end of the lower tubular portion *b* of the lower recuperator por-

tion delivers the air to be heated to the part of the tubular member *a* which is located at its entrance end, and the gases which are to be heated flow along the annular passage defined by the lower portion of tubular member *a* and the lower tubular member *b* concurrently with the hot gases within the tubular member *a*.

On the other hand, the gases delivered through the conduit *i* to the ring *c* engage the tubular member *a* adjacent its discharge end, and these gases flow downwardly along the annular passage between the upper tubular member *b* and the upper portion of the inner tubular member *a*, so that these parts define a second recuperator portion in which the gases to be heated flow in counter-current to the gases which give up their heat. The hot gases within the tubular member *a* heat the latter by radiation while the air at the exterior of member *a* is heated primarily by convection. It will be noted that with this arrangement the pair of inner tubular portions formed by the lower and upper parts of the tubular member *a* are connected in series whereas the outer tubular members *b* are connected in parallel.

A collecting ring *d* forms together with the conduit *k* which communicates and leads from the collecting ring *d* a conduit means communicating with an intermediate portion of the elongated annular passage defined between the entire tubular member *a* and the tubular means *b*, *c*, *e*, in order to lead from this intermediate portion of the elongated annular passage the preheated gases which are then delivered to the combustion chamber of the unillustrated furnace by the conduit *k*. Thus, both of the tubular members *b* communicate at their discharge ends which are adjacent each other with the collecting ring *d*, while the entrance ends of the upper and lower tubular members *b* respectively communicate with the annular spaces defined by the end rings *c* and *e* with the tubular member *a*.

The above-described recuperator portions which are connected in series with respect to the hot gases and in parallel with respect to the cool gases are so designed that the cool gases may be preheated to the desired temperature of 650° C., for example.

Concurrent flow of the gases which are in heat exchanging relation with respect to each other is desirable where extremely high temperatures are involved so that the cool gases engage the wall of the heat exchanger where the hot gases have the highest temperature and thus there is less possibility of breakdown of the heat exchanger. However, the efficiency obtained with such concurrent flow arrangements is relatively low. Much greater efficiency is obtained by countercurrent flow of the heat exchanging mediums, but such an arrangement would mean that the cool gases are heated to their greatest extent at the place where they engage the wall portion of the heat exchanger located at the entrance of the hot gases, and thus when operating at extremely high temperatures great difficulties are involved in maintaining the heat exchanger in operation under such countercurrent flow conditions. With the structure of the present invention, however, the advantages of both concurrent and countercurrent flow arrangements are obtained so that on the one hand there is no danger of breakdown of the recuperator and on the other hand a relatively high efficiency is maintained.

As was pointed out above, under certain circumstances a furnace is operated with approximately 10% of the amount of combustion air which is used during normal operation, and under these conditions a recuperator as described above will not in general suffice because of the low rate of heat transfer to the air which is to be preheated, even if this air is at quite a low temperature. In order to avoid overheating of the recuperator during such operation the wall of the lower outer tubular member *b* which surrounds the entrance end *f* of the tubular member *a* is not insulated in the usual way and is instead composed of a ceramic material *l* having the highest

possible coefficient of thermal conductivity and the highest possible specific weight, so that it has the highest capability of storing heat. This wall *l* is spaced from and directed toward the outer surface of the tubular member *a* at the entrance end of the latter. The term "ceramic" in connection with the wall *l* is intended to cover in this specification and the claims which follow not only manufactured ceramic materials such as fire-brick and the like, but in addition natural stone.

If, for example, the wall *l* has a thickness of 125 mm. and a specific weight of 2,000 kg./m.³, higher specific weights being possible, then the coefficient of thermal conductivity is 1.0 kcal./mh.° C., and such materials are easily obtained, and in a period of more than ½ hour each square meter absorbs an amount of heat which is substantially the same as the amount of heat transferred during normal operation of the recuperator. Thus, this wall *l* provides a very pronounced cooling effect and therefore protects the recuperator from unexpected or periodic temporary overheating of short duration. The heat is transferred to the ceramic wall *l* from the inner tubular member *a* across the air gap between the wall *l* and the tubular member *a* to the wall *l* by radiation.

At the elevated temperatures referred to above the radiation is so strong that substantially the same results are obtained as if the heat storing wall *l* were located directly against the outer surface of the inner tubular member *a*.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of recuperators differing from the types described above.

While the invention has been illustrated and described as embodied in radiation recuperators, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a radiation recuperator, in combination, a continuous elongated inner metallic tubular member; a pair of end rings surrounding said inner tubular member adjacent the ends thereof and defining a pair of annular spaces therewith; an intermediate ring surrounding said inner tubular member at an intermediate portion between the ends thereof and defining an annular collecting space therewith, said intermediate ring having an outlet means; a pair of outer tubular members extending from said intermediate ring respectively to said end rings, respectively spaced from and surrounding said inner tubular member, and respectively communicating with said spaces defined by said rings so that gases in said annular end spaces will flow in opposite directions along the space between said outer tubular members and said inner tubular member to said collecting space and turbulently mix in said collecting space before passing through said outlet means; supply means for simultaneously supplying gases to be heated to said annular end spaces; and means for directing hot gases along the interior of said inner tubular member from one end to the other end thereof whereby the gases flowing from said annular end spaces toward said collecting space flow in parallel streams the one concurrently with and the other in countercurrent to the hot gases in said inner tubular member.

2. In a radiation recuperator, in combination, a continuous elongated inner metallic tubular member having

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a gas inlet end and a gas outlet end; one end ring surrounding said inner tubular member adjacent the gas outlet end thereof and defining an annular space therewith; another end ring surrounding said inner tubular member adjacent the gas inlet end thereof and defining an annular space therewith; an annular wall of ceramic material of high heat conductivity and heat storage capacity within said ring adjacent the gas inlet end directed toward said inner tubular member thereof and adapted to absorb heat of the hot gases entering said tubular member transmitted therefrom by radiation outwardly across said annular space; an intermediate ring surrounding said inner tubular member at an intermediate portion between the ends thereof and defining an annular collecting space therewith, said intermediate ring having an outlet means; a pair of outer tubular members extending from said intermediate ring respectively to said end rings, respectively spaced from and surrounding said inner tubular member, and respectively communicating with said spaces defined by said rings so that gases in said annular end spaces will flow in opposite directions along the space between said outer tubular members and

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said inner tubular member to said collecting space and turbulently mix in said collecting space before passing through said outlet means; supply means for simultaneously supplying gases to be heated to said annular end spaces; and means for directing hot gases along the interior of said inner tubular member from one end to the other end thereof whereby the gases flowing from said annular end spaces toward said collecting space flow in parallel streams the one concurrently with and the other in countercurrent to the hot gases in said inner tubular member.

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