

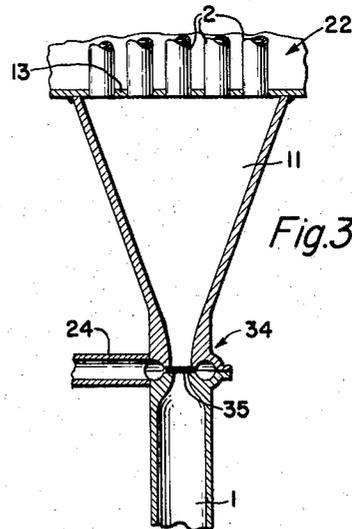
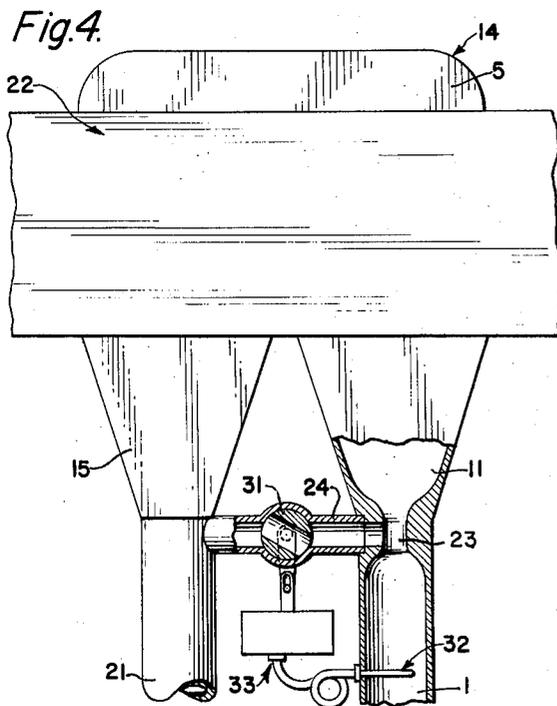
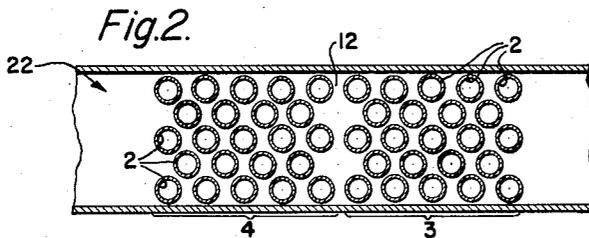
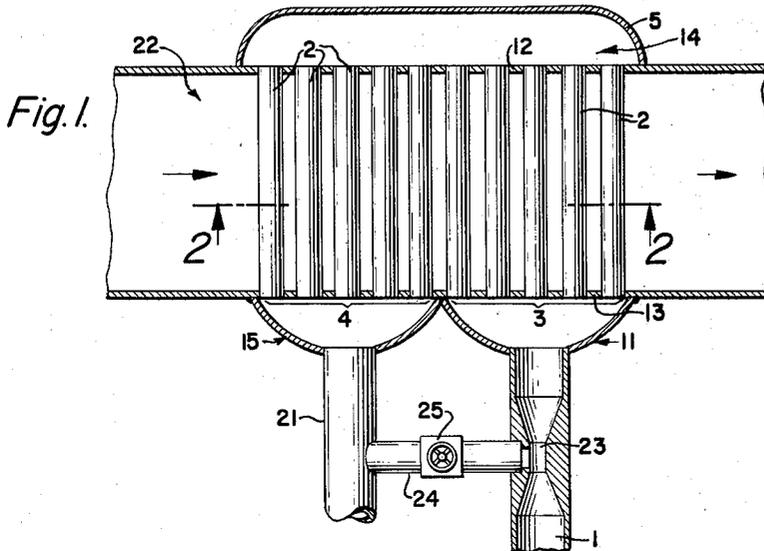
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PROTECTIVE RECIRCULATION MEANS FOR HEAT EXCHANGERS

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## PROTECTIVE RECIRCULATION MEANS FOR HEAT EXCHANGERS

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In the operation of heat exchangers of the type where-  
 in a first fluid at one temperature is cooled by heat transfer  
 to a second fluid at a lower temperature, it is often  
 desirable to provide means whereby the temperature of  
 the inlet fluid to be cooled may be adjusted to a tolerable  
 or an optimum level before it is admitted to the heat  
 transfer elements themselves. This is especially true in  
 vehicular and similar practice where it is important that  
 the size and weight of component assemblies be minimal  
 and where the materials of construction are often called  
 upon to perform close to the limits of their strength and  
 thermal capabilities.

The present invention, which relates to a novel construction  
 for heat exchangers, such as those commonly  
 used to cool liquid or gaseous fluids in propulsion, control,  
 heating or refrigeration systems, provides effective  
 means for adjusting the temperature of the inlet fluid to  
 a level consistent with the thermal tolerance and optimum  
 performance of the heat exchange elements themselves.  
 More specifically, it relates to such a construction which  
 is particularly adapted to use with heat exchangers of  
 the type in which a first fluid, either liquid or gaseous,  
 is to be cooled by heat transfer, through a thermally  
 conductive flow barrier, to a second fluid, which may likewise  
 be either liquid or gaseous.

One of the objects of the invention is to provide means  
 for protecting the interior structure of a heat exchanger  
 of the type described from the adverse effects of high  
 temperature by precooling the inlet fluid admitted thereto.

Another object of the invention is to provide such  
 precooling of the inlet fluid through the introduction and  
 admixture therewith of a recirculated portion of fluid  
 which has been cooled by passage through the heat  
 exchanger.

Another object of the invention is to provide means  
 for metering the quantity of cooled fluid to be admitted  
 to the heat exchanger inlet and for assuring that said  
 fluid will be uniformly dispersed in the inlet fluid so  
 as to effectively lower the temperature thereof.

Another object of the invention is to provide means  
 whereby the quantity of cooled fluid introduced into the  
 inlet of the heat exchanger may be regulated in accordance  
 with the temperature of the fluid at either the inlet  
 or the outlet thereof, or in accordance with other parameters  
 that may be of critical importance in particular  
 applications.

Another object of the invention is to provide means  
 for the introduction of cooling fluid at a heat exchanger  
 inlet so as to form a thermally protective boundary  
 layer to shield the structure at the region of the inlet from  
 direct contact with high temperature incoming fluid.

Another object of the invention is to provide for the  
 introduction of cooled fluid to a heat exchanger inlet  
 by self-energized means responsive to the prevailing flow  
 conditions therein.

Still further objects of the invention will be apparent  
 to those skilled in the art from the following specification  
 and the appended drawings.

The invention may be more clearly understood by  
 reference to the accompanying drawings, which are intended  
 only to illustrate typical preferred practice thereof,  
 it being understood that variations in constructional  
 details apparent to those skilled in the art may be made

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without departing from the spirit or scope of the invention.  
 In the drawings, in which like elements are designated  
 by like reference numerals:

FIG. 1 is a partially schematic view of a heat exchanger  
 according to the present invention;

FIG. 2 is a sectional view, taken perpendicular to  
 the plane of FIG. 1 and along the line 2-2 thereof,  
 further illustrating the construction of the core in which  
 heat transfer is effected;

FIG. 3 is a sectional view illustrating an alternate  
 construction for certain elements of the heat exchanger shown  
 in FIG. 1; and

FIG. 4 diagrammatically illustrates an embodiment of  
 the invention in which the recirculation of cooled fluid  
 is controlled in accordance with a measurable parameter.

Referring now to FIG. 1, a heat exchanger of the general  
 type described is schematically illustrated in cross  
 section. A fluid inlet 1 communicates, through a diffuser  
 or manifold 11, with a plurality of tubular elements 2  
 which may, in certain practices of the invention, be arranged  
 in separate groups so as to achieve a compact and  
 thermally efficient structure. In the embodiment shown,  
 for example, the tubular elements 2 secured between  
 header plates 12 and 13 are grouped in a first pass 3,  
 wherein the fluid to be cooled flows from bottom to  
 top as shown in the drawing, and a second pass 4, where-  
 in the fluid flows in the reverse direction, communication  
 between the first and second passes being provided by  
 a transfer passage 14, which may, for example, be formed  
 by a suitably shaped cover 5 secured to the top header  
 plate 12, the space between the cover 5 and the header  
 plate 12 being sufficient to afford unimpeded flow  
 communication between the first and second passes 3 and 4.  
 From the second pass 4, the fluid is conducted through  
 a suitably shaped collector 15 to an outlet 21.

A fluid coolant is conducted, via a conduit 22, around  
 the exterior surfaces of the tubular conduits 2 comprising  
 the first and second passes 3 and 4, the header plates  
 12 and 13 and the side walls of the conduit 22 serving  
 to define a fluid-tight enclosure therefor. As will be  
 apparent to those skilled in the art, the flow of coolant  
 through the conduit 22 should preferably be from left to  
 right as shown in the drawing; that is, the coolant should  
 traverse the second pass 4 before traversing the  
 first pass 3, maximal heat transfer being effected when  
 the temperature difference between the two fluids is  
 greatest.

As previously discussed, it frequently occurs that  
 heat exchangers of the type shown must be used at or  
 near the maximum temperature at which the materials  
 of their construction may be safely or efficiently used.  
 Where this is the case, it is desirable to provide some  
 means for regulating the temperature of the fluid introduced  
 at the inlet 1, thereby to assure efficient and safe  
 operation. It will be apparent, however, that many  
 cases may occur, for example, in the cooling of gas turbine  
 exhaust gases, where it is not feasible to accomplish  
 such regulation without either altering the operating  
 parameters of the engine or providing a second, supplementary  
 heat exchanger. To circumvent this difficulty and  
 thereby accomplish a primary object of the invention,  
 namely to afford control of inlet temperature through  
 the recirculation of cooled fluid, the present invention  
 provides a Venturi injector or aspirator 23 positioned  
 in the inlet 1 so as to induce flow thereinto from the outlet  
 21 through a recirculation passage 24 connected to the  
 throat of the Venturi. Thus, the temperature of the  
 outlet fluid having been lowered by passage through the  
 first and second passes of heat exchange conduits 3  
 and 4, its admixture to the inlet fluid results in a corresponding  
 reduction in the temperature thereof. The  
 extent of this reduction is proportional to the temperature

difference between the fluid expelled from the outlet 21 after passage through the exchanger and the uncooled fluid introduced at the inlet 1, and to the relative quantity or mass of cooled fluid introduced via the recirculation passage 24 and the Venturi injector 23. Accordingly, the present invention provides for the inclusion in the recirculation passage 24 of appropriate control means in the form of a flow limiter 25. Where the flow and temperature conditions at which the heat exchanger is required to operate are relatively constant, the flow limiter 25 may comprise a fixed metering element or orifice, the maximum rate of flow through which is limited by the establishment of sonic velocity. Where operation over a varying range of conditions is anticipated, however, a variable flow limiter, which may for example be a butterfly, needle, piston or other type of valve, controllable in relation to the fluid temperature at the inlet or outlet or to both temperatures, or to other criteria, may be provided.

FIG. 4 schematically illustrates such an arrangement in which a variable flow limiter or valve 31 is thermostatically controlled in response to the temperature of the fluid introduced at the inlet 1. A temperature sensing element 32 is exposed to the inlet fluid so as to develop a signal indicative of the temperature thereof for transmission to a valve actuating means 33. It will be apparent to those skilled in the art that the temperature sensing element 32 and the valve actuating means 33 may operate on mechanical or electrical principles or on a combination thereof and may be selected for particular applications and design conditions from a wide variety of such instruments well known in the art and readily available in commerce. Further, it is to be understood that the invention is not limited to the particular arrangement of sensing and control elements shown, but that numerous variations thereon may be devised to meet particular operating requirements. The sensing element 32, for example, may be moved downstream of the Venturi injector 23 so as to provide, in effect, a feedback loop in the control system, or it may be positioned in the outlet 21 or in the conduit 22. Similarly, a differential sensing instrument responsive to the temperature difference between the inlet and outlet fluid may be used, or alternately, a measurable physical parameter remote from the heat exchanger itself may, in some cases, be used to develop control signals for operation of the variable flow limiter 31.

As previously mentioned, the temperature reduction of the incoming fluid afforded by the present invention is proportional to the relative mass of fluid introduced at the Venturi injector 23 and the temperature difference between the incoming fluid at the inlet 1 and the fluid expelled at the outlet 21. Thus, for example, if the temperature of the incoming fluid is designated  $T_1$  and that of the expelled fluid  $T_3$ , and the mass of fluid recirculated through the conduit 24 and Venturi injector 23 is a fraction  $x$  of the mass originally introduced at the inlet 1, the temperature  $T_2$  of the mixed fluids leaving the injector 23 may be determined according to the approximate equation:

$$T_2 = \frac{T_1 + T_3(x)}{1+x}$$

In conjunction with the physical characteristics of the particular fluid under consideration, this expression affords means for computation of the degree of recirculation required for a specific application.

In cases where it may be more important to protect the structure of the inlet diffuser 11, rather than the interior of the heat exchanger itself, from the effects of high incoming fluid temperatures, an alternate form of Venturi injector 34 as illustrated in FIG. 3 may be used to advantage. In the construction shown, the Venturi injector 34 is provided with an annular port 35 positioned in the throat of the Venturi and in flow com-

municating relation with the recirculation passage 24. By virtue of this arrangement a protective boundary layer of cooler fluid from the outlet 21 may be distributed over the divergent surfaces of the Venturi injector 34 and the diffuser 11, thereby insulating these surfaces from direct contact with the high temperature fluid introduced at the inlet 1.

It will be apparent from the foregoing specification that the present invention affords simple, economical and effective means for the regulation of heat exchanger inlet temperatures so as to confer the benefits of operating safety and efficiency under conditions where it is necessary to approach the maximum safe thermal limits of the materials of construction. Further, it provides means adaptable to all types of fluid heat exchangers whereby inlet or outlet temperatures, or the difference between said temperatures, may be subject to continuous regulation without incurring undue penalties in the efficiency, complexity or weight of the heat exchange unit or its connecting ducting.

It is anticipated that those skilled in the art will have opportunity to practice numerous variations on the invention as herein disclosed, and it is intended that all such variations falling within the spirit and scope of the invention be secured to us by United States Letters Patent.

We claim:

1. In combination: a heat exchanger having first and second fluid passages including portions disposed internally of the exchanger in heat transfer relationship for conveying a first, relatively hot fluid and a second relatively cold fluid, respectively, in heat transfer relation to one another; said first passage having first and second fluid inlets and first and second fluid outlets, said first inlet and said first outlet being adapted for connection to an external fluid circuit; means defining a recirculation passage directly communicating said second outlet to said second inlet through which a portion of said first fluid exhausting from said heat exchanger after having been cooled by said second fluid may recirculate to mix with and cool the relatively hot first fluid entering the heat exchanger from said external fluid circuit through said first inlet; means for inducing flow of said first fluid through said recirculation passage from said second outlet to said second inlet; temperature responsive means disposed in efficient heat transfer relation to said first passage adjacent said first inlet so as to be highly responsive to the temperature of the hot fluid entering the heat exchanger through said first inlet; and means in said recirculation passage controlled by said temperature responsive means for regulating recirculation flow of said first fluid through said recirculation passage in such manner that said recirculation flow increases in response to increasing temperature of the first fluid entering the heat exchanger and decreases in response to decreasing temperature of the first fluid entering the heat exchanger, thereby to maintain the temperature of the combined first fluid flowing from said first and second inlets to said internal portion of said first passage below a predetermined maximum temperature.

2. In combination: a heat exchanger having first and second fluid passages including portions disposed internally of the exchanger in heat transfer relationship for conveying a first, relatively hot fluid and a second relatively cold fluid, respectively, in heat transfer relation to one another; said first passage having first and second fluid inlets and first and second fluid outlets, said first inlet and said first outlet being adapted for connection to an external fluid circuit; means defining a recirculation passage directly communicating said second outlet to said second inlet through which a portion of said first fluid exhausting from said heat exchanger after having been cooled by said second fluid may recirculate to mix with and cool the relatively hot first fluid entering the heat exchanger from said external fluid circuit through said first inlet; means for inducing flow of said first fluid through said

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recirculation passage from said second outlet to said second inlet; temperature responsive means disposed in efficient heat transfer relation to said first passage adjacent said first inlet so as to be highly responsive to the temperature of the hot fluid entering the heat exchanger through said first inlet; and valve means in said recirculation passage controlled by said temperature responsive means for regulating recirculation flow of said first fluid through said recirculation passage in such manner that said recirculation flow increases in response to increasing temperature of the first fluid entering the heat exchanger and decreases in response to decreasing the temperature of the first fluid entering the heat exchanger, thereby to maintain the temperature of the combined first fluid flowing from said first and second inlets to said internal portion of said first passage below a predetermined maximum temperature.

3. In combination: a heat exchanger having first and second fluid passages including portions disposed internally of the exchanger in heat transfer relationship for conveying a first, relatively hot fluid and a second relatively cold fluid, respectively, in heat transfer relation to one another; said first passage having first and second fluid inlets and first and second fluid outlets, said first inlet and said first outlet being adapted for connection to an external fluid circuit; means defining a recirculation passage directly communicating said second outlet to said second inlet through which a portion of said first fluid exhausting from said heat exchanger after having been cooled by said second fluid may recirculate to mix with and cool the relatively hot first fluid entering the heat

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exchanger from said external fluid circuit through said first inlet; means for inducing flow of said first fluid through said recirculation passage from said second outlet to said second inlet; a valve in said recirculation passage; and means including a temperature sensing element situated directly in said first inlet for operating said valve in such manner that said valve opens to increase fluid flow through said recirculation passage in response to increasing fluid temperature in said first inlet and closes to decrease fluid flow through said latter passage in response to decreasing fluid temperature in said first inlet, thereby to maintain the temperature of the combined first fluid flowing from said first and second inlets of said internal portion of said first passage below a predetermined maximum temperature.

References Cited by the Examiner

UNITED STATES PATENTS

20	1,223,976	4/17	Hiller	-----	122-412
	1,749,654	3/30	Wyndham, et al.	-----	165-108
	2,104,333	1/38	Rosenblad	-----	165-34
	2,178,805	11/39	Olcott	-----	165-40
	2,363,870	11/44	Karlsen, et al.	-----	165-7
25	2,488,267	11/49	Cassie.		
	2,836,399	5/58	Fallon	-----	165-108
	3,063,681	11/62	Duguid.		

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