



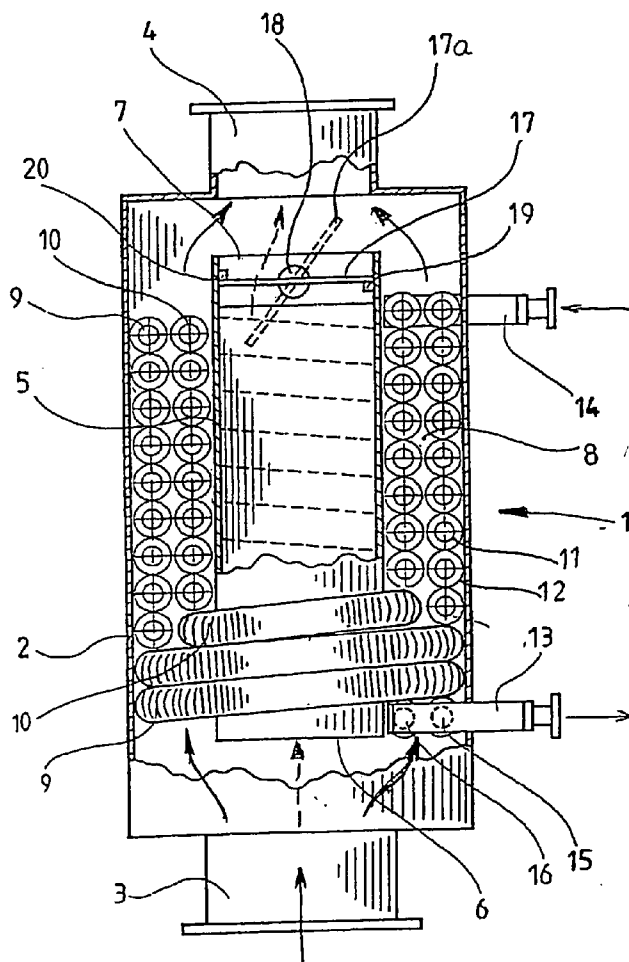
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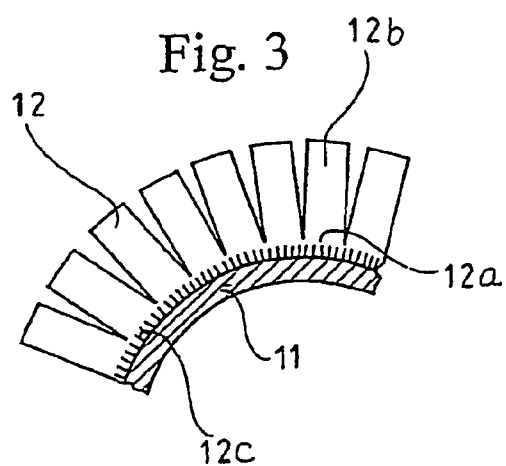
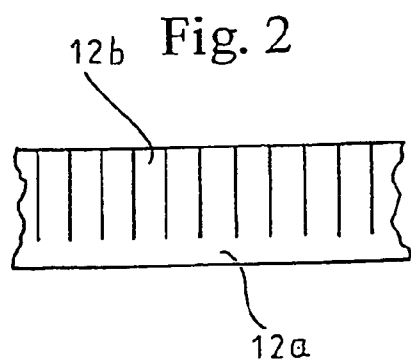
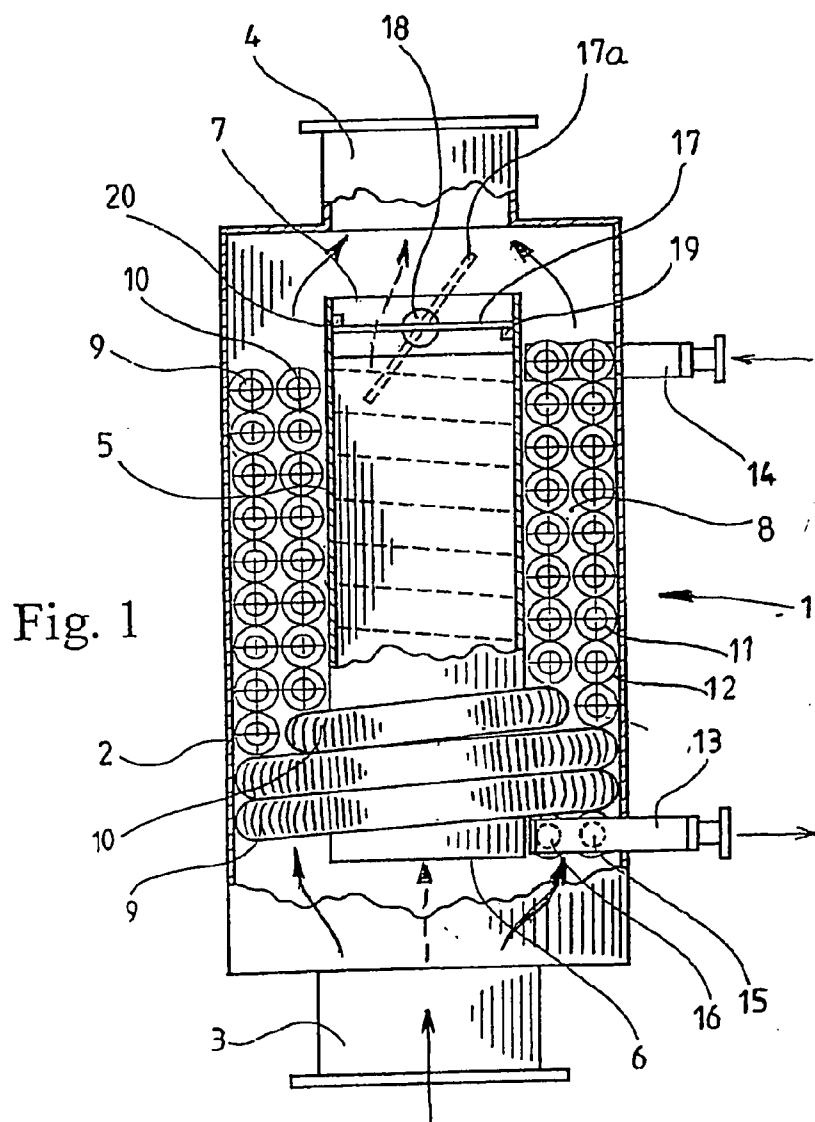
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HEAT EXCHANGER AND METHOD OF
MANUFACTURING THE HEAT
EXCHANGER**(30) **Foreign Application Priority Data**

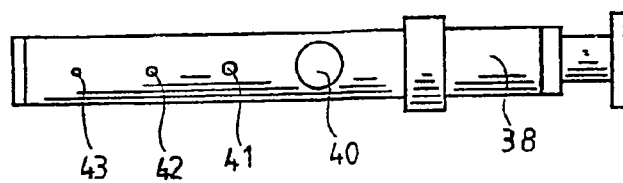
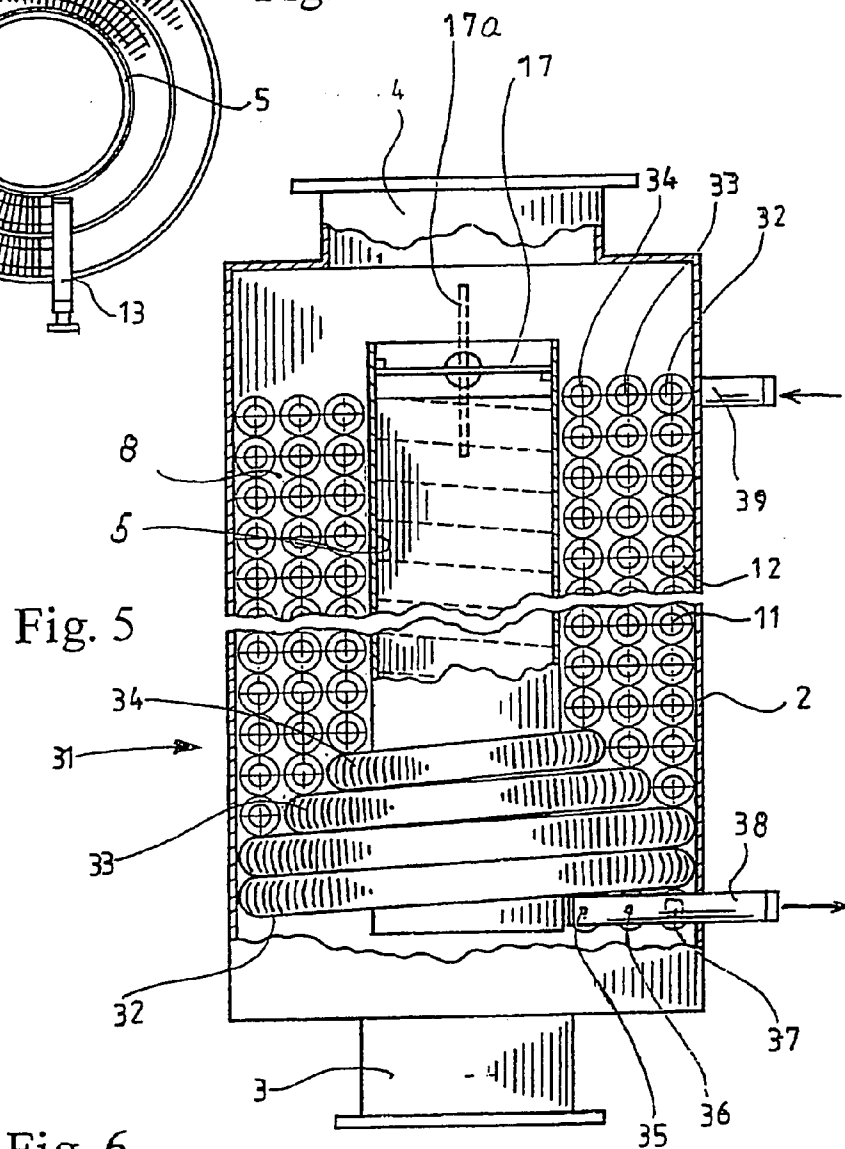
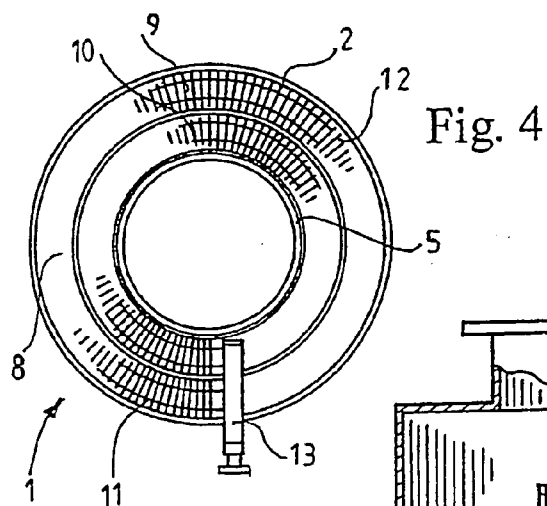
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IRVINE, CA 92614 (US)(57) **ABSTRACT**

A heat exchanger for heat exchange between a first and a second fluid and comprising a cylindrical casing 2, a cylindrical fluid conduit 5 arranged inside the casing such that an axially extending tubular space 8 is defined, at least one helical coil 9, 10 of a finned or corrugated tube being arranged inside the tubular space, and adjustable throttle means 17, 17a, 18 adapted and arranged for adjustably throttling flow of the first fluid through the conduit 5 to adjust the flow of the first fluid through the conduit and the first tubular space for adjusting the heat exchange between the first fluid and the second fluid flowing through the helical coils 9, 10.

(73) Assignee: **Aalborg Industries A/S**, Aalborg (DK)(21) Appl. No.: **10/840,952**(22) Filed: **May 7, 2004****Related U.S. Application Data**(63) Continuation of application No. PCT/DK02/00748,
filed on Nov. 7, 2002.





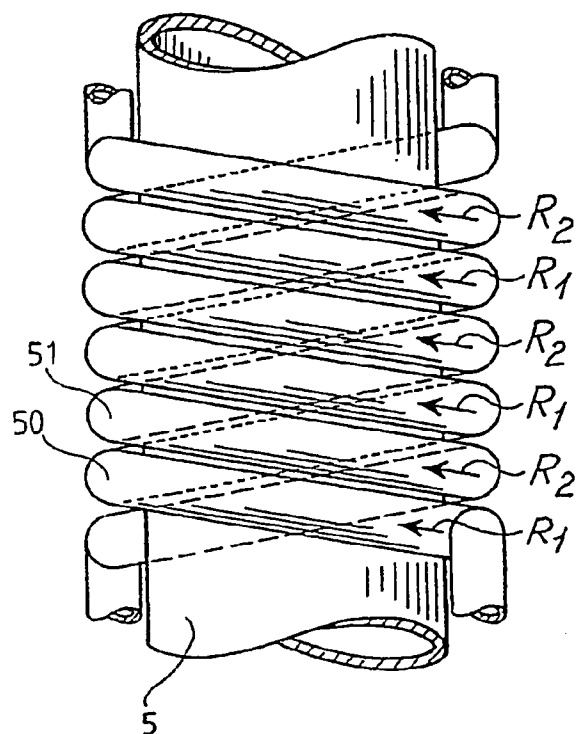


Fig. 7

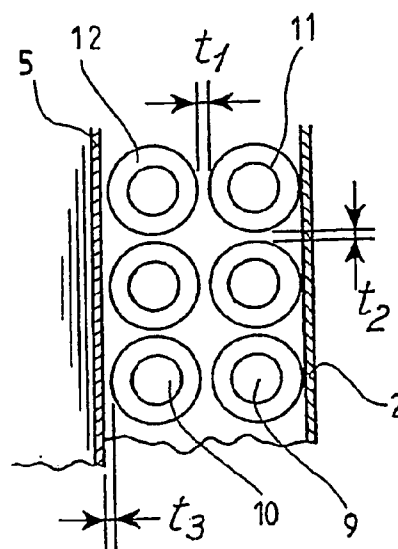


Fig. 8

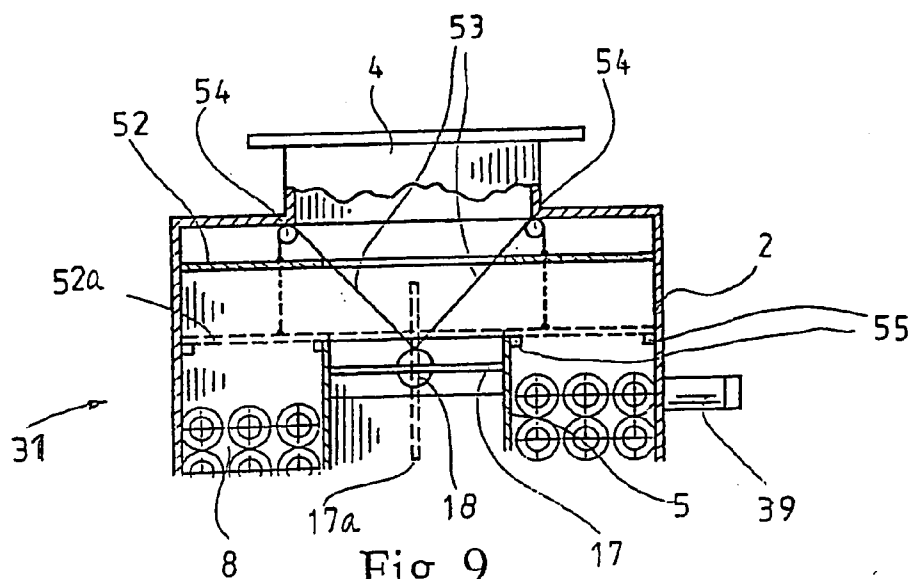


Fig. 9

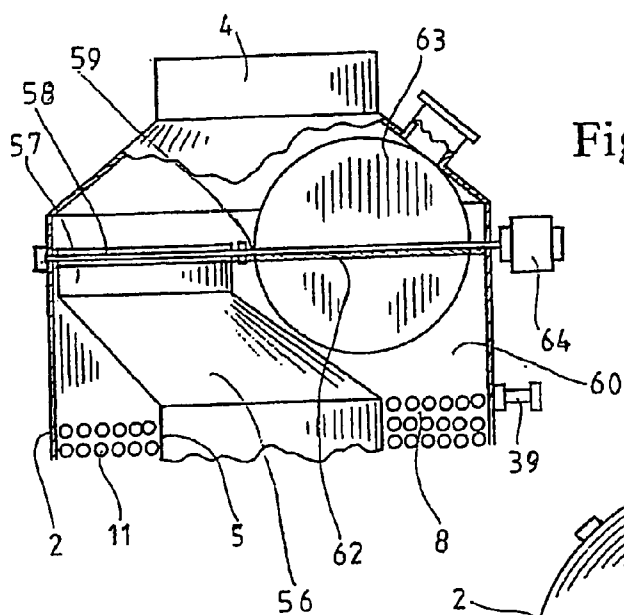


Fig. 10

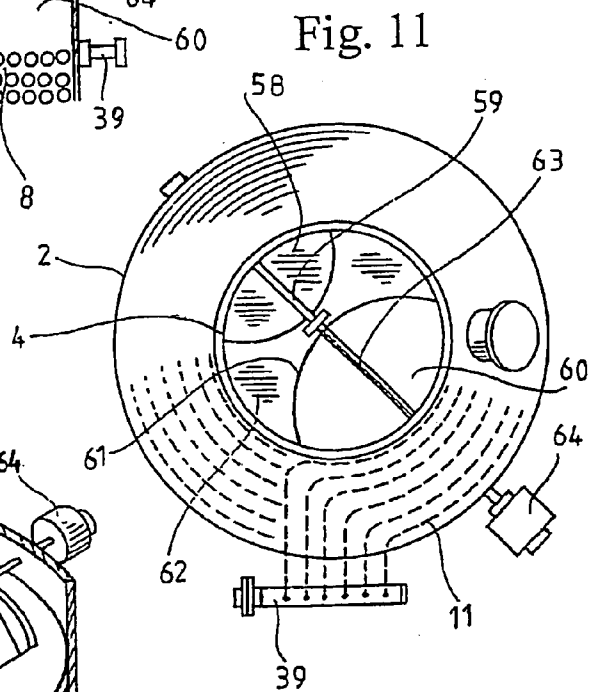


Fig. 11

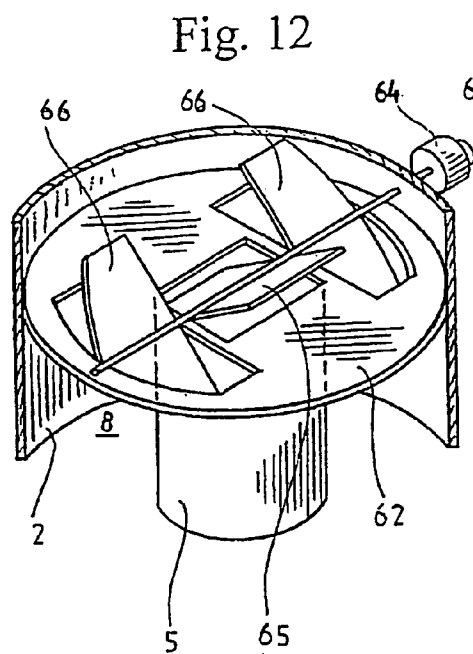


Fig. 12

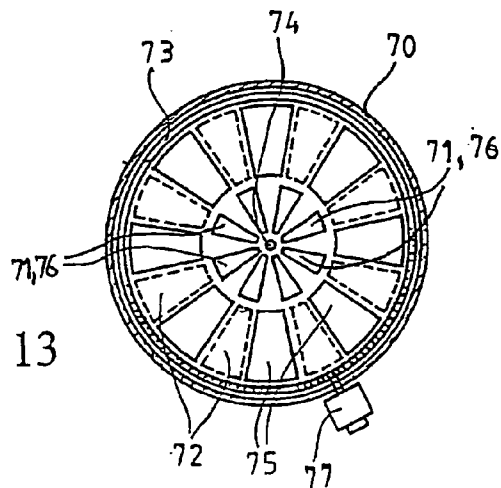


Fig. 13

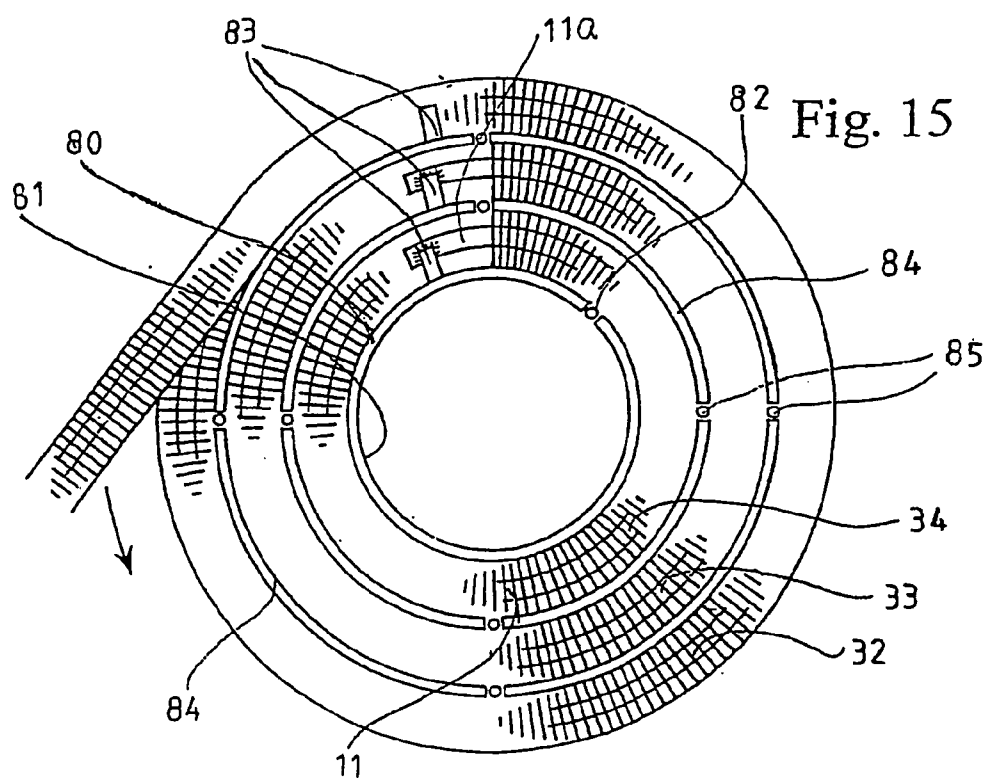
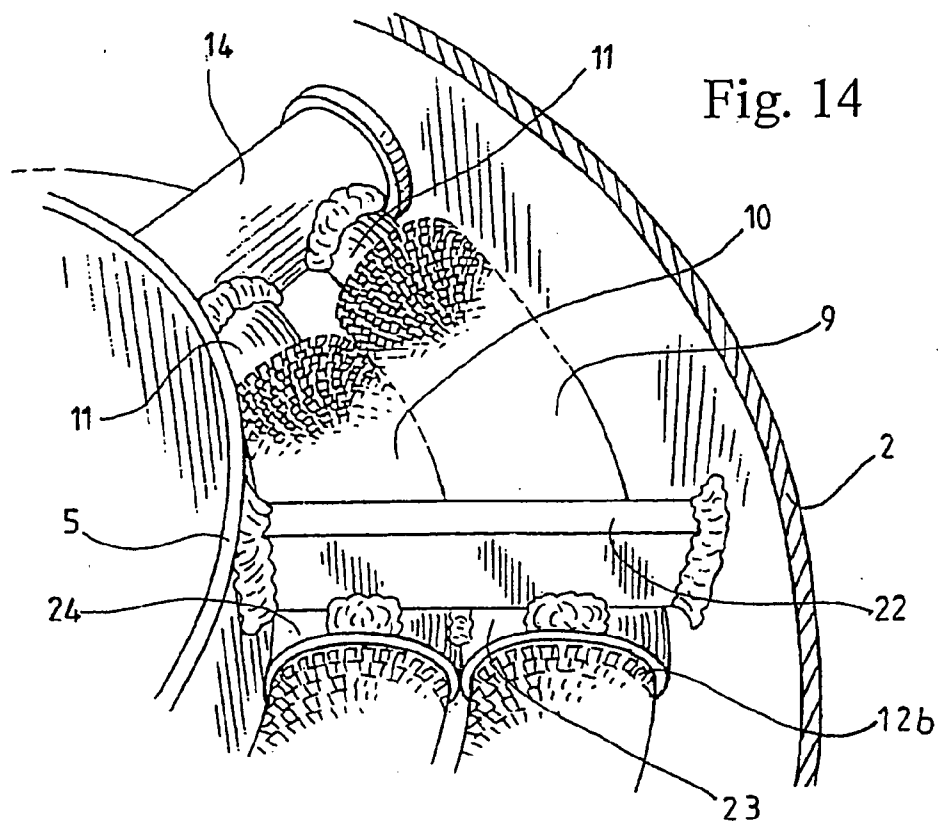
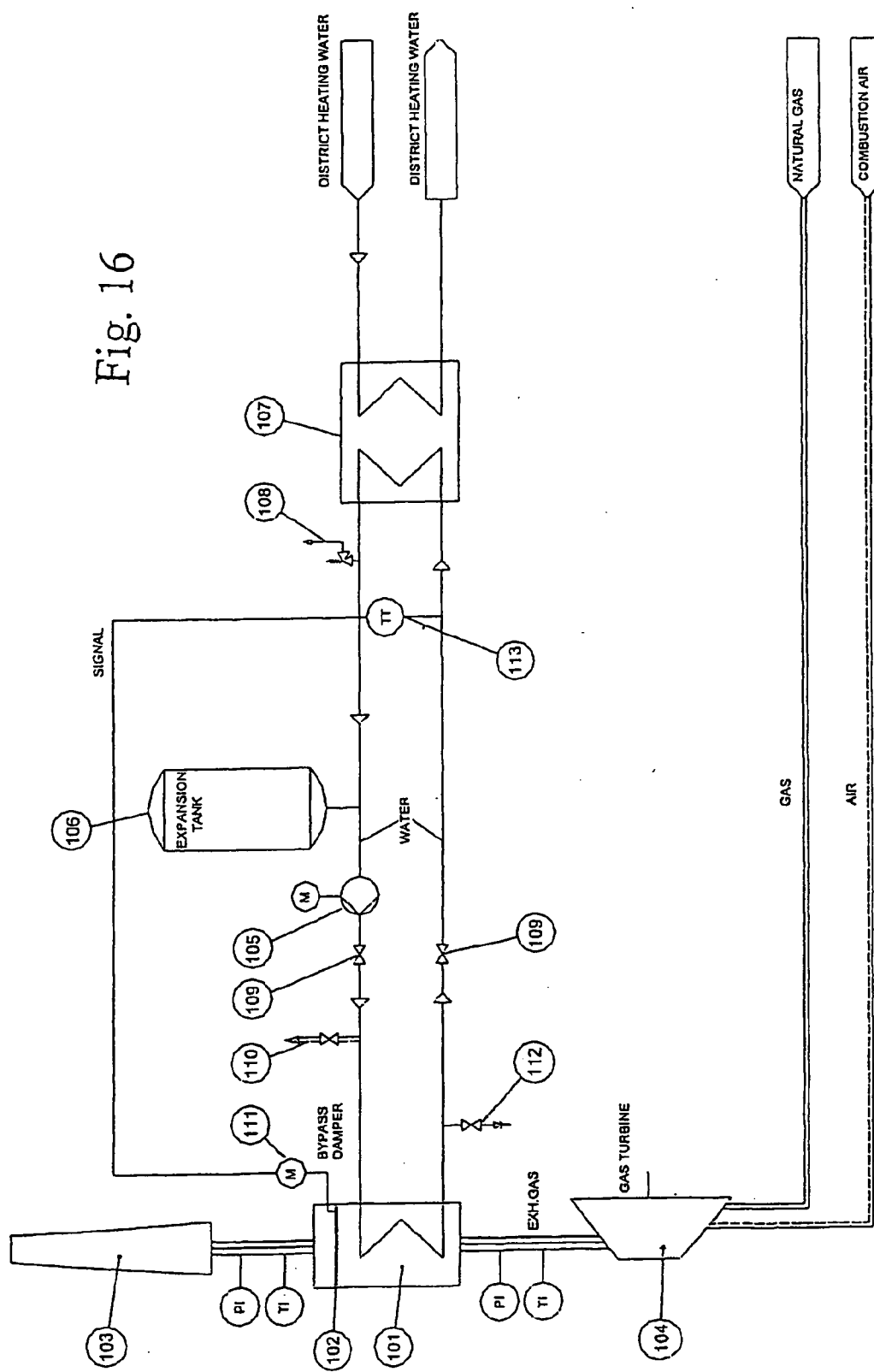


Fig. 16



HEAT EXCHANGER, COMBINATION WITH HEAT EXCHANGER AND METHOD OF MANUFACTURING THE HEAT EXCHANGER

[0001] The present invention relates to a heat exchanger for heat exchange between a first fluid and a second fluid and comprising a generally cylindrical casing with a first inlet and a first outlet for allowing said first fluid to flow through said casing in a generally axial direction, and at least one helical coil of a finned or corrugated tube arranged inside said casing.

[0002] Heat exchangers of this type are known where the first fluid is forced to flow from inside the coil or coils outwards or vice versa. The transfer of heat from the first fluid to the second fluid in the coils is not very well controlled and therefore not as efficient as possible.

[0003] It is an object of the invention to provide a heat exchanger of the type in reference where the flow of first fluid, for instance exhaust gas from a natural gas fired turbine, an internal combustion engine, an incinerator, a furnace, a burner or the like, takes place around the finned tube in a well controlled and efficient manner affording a highly efficient heat transfer from the first fluid to the second fluid, for instance water.

[0004] According to the invention this object is obtained by providing a generally cylindrical fluid conduit inside said casing generally coaxial therewith so that an axially extending first tubular space is defined between said conduit and said casing, said conduit having a second inlet and a second outlet for allowing said first fluid to flow through said conduit in a generally axial direction, and said first tubular space having a third inlet and a third outlet for allowing said first fluid to flow through said first tubular space in a generally axial direction, the at least one helical coil of a finned or corrugated tube being arranged inside said first tubular space generally coaxial therewith and having a fourth inlet and a fourth outlet for allowing said second fluid to flow through said finned tube.

[0005] Hereby, the first fluid is forced to flow around the finned tube coil windings in a very efficient manner for heat exchange. This also reduces the space requirements for the heat exchanger, the so-called "footprint".

[0006] According to the invention, the heat exchanger further comprises first adjustable throttle means for adjustably throttling said flow of said first fluid through said conduit and/or second adjustable throttle means for adjustably throttling said flow of said first fluid through said first tubular space.

[0007] Hereby, the flow of first fluid may by-pass the finned tube coils so that the heat transfer to the second fluid may be reduced according to the demand for heated second fluid. Furthermore, the pressure loss from the inlet of the casing to the outlet thereof may be reduced by by-passing the finned tube coils which is desirable during start up of for instance a gas fired turbine generating the first fluid in the form of exhaust gas from the gas combustion.

[0008] In one of the currently preferred embodiments of the heat exchanger according to the invention, said first throttle means comprise a first butterfly valve, preferably arranged adjacent said second inlet or said second outlet, and said second throttle means comprise a second butterfly

valve, preferably arranged adjacent said third inlet or said third outlet. Hereby, rather simple mechanisms that are simple to adjust and regulate are provided.

[0009] In an alternative embodiment, said first throttle means comprise a first butterfly valve, preferably arranged adjacent said second inlet or said second outlet, and said second throttle means comprise a ring having planar dimensions corresponding to the cross section of said first tubular space and being arranged for being displaced from a heating position wherein said flow of first fluid through said tubular space is substantially unhindered to a bypass position wherein said flow is substantially obstructed. In this embodiment, the space requirements are reduced.

[0010] In another currently preferred embodiment, said first and second throttle means comprise a fixedly arranged stationary plate with first and second apertures provided therein arranged such that said second and third inlets or outlets are obstructed by said plate such that the flow of first fluid through said conduit and said first tubular space takes place through said first and second apertures, respectively, in said stationary plate, and one or two movable plates with third and fourth apertures provided therein and arranged displaceable, preferably rotatably displaceable, from a bypass position overlying said stationary plate, wherein said third apertures coincide with said first apertures and said fourth apertures do not coincide with said second apertures, to a heating position overlying said stationary plate wherein said fourth apertures coincide with said second apertures and said third apertures do not coincide with said first apertures. This embodiment of the first and second throttle means requires a minimum of space and is particularly well suited for precise adjustment of the by-pass flow through the conduit relative to the heat transfer flow through the tubular space.

[0011] In the currently preferred embodiment, the heat exchanger according to the invention further comprises preferably motorized actuating means for adjusting the throttling effect of said first and second throttle means, and said throttling means and said actuating means are preferably adapted such that substantially any rate of flow between a maximum and minimum rate of flow of said first fluid through said second inlet and said third inlet may be obtained. Said minimum rate is substantially equal to zero. Hereby, any distribution of fluid flow between the by-pass conduit and the tubular space may be obtained which allows simple and precise regulation of the output of the heat exchanger according to the requirements for heat transfer from the first fluid. By allowing substantially total by-pass, no heat is transferred to the second fluid which is advantageous in case no heat transfer is needed to means exterior of the heat exchanger and therefore no temperature increase with consequent steam formation will take place in the finned coil or coils.

[0012] The currently preferred embodiment of a heat exchanger according to the invention comprises two or more of said helical coils arranged concentrically and such that mutually adjacent coils are radially spaced such that an axially extending second tubular space is provided between said mutually adjacent coils, and the outer surface of said conduit is spaced radially from the coil adjacent said surface such that an axially extending third tubular space is provided between said surface and said adjacent coil, the radial

dimensions of said second and third tubular spaces being adapted so as to achieve a certain pressure loss for a given rate of flow of said first fluid through said first tubular space.

[0013] Hereby, the pressure loss from said first inlet to said first outlet for a given flow of first fluid may be kept at a minimum while not substantially reducing the efficiency of the heat exchanger. This is particularly of importance in connection with gas fired turbines being the origin of said first fluid because gas turbines are particularly sensitive to the back pressure at the exhaust outlet thereof.

[0014] Preferably, the mutually adjacent individual windings of a coil are mutually axially spaced such that a helically extending space is provided between said adjacent windings. Hereby any differential thermal expansion or contraction of the casing and/or conduit relative to the coils in the axial direction will be taken up by said helically extending space.

[0015] In a currently preferred embodiment of a heat exchanger according to the invention and comprising three or more of said helical coils arranged concentrically and the interior diameter of the finned tubes constituting the coils preferably being the same, third throttling means are provided in the tubes constituting the coils located radially inwards of the outermost coil for increasing the pressure loss through the tubes of said inner coils so as to compensate for the shorter length of said tubes relative to the length of the tubes of the outermost coil such that the rate of flow of said second fluid through the tubes of all the coils is substantially the same for a given uniform pressure in said second fluid at said fourth inlets. Hereby, the heat transfer efficiency of each coil will be substantially the same without having to vary the diameter of the tubes of each coil to achieve this effect.

[0016] In the currently preferred embodiment of a heat exchanger according to the invention said third throttling means are constituted by a reduction of the cross sectional area of the flow of said second fluid relative to the internal cross sectional area of said tubes, the heat exchanger preferably further comprising an inlet header tube and an outlet header tube in fluid communication with said fourth inlets and fourth outlets, respectively, of all said tubes through corresponding communication apertures in said header tubes, said reduction of flow cross sectional area being constituted by reduced size of said communication apertures in said inlet header tube and/or in said outlet header tube. This is a particularly simple and inexpensive way of compensating for the different lengths of the different coils.

[0017] In case the heat exchanger according to the invention is to be used for generating steam, then according to the invention each helical coil may advantageously comprise two or more helically wound finned tubes extending adjacent one another with the same pitch. Hereby the number of flow paths is increased which is advantageous in connection with the large volume expansion of the water in the coil tubes resulting from the steam generation.

[0018] In another aspect, the present invention relates to a combination of a heat exchanger according to the invention and an exhaust gas generating combustion means such as a natural gas fired turbine, an internal combustion engine based on gasoline, diesel oil or natural gas, a furnace, a burner, an incinerator and the like, the combination comprising interconnection means for interconnecting an

exhaust gas outlet of the combustion means with said second and third inlets of the heat exchanger such that said exhaust gas constitutes said first fluid.

[0019] The currently preferred embodiment of the combination according to the invention may further comprise heat exchanging means for heat exchange between said second fluid and a third fluid and/or the surroundings of said heat exchanging means, said heat exchanging means being in fluid communication with said fourth outlet, measuring means for measuring the rate of heat exchange of said heat exchanging means, signal output means for emitting a signal representing the result of a measurement carried out by said measuring means, and first control means for controlling the adjustment of said first and second throttle means and adapted for receiving said signal.

[0020] Preferably, the combination according to the invention further comprises second control means for controlling the adjustment of said first throttle means such that the throttling effect thereof is at a minimum during the start up phase of the combustion means.

[0021] In yet another aspect, the present invention relates to a method of manufacturing a heat exchanger according to the invention and comprising the steps of providing a first length of finned or corrugated tube, providing a body having a substantially circular cylindrical surface, providing rotating means for causing relative rotation of said tube and said surface, arranging a lead portion of said tube abutting against said surface, and causing relative rotation of said surface and said lead portion such that said first length of tube is helically wound on said surface to form a first helical coil. Hereby, a particularly simple, precise and inexpensive method of manufacturing a heat exchanger according to the invention is achieved.

[0022] In connection with heat exchangers according to the invention having two or more concentric coils, the method according to the invention preferably comprises the further steps of providing spacing means, attaching said spacing means to said first helical coil, providing a second length of finned or corrugated tube, arranging a lead portion of said second length of finned tube abutting against said spacing means, causing relative rotation of first helical coil and said lead portion of said second length of tube such that said second length of tube is helically wound on said spacing means to form a second helical coil radially spaced from said first helical coil.

[0023] So as to avoid inaccuracies in the diameter of the coils and other disadvantages, the method according to the invention preferably comprises the further steps of fixating said helical coil relative to said body, and subjecting said body and said coil to annealing heat treatment and/or fixating said second helical coil relative to said body and/or said first helical coil, and subjecting said body and said first and second coils to annealing heat treatment. Hereby the diameter alteration of the coils because of elasticity and stresses in the steel of the coil tubes is avoided in a simple and cost efficient manner.

[0024] In the following the invention will be explained more in detail with reference to different embodiments thereof shown, solely by way of example, in the accompanying drawings where:

[0025] FIG. 1 is an elevational partly sectional diagrammatic view of a first currently preferred embodiment of a heat exchanger according to the invention,

[0026] FIGS. 2-3 are schematic plan views illustrating a fin configuration of the finned tubes according to the invention,

[0027] FIG. 4 is a schematic bottom view of the embodiment of FIG. 1,

[0028] FIG. 5 is an elevational partly sectional diagrammatic view of a second currently preferred embodiment of a heat exchanger according to the invention,

[0029] FIG. 6 is a schematic view of an inlet header tube for an embodiment of the heat exchanger according to the invention provided with four concentrically arranged finned tube coils,

[0030] FIG. 7 is a broken away elevational view of a third embodiment of a heat exchanger according to the invention,

[0031] FIG. 8 is a diagrammatic enlarged scale view of a portion of the embodiment in FIG. 1 illustrating the spacing of the finned tubes of the coils,

[0032] FIG. 9 is a schematic elevational, broken away, partly sectional view of the top of the embodiment shown in FIG. 5 illustrating a first embodiment of throttle means according to the invention,

[0033] FIG. 10 is a schematic elevational, broken away, partly sectional view of the top of a fourth embodiment of a heat exchanger according to the invention illustrating a second embodiment of throttle means according to the invention,

[0034] FIG. 11 is a schematic top view of the embodiment of FIG. 10,

[0035] FIG. 12 is a schematic elevational, cut away view illustrating a third embodiment of throttle means according to the invention,

[0036] FIG. 13 is a schematic top view illustrating a fourth embodiment of throttle means according to the invention,

[0037] FIG. 14 is a schematic, partly sectional, perspective, enlarged scale view of the top header tube and fastening means for the coils of the embodiment of FIG. 1,

[0038] FIG. 15 is a schematic top view illustrating the method according to the invention of manufacturing the embodiment of FIG. 5, and

[0039] FIG. 16 is a diagram illustrating one embodiment of control means according to the invention for adjusting the throttle means according to the invention.

[0040] Referring first to FIGS. 1 and 4, a heat exchanger 1 according to the invention comprises an outer cylindrical casing 2 provided with a flanged inlet 3 and a flanged outlet 4. An interior cylindrical casing or conduit 5 having an inlet 6 and an outlet 7 is arranged coaxially with the outer casing 2 thereby defining a tubular space 8 wherein two coils 9 and 10 of finned tubing are arranged. The finned tubing consists of a tube 11 provided with fins 12 arranged generally transversely to the axis of the tube 11.

[0041] The finned tube coils 9 and 10 are arranged mutually concentric and coaxially with the outer and inner casings 2 and 5. A flanged outlet header tube 13 and a flanged inlet header tube 14 communicate with the interior of the tubes 11 of the coils 9 and 10 through apertures 15 and 16, respectively.

[0042] A butterfly valve 17 (by-pass valve) is pivotably arranged on a shaft 18 at the outlet 7 of the conduit 5, a position wherein the valve 17 is in an intermediate position between fully closing the outlet 7 and fully opening said outlet 7 being shown with dotted lines at 17a. Semicircular rings 19 and 20 are arranged for abutting the rim of the butterfly valve 17 in the closed position thereof thereby ensuring a good closing function of the valve 17.

[0043] The heat exchanger 1 is primarily intended for use in combination with a natural gas fired turbine for recuperating and utilizing the heat of the exhaust gases thereof, but may in principle be used in combination with any means producing a heated gas such as internal combustion engines, furnaces, burners, incinerators and the like.

[0044] During maximum output operation of the heat exchanger 1, the butterfly by-pass valve 17 is in the closed position shown in full lines in FIG. 1 whereby all the exhaust gas from the gas turbine introduced into the inlet 3 flows through the tubular space 8 past the finned tube coils 9 and 10 as indicated by the full line arrows. Water to be heated is introduced into the coils 9 and 10 through inlet header 14 and is discharged through apertures 15 and 16 and outlet header 4 after having been heated by heat transmission from the exhaust gas through fins 12 to the tubes 11 and thereby to the water in said tubes.

[0045] The heated water is transported to not shown exterior heat exchange means for transmitting some of the heat of the water to some other fluid or to the surroundings, typically radiators in a building heating system or a district heating system.

[0046] Either during start up of the gas turbine (when the pressure loss through the heat exchanger 1 should be at a minimum to facilitate the turbine start up) or when the exterior heat exchange means do not require the full heating capacity of the heat exchanger 1, then the butterfly valve 17 is pivoted on shaft 18 so as to allow some or all the exhaust gas from the gas turbine to flow through the internal conduit 5 as indicated with dotted arrows thereby by-passing the tubular space 8 and the coils 9 and 10.

[0047] Hereby, the pressure loss through the heat exchanger 1 is decreased and the heat transmission to the water in the tubes 9 and 10 is decreased. The butterfly valve 7 can also be described as a throttling means and may be substituted by other throttling means as described in the following in connection with FIGS. 9-13.

[0048] Referring now to FIGS. 2 and 3, a strip 12a of carbon steel is laterally cut to form tabs or fingers 12b that are bent transverse to the plane of the strip in alternating directions and thereafter welded onto the surface of the tube 11 in a spiral configuration by means of welding seam 12c. Hereby a very effective heat transfers from the hot exhaust gas to the fingers 12b and thereby to the tube 11 may be achieved. Other configurations with circular plate shaped fins or corrugations may also be employed instead of the serrated spirally wound fins shown in FIGS. 2 and 3.

[0049] Referring now to FIG. 14, the tubes 11 are welded to the upper header tube 14 around the apertures 15 and 16 thereof whereby the interior of the tubes 11 communicates with the interior of the header tube 14. The coils 9 and 10 are attached to and suspended from the outer casing 2 and the inner conduit 5 by means of a beam 22 welded to said casing and conduit. The beam 22 is welded to two rings 23 and 24 fitting tightly around the fins 12b of the coils 9 and 10. A similar attachment is carried out at the bottom of the heat exchanger adjacent the inlet header tube 13.

[0050] Referring now to FIG. 8, the position of the coils 9 and 10 relative to one another and relative to the outer casing 2 and the inner conduit 5 as well as the spacing between the windings of each coil is illustrated.

[0051] The innermost coil 10 is spaced from the outermost coil 9 by a tubular space having a thickness or radial dimension t1, while the innermost coil 10 is spaced from the outer surface of the conduit 5 by a tubular space having a thickness or radial dimension t3. The outermost coil 9 is not spaced from the inner surface of the outer casing 2, i.e. the coil 9 abuts the casing 2.

[0052] The spacings t1 and t3 are chosen such that the loss of pressure through the tubular space 8 is maintained at a level acceptable for the optimal operation of the gas turbine (or other hot exhaust gas generating means) delivering exhaust gas to the heat exchanger 1. The heat exchange efficiency of the heat exchanger 1 is not substantially affected by the spacings t1 and t3. On the other hand, operational tests show that if a spacing were present between the outer casing 2 and the outermost coil 9, then the efficiency of the heat exchanger 1 would be considerably reduced. These two phenomena are at least to a certain degree owing to, on one hand, turbulent flow between the coils 9 and 10 and between the conduit 5 and the coil 10 and, on the other hand, laminar flow in a tubular space between the outer coil 9 and the casing 2.

[0053] There are several parameters determining the spacings t1 and t3 between the coils and between the innermost coil and the conduit 5. The two most important considerations or parameters are:

[0054] Exhaust Gas Pressure Drop

[0055] The exhaust gas pressure drop or loss is very dependent on the exhaust gas velocity and the geometry of the heating surface of the coil windings. The velocity is dependent on the free gas flow cross sectional area (total area for the gas flow between the tubes and fins in a cross section).

[0056] $\Delta p = \xi \cdot \frac{1}{2} \rho \cdot w^2$, where

[0057] Δp : exhaust gas pressure drop [Pa]

[0058] ξ : pressure drop coefficient, dependent on geometry (fin shapes, tube diameter, inline/staggered configuration, number of windings etc),

[0059] ρ : Density of the gas at mean temperature between inlet 3 and outlet 4 [kg/m³]

[0060] w : exhaust gas velocity [m/s]

[0061] In most cases, the allowable exhaust gas pressure drop in heat exchangers and boilers after gas turbines (and engines as well) is quite limited. For gas turbines it is extremely important to minimize the exhaust gas pressure drop as the power production on the turbine (and thus the efficiency of the turbine) is very dependent on the back pressure. In connection with the heat exchanger according to the invention the allowable exhaust gas pressure drop is preferably limited to be below 500 Pa (50 mm water column), giving very low exhaust gas velocities and thus large distance between the coils (alternatively more coils giving larger gas cross section area and larger diameter of the unit).

[0062] Heat Transfer Coefficient

[0063] In general the heat transfer coefficient should be as high as possible to minimize the heating surface area. The heat transfer coefficient is increased with higher exhaust gas velocities and more turbulent flow. For the heating surface chosen (serrated spiral wound fin tubes) the turbulence of the flow is very good, in general giving high heat transfer coefficient even for low exhaust gas velocities.

[0064] Designing the heat exchanger according to the invention with the spacings t1 and t3 is also advantageous from a production point of view because it allows the coils to be inserted in the casing individually as compared with coils designed to abut one another or to be nested in one another that must be handled and inserted as a unit comprising several coils.

[0065] Still referring to FIG. 8, a helically extending space is provided between adjacent windings of each coil 9 and 10, the thickness or axial dimension of said space being t2. This spacing t2 of the windings allows the casing 2 and/or the conduit 5 to thermally expand and contract axially relative to the coils 9 and 10 without causing unacceptable stresses as any differences in such expansion or contraction is taken up by variations of the spacing t2 between the windings of the coils.

EXAMPLE

[0066] In the following, the basic technical specifications for a combination according to the invention of a two coil heat exchanger according to the invention and a gas fired turbine are listed as a non-limiting example:

[0067] Dimensions of the Heat Exchanger

Height excl. inlet:	1550 mm
Diameter excl. insulation:	633 mm
Insulation:	100 mm covered with galvanized steel plate
Flue gas outlet flange:	DN 450, DIN 86044

-continued

Water inlet/outlet connections:	Carbon steel pipe, OD 60.5 × 3.6 mm, 2 "RGW
Thickness of casing (inner 5 and outer 2):	5 mm
Weight of heat exchanger excl. water:	475 kg
Weight of heat exchanger incl. water:	500 kg
Outside diameter of tubes 11:	38 mm
Tube material thickness:	3.6 mm
Fin type:	Serrated spiral wound fins
Height of fins:	15 mm
Fin density:	250 pcs/m
Thickness of fins:	1 mm
Material, tube and fins:	Carbon steel
Tube configuration:	Inline
Number of coaxial and concentric coils:	2
Number of windings:	10
Tube pitch in gas direction:	70 mm
Free spacing t2 between fins on coil windings in gas direction:	2 mm
Diameter of by-pass channel (inner casing 5):	323.9 mm
Length of inner casing 5, incl. by-pass valve:	860 mm
Centre diameter of inner coil 10:	401 mm
Centre diameter of outer coil 9:	555 mm
Free space t3 between inner casing 5 and fins on inner coil 10:	4.5 mm
Free space t1 between fins on the two coils:	9 mm
Free space between fins on outer coil and inside of outer casing 2:	0 mm
Size of holes 15, 16 in header 13 for coil connection (both coils)	30.8 mm

[0068] Process Data

Micro Gas turbine type:	HONEYWELL
	Parallon 75
Max. electric output power from gas turbine:	75 kW(e)
Exhaust gas flow:	0.68 kg/s
Exhaust gas inlet temperature to heat exchanger:	246° C.
Exhaust gas outlet temperature from heat exchanger:	90° C.
Exhaust gas pressure loss across heating surface:	300 Pa
Heating capacity of heat exchanger:	120 kW
Water inlet temperature:	50° C.
Water outlet temperature:	70° C.
Water flow, approx:	1.44 kg/s
Pressure drop, water side:	0.2 bar

[0069] Referring now to **FIG. 5**, an embodiment of a heat exchanger **31** according to the invention having three concentric coils **32-34** is shown with the same reference numbers being utilized for elements similar to elements in **FIG. 1**. The main difference between the **FIG. 1** and **FIG. 5** embodiments, apart from the number of coils, is that inlet apertures **35, 36** and **36** of the outlet header tube **38** are different sizes so as to compensate for the difference in coil length between the coils **32-34** as explained below.

[0070] As the length of the tubes **11** of the different coils **32-34** are different and all the coils are interconnected at the outlet header **38** and at the inlet header **39**, a flow distribution will be established in the coils giving the same pressure loss through each of the coils.

[0071] Thus, the inner coils **33** and **34** [where the second fluid (typically water) have shorter flow paths than in the outermost coil **32**] can transport more water than the outer coil **32**. The water in the coils **33, 34** and **35** will then not be heated to the same temperature and will result in a skewed and reduced recuperation of the heat contained in the first fluid (for instance exhaust gas from a gas fired turbine).

[0072] It is therefore desirable that the flow rate through the coils be regulated so that best possible heat recuperation

is obtained with best possible temperature distribution both in the water and in the exhaust gas. This is achieved by creating an extra pressure loss in the inner coils **33** and **34** relative to the outer coil **35** and each other.

[0073] This can be achieved in two manners:

[0074] By providing the tubes of the coils with different diameters. From a practical point of view this is not desirable except in case a large number of concentric coils are involved in which case 2-3 different tube diameters may be acceptable.

[0075] By installing throttle or baffle means in the tubes or at the inlet or outlet thereof. As can be seen in **FIG. 5** and **FIG. 6**, this can be achieved by providing the outlet header tube **38** with apertures **35-37** and **40-43**, respectively, having different diameters. The diameters of the individual apertures are determined based on the tube diameter and tube length in the individual coils of a heat exchanger. As an example of diameters for the four apertures shown in **FIG. 6** for an inner diameter of 56 mm of all four coil tubes, aperture **40** is 56 mm, aperture **41** is 13 mm, aperture **42** is 11 mm and aperture **43** is 9 mm. Other throttle or baffle means well known in the art may also be used to achieve the different pressure loss coefficients for the individual coil tubes.

[0076] Referring now to **FIG. 7**, the inner coil adjacent the inner conduit **5** comprises two parallel wound finned tubes **50** and **51** establishing two parallel flow paths for the second fluid (typically water) indicated by the arrows **R1** and **R2**.

[0077] This embodiment is intended for use for steam generation where it is necessary to take into consideration the large volume expansion of the mass inside the tubes (at the transition from liquid to vapour, water to steam) with corresponding increase in flow rate and velocity as well as pressure loss at the inner surface of the tubes. So as to provide sufficient inner flow cross sectional area in the tubes it will therefore often be necessary to use a larger tube

diameter, a larger number of coils or provide for a larger number of flow paths in other ways.

[0078] Apart from providing many coils, more flow paths may be obtained by having several parallel extending windings in the same coil as shown in **FIG. 7**, i.e. several coils with the same coil diameter and large pitch “screwed” into each other. Hereby it is obtained that a larger inner cross section area is achieved without having a large number of coils with a large diameter of the outermost coil and therefore the outer casing **2** (large footprint). This smaller footprint or outer diameter of the heat exchanger entails important advantages both for the end user and during manufacture, erection and transport. The axial length or height of the heat exchanger for a given output will of course be larger, but this does normally not represent a substantial problem during manufacture or for the end user.

[0079] Referring now to **FIGS. 9-13**, various embodiments of throttle means for throttling the flow of first fluid (typically exhaust gas) through the conduit **5** and the tubular space **8**, respectively, are shown.

[0080] In the embodiment of **FIG. 9**, the butterfly valve **17** cooperates with a ring **52** that is suspended in three steel wires **53** attached at equidistant points along the ring **52**. The wires **53** extend over pulleys **54** to the shaft **18**.

[0081] In the situation shown with full lines, the butterfly valve **17** is closed and does not allow any exhaust gas to flow through conduit **5** while the ring **52** is in its highest position in which it does not throttle the flow of exhaust gas through the tubular space **8**.

[0082] In the situation shown with dotted lines, the butterfly valve **17a** functions as a by-pass valve and allows unthrottled flow of exhaust gas through the conduit **5** while the ring **52a** is in its full throttle position supported on tightening rings **55** thereby preventing flow of exhaust gas through the tubular space **8**.

[0083] The shaft **18** may be actuated manually, by an electric motor or a pneumatic or hydraulic mechanism. In the simplest version, the wires are wound onto and off not shown pulleys arranged on the shaft **18** such that rotation of the shaft **18** for opening of the butterfly valve **17** automatically entails lowering of the ring **52** and vice versa.

[0084] When no heat is required by the external heat consumption means connected to the heat exchanger **31**, then the butterfly valve **17** is in its fully open position (**17a**) and the ring **52** is in its lowered fully closed position (**52a**) so that all the exhaust gas is by-passed through the conduit **5**. Hereby, the water in the finned tube coils is not heated so that external cooling means to avoid overheating of this water are not necessary.

[0085] A very simple means for regulating the heat output of the heat exchanger **31** is thus provided. A temperature sensor and transmitter (not shown) may be provided in the outlet header **38** for transmitting a signal to the not shown actuator (electric motor) for the shaft **18** so that if the temperature measured at the outlet header does not conform to the required temperature, then the shaft rotates in the corresponding direction to either open or shut the by-pass valve **17**. Many different regulating circuits are conceivable depending on the requirements of the end user and the

configuration of the external heat consumption devices connected to the heat exchanger **31**.

[0086] Referring now to **FIGS. 10 and 11** showing an elevational and top view, respectively, of a second embodiment of the first and second throttling means for the flow of exhaust gas through the internal conduit and the tubular space, respectively, the internal conduit **5** is connected to a further conduit **56** having an outlet **57** in which a butterfly valve **58** is rotatably mounted on a shaft **59**. The outlet **57** communicates with the outlet **4** of the casing **5**. The butterfly valve **58** may rotate with the shaft **59** from the shown closed position wherein the outlet **57** is totally obstructed and an open position wherein flow of exhaust gas through outlet **57** is unhindered.

[0087] The tubular space **8** communicates with a space **60** defined by an extension of the outer casing **2**, said space communicating with the outlet **4** through an aperture **61** in a plate **62**. A butterfly valve **63** is mounted in said aperture **61** on the shaft **59** such that rotation of the shaft **59** rotates the butterfly valve **63** from the shown fully open position in which flow of exhaust gas from the tubular space **8** through the space **60** and through the aperture **61** is unhindered to a fully closed position in which flow of exhaust gas through the aperture **61** is totally obstructed. The shaft **59** is connected to an electric motor **64** for being rotated in opposite directions so as to rotate the valves **58** and **63** between the two positions described above and to any intermediate position.

[0088] Referring now to **FIG. 12**, in this embodiment the butterfly valves **58** and **63** of the embodiment in **FIGS. 10 and 11** have been substituted by a butterfly valve **65** and two butterfly valves **66**, respectively, the operation of the valves **65** and **66** and the shaft **59** being the same as described in connection with the embodiment of **FIGS. 10 and 11**.

[0089] Referring now to **FIG. 13**, a stationary circular plate **70** is arranged horizontally in an embodiment of the heat exchanger similar to the one shown in **FIG. 1** or **FIG. 4** (without the butterfly valve **17**) over the outlet of the conduit **5** and the annular outlet of the tubular space **8**. The plate **70** is provided with apertures **71** communicating with the interior of conduit **5** and apertures **72** communicating with the tubular space **8**.

[0090] A rotatably arranged circular plate **73** is arranged on top of plate **70** on a pivot **74**. The plate **73** is provided with apertures **75** identical in shape and distribution to apertures **72** in plate **70** and with apertures **76** identical in shape and distribution to apertures **71** in plate **70**. An electrical motor **77** is arranged for rotating the rotatable plate **73** in both directions.

[0091] In the position of the rotatable plate shown in **FIG. 13** the apertures **71** and **76** coincide or overly each other so that exhaust gas can flow practically unhindered through the conduit **5** underlying these coinciding apertures while flow through the tubular space **8** is obstructed because the apertures **72** and **75** do not communicate with each other at all. By rotating the plate **73** by means of the motor **77**, a position thereof may be attained where flow through the tubular space is relatively unhindered because the apertures **72** and **75** coincide and flow through the conduit **5** is totally obstructed because the apertures **71** and **76** do not communicate with each other at all.

[0092] The lower plate **70** may instead be the rotatable one whereby the pressure from the exhaust gas will press the plate **70** against the stationary plate **73** and enhance the sealing effect of abutment of the plates **70** and **73** against each other. Sealing between the plates may also be achieved in many other ways obvious to those skilled in the art.

[0093] Referring now to **FIG. 15**, a method according to the invention of manufacturing a heat exchanger (the embodiment of **FIG. 5**) according to the invention is illustrated.

[0094] A cylindrical body **80** is constituted by a steel plate **81** with a thickness of **10** mm, a steel rod **82** inserted between the free axially extending edges of the plate **81**, and not shown circumferentially extending tightening straps or wires for holding the plate **81** and rod **82** in the shown cylindrical configuration.

[0095] The inner coil **34** is wound helically around the body or core **80**, the leading end (not shown) and the trailing end **11a** of the pipe **11** of the coil **34** being attached to the body by means of brackets or rods **83** welded to said ends and to the body **80**. The tightening straps mentioned above are located outside the area of the body **80** to be covered by the coil **34**.

[0096] Four cylindrical plates **84** having a quarter circle cross section and a thickness equal to the required radial dimension **t1** (see **FIG. 8**) are arranged on the outer surface of coil **33** with rods **85** arranged between mutually adjacent axially extending edges of the plates **84**. The plates **84** and rods **85** are held in place by not shown circumferentially extending tightening straps or wires. The rods **85** have an oval or elliptical cross section and are placed between the plates **84** such that the major cross sectional dimension of the oval or ellipse is tangential to the circular circumference of the plates **84**.

[0097] The next coil **33** is wound helically around the plates **84** and rods **85** with the leading and trailing ends of

the coil **33** being welded to one of the plates **84** by means of brackets or rods **83** in a manner very similar to the winding and attachment of the inner coil **34**.

[0098] The process is repeated for the next coil **32**. If more coils than three are required, the process described above may be repeated for any such further coils.

[0099] The unit comprising the body **80**, the coils **32-34** and the plates **84** with rods **85** is thereafter subjected to annealing heat treatment for avoiding elastic diameter expansion of the coils and to remove potentially damaging stresses.

[0100] After annealing, the attachments by means of brackets **83** are removed, the rods **85** are rotated such that the major dimension of the oval or elliptical cross section is oriented radially whereby the coils **32-34** are forced to expand slightly such that the cylindrical plates **84** may be removed. Finally rod **82** is removed such that the body **80** may be removed. The coils **32-34** are now ready for being inserted in a casing **2** with a conduit **5** placed inside the inner coil **34**.

[0101] A heat exchanger according to the invention is particularly well suited for use in a combination or system comprising a gas fired turbine (or an internal combustion engine utilizing natural gas as fuel). Such a system is furthermore particularly well suited for (but not in any way limited to) for use in a system for small scale combined production of electricity and heat, for instance for large buildings, hospitals, small district heating systems and the like.

[0102] Referring now to **FIG. 16**, a system or combination according to the invention including a heat exchanger according to the invention, a gas fired turbine and external heat consuming devices is shown with the following characteristics:

Item	Component	Description
101	Heat exchanger according to the invention.	
102	Exhaust gas by-pass damper or valve (butterfly valve for instance)	Can be regulated manually or as shown here: regulated by an actuator (electrical motor), item 11
103	Exhaust gas stack	
104	Gas fired turbine	Could be another kind of component producing exhaust gas
105	Circulation pump	A forced circulation system, to circulate the required water/fluid flow. The pressure drop on water side in the heat exchanger, valves and piping system to be taken into account when calculating the delivery head of the pump.
106	Expansion tank	To take the expansion/contraction of the fluid in the system, when the temperature varies.
107	External end user Heat exchanger	Or other heat consumption device. Can be for heating use in buildings, in greenhouses, district heating systems etc.
108	Safety valve	To be opened if the pressure in the system becomes too high
109	Stop valves	Normally open. Possible to close in case of repair.

-continued

Item	Component	Description
110	Air venting valve	
111	Electrical motor	Electrical motor, automatically controlled by signals from the temperature transmitter 113. Opens the by-pass valve 102 a little, if the water temperature becomes too high, closes the valve 102 a little if the water temperature becomes too low. Set points to be decided by the end user.
112	Drain valve	To drain the water/fluid from the system
113	Temperature transmitter	Sends signal to electrical motor if temperature measured is too high or too low

[0103] The system can comprise other exhaust gas generating devices, and the regulation of the heat exchanger's by-pass valve (and the heat exchanger's throttle valve for throttling fluid flow through the tubular space containing the finned tube coils) can be provided for in many different manners depending on the configuration of the end user's heat consuming devices.

1. A heat exchanger for heat exchange between a first fluid and a second fluid and comprising:

a generally cylindrical casing with a first inlet and a first outlet for allowing said first fluid to flow through said casing in a generally axial direction,

a generally cylindrical fluid conduit arranged inside said casing generally coaxial therewith so that an axially extending first tubular space is defined between said conduit and said casing, said conduit having a second inlet and a second outlet for allowing said first fluid to flow through said conduit in a generally axial direction, and said first tubular space having a third inlet and a third outlet for allowing said first fluid to flow through said tubular space in a generally axial direction,

at least one helical coil comprising a tube selected from the group consisting of a finned tube and a corrugated tube arranged inside said first tubular space generally coaxial therewith and having a fourth inlet and a fourth outlet for allowing said second fluid to flow through said tube.

2. A heat exchanger according to claim 1 further comprising first adjustable throttle means for adjustably throttling said flow of said first fluid through said conduit and second adjustable throttle means for adjustably throttling said flow of said first fluid through said first tubular space.

3. A heat exchanger according to claim 2, wherein said first throttle means comprise a first butterfly valve, arranged adjacent one of said second inlet and said second outlet, and said second throttle means comprise a second butterfly valve, arranged adjacent one of said third inlet and said third outlet.

4. A heat exchanger according to claim 2, wherein said first throttle means comprise a first butterfly valve, arranged adjacent one of said second inlet and said second outlet, and said second throttle means comprise a ring having planar dimensions corresponding to the cross section of said first tubular space and being arranged for being displaced from a heating position wherein said flow of first fluid through said tubular space is substantially unhindered to a bypass position wherein said flow is substantially obstructed.

5. A heat exchanger according to claim 2, wherein said first and second throttle means comprise:

a fixedly arranged stationary plate with first and second apertures provided therein arranged such that said second and third inlets or outlets are obstructed by said plate such that the flow of first fluid through said conduit and said first tubular space takes place through said first and second apertures, respectively, in said stationary plate, and

at least one movable plate with third and fourth apertures provided therein and arranged so as to be displaceable from a bypass position overlying said stationary plate, wherein said third apertures coincide with said first apertures and said fourth apertures do not coincide with said second apertures, to a heating position overlying said stationary plate wherein said fourth apertures coincide with said second apertures and said third apertures do not coincide with said first apertures.

6. A heat exchanger according to any of the claims 2-5 and further comprising actuating means for adjusting the throttling effect of said first and second throttle means.

7. A heat exchanger according to claim 6, wherein said throttling means and said actuating means are adapted such that substantially any rate of flow between a maximum and minimum rate of flow of said first fluid through said second inlet and said third inlet may be obtained.

8. A heat exchanger according to claim 7, wherein said minimum rate is substantially equal to zero.

9. A heat exchanger according to claim 1 and comprising at least two coil arranged concentrically and such that mutually adjacent coils are radially spaced such that an axially extending second tubular space is provided between said mutually adjacent coils.

10. A heat exchanger according to claim 1, wherein the outer surface of said conduit is spaced radially from the coil adjacent said surface such that an axially extending third tubular space is provided between said surface and said adjacent coil.

11. A heat exchanger according to claim 9 or 10, wherein the radial dimensions of said second and third tubular spaces are adapted so as to achieve a certain pressure loss for a given rate of flow of said first fluid through said first tubular space.

12. A heat exchanger according to claim 1, wherein the coil has mutually adjacent individual windings that are mutually axially spaced such that a helically extending space is provided between said adjacent windings.

13. A heat exchanger according to claim 1 and comprising three or more helical coils arranged concentrically, each comprising a finned tube one of the coils being an innermost coil and another of the coils being an outermost coil, the interior diameter of the finned tubes constituting the coils being the same, wherein third throttling means are provided in the tubes constituting the coils located radially inwards of the outermost coil for increasing the pressure loss through the tubes of the remaining coils so as to compensate for the shorter length of said tubes relative to the length of the tubes of the outermost coil such that the rate of flow of said second fluid through the tubes of all the coils is substantially the same for a given uniform pressure in said second fluid at said fourth inlets.

14. A heat exchanger according to claim 13, wherein said third throttling means are constituted by a reduction of the cross sectional area of the flow of said second fluid relative to the internal cross sectional area of said tubes.

15. A heat exchanger according to claim 14 and further comprising an inlet header tube and an outlet header tube in fluid communication with said fourth inlets and fourth outlets, respectively, of all said tubes through corresponding communication apertures in said header tubes, said reduction of flow cross sectional area being constituted by reduced size of said communication apertures in one of said inlet header tube and said outlet header tube.

16. A heat exchanger according to claim 1, wherein the helical coil comprises two or more helically wound finned tubes extending adjacent one another with the same pitch.

17. A combination of a heat exchanger according to claim 1 and an exhaust gas generating combustion means selected from the group consisting of at least one of a natural gas fired turbine, an internal combustion engine, a furnace, a burner, an incinerator, the combination comprising interconnection means for interconnecting an exhaust gas outlet of the combustion means with said second and third inlets of the heat exchanger such that said exhaust gas constitutes said first fluid.

18. A combination according to claim 17 and further comprising

heat exchanging means for heat exchange between said second fluid and at least one of a third fluid and the surroundings of said heat exchanging means, said heat exchanging means being in fluid communication with said fourth outlet,

measuring means for measuring the rate of heat exchange of said heat exchanging means,

signal output means for emitting a signal representing the result of a measurement carried out by said measuring means, and

first control means for controlling the adjustment of said first and second throttle means and adapted for receiving said signal.

19. A combination according to claim 17 or 18 and further comprising second control means for controlling the adjustment of said first throttle means such that the throttling effect thereof is at a minimum during the start up phase of the combustion means.

20. A combination of a heat exchanger for heat exchange between a first fluid and a second fluid and an exhaust gas generating combustion means, the heat exchanger comprising:

a generally cylindrical casing with a first inlet and a first outlet for allowing said first fluid to flow through said casing in a generally axial direction,

a generally cylindrical fluid conduit arranged inside said casing generally coaxial therewith so that a axially extending first tubular space is defined between said conduit and said casing, said conduit having a second inlet and a second outlet for allowing said first fluid to flow through said conduit in a generally axial direction, and said first tubular space having a third inlet and a third outlet for allowing said first fluid to flow through said tubular space in a generally axial direction, and

at least one helical coil comprising a tube selected from the group consisting of a finned tube and a corrugated tube arranged inside said first tubular space generally coaxial therewith and having a fourth inlet and a fourth outlet for allowing said second fluid to flow through said finned tube,

the combination comprising interconnection means for interconnecting an exhaust gas outlet of the combustion means with said second and third inlets of the heat exchanger such that said exhaust gas constitutes said first fluid.

21. A combination according to claim 20 further comprising first adjustable throttle means for adjustably throttling said flow of said first fluid through at least one of said conduit and second adjustable throttle means for adjustably throttling said flow of said first fluid through said first tubular space.

22. A combination according to claim 21, wherein said first throttle means comprise a first butterfly valve, arranged adjacent one of said second inlet and said second outlet, and said second throttle means comprise a second butterfly valve, arranged adjacent one of said third inlet and said third outlet.

23. A combination according to claim 21, wherein said first throttle means comprise a first butterfly valve, arranged adjacent said one of second inlet and said second outlet, and said second throttle means comprise a ring having planar dimensions corresponding to the cross section of said first tubular space and being arranged for being displaced from a heating position wherein said flow of first fluid through said tubular space is substantially unhindered to a bypass position wherein said flow is substantially obstructed.

24. A combination according to claim 21, wherein said first and second throttle means comprise:

a fixedly arranged stationary plate with first and second apertures provided therein arranged such that either said second and third inlets or said second and third outlets are obstructed by said plate such that the flow of first fluid through said conduit and said first tubular space takes place through said first and second apertures, respectively, in said stationary plate, and

at least one movable plate with third and fourth apertures provided therein and arranged displaceable from a bypass position overlying said stationary plate, wherein said third apertures coincide with said first apertures and said fourth apertures do not coincide with said second apertures, to a heating position overlying said stationary plate wherein said fourth apertures coincide with said second apertures and said third apertures do not coincide with said first apertures.

25. A combination according to claim 21 and further comprising actuating means for adjusting the throttling effect of said first and second throttle means.

26. A combination according to claims 21, wherein said throttling means and said actuating means are adapted such

that substantially any rate of flow between a maximum and minimum rate of flow of said first fluid through said second inlet and said third inlet may be obtained.

27. A combination according to claim 26, wherein said minimum rate is substantially equal to zero.

28. A combination according to claim 21 and comprising two or more helical coils arranged concentrically and such that mutually adjacent coils are radially spaced such that an axially extending second tubular space is provided between said mutually adjacent coils.

29. A combination according to claim 21, wherein the outer surface of said conduit is spaced radially from the coil adjacent said surface such that an axially extending third tubular space is provided between said surface and said adjacent coil.

30. A combination according to claim 28, wherein the radial dimension of said second tubular space is adapted so as to achieve a certain pressure loss for a given rate of flow of said first fluid through said first tubular space.

31. A combination according to claim 29, wherein the radial dimension of said third tubular space is adapted so as to achieve a certain pressure loss for a given rate of flow of said first fluid through said first tubular space.

32. A combination according to claim 21, wherein the mutually adjacent individual windings of a coil are mutually axially spaced such that a helically extending space is provided between said adjacent windings.

33. A combination according to claim 21 and comprising three or more helical coils arranged concentrically, one of said coils being an outermost coil, each of the coils comprising a finned tube, the interior diameter of the finned tubes being the same, wherein third throttling means are provided in the tubes of the coils located radially inward of the outermost coil for increasing the pressure loss through the tubes of said radially inward located coils so as to compensate for the shorter length of said tubes of said radially inward located coils relative to the length of the tubes of the outermost coil such that the rate of flow of said second fluid through the tubes of all the coils is substantially the same for a given uniform pressure in said second fluid at said fourth inlets.

34. A combination according to claim 33, wherein said third throttling means are constituted by a reduction of the cross sectional area of the flow of said second fluid relative to the internal cross sectional area of said tubes.

35. A combination according to claim 34 and further comprising an inlet header tube and an outlet header tube in fluid communication with said fourth inlets and fourth outlets, respectively, of all said tubes through corresponding communication apertures in said header tubes, said reduction of flow cross sectional area being constituted by reduced size of said communication apertures in one of said inlet header tube and said outlet header tube.

36. A combination according to claim 21, wherein a helical coil comprises two or more helically wound finned tubes extending adjacent one another with the same pitch.

37. A combination according to claim 21 and further comprising

heat exchanging means for heat exchange between said second fluid and at least one of a third fluid and the surroundings of said heat exchanging means, said heat exchanging means being in fluid communication with said fourth outlet,

measuring means for measuring the rate of heat exchange of said heat exchanging means,

signal output means for emitting a signal representing the result of a measurement carried out by said measuring means, and

first control means for controlling the adjustment of said first and second throttle means and adapted for receiving said signal.

38. A combination according to claim 21 and further comprising second control means for controlling the adjustment of said first throttle means such that the throttling effect thereof is at a minimum during the start up phase of said combustion means.

39. A combination according to claim 20, wherein said exhaust gas generating combustion means is chosen from the group comprising a natural gas fired turbine, an internal combustion engine, a burner, a furnace and an incinerator.

40. A method of manufacturing a heat exchanger according to claim 1 and comprising the steps of:

providing a first length of tube selected from the group consisting of a finned tube and a corrugated tube,

providing a body having a substantially circular cylindrical surface,

providing rotating means for causing relative rotation of said tube and said surface,

arranging a lead portion of said tube abutting against said surface,

causing relative rotation of said surface and said lead portion such that said first length of tube is helically wound on said surface to form a first helical coil.

41. A method according to claim 40 and comprising the further steps of:

providing spacing means,

attaching said spacing means to said first helical coil,

providing a second length of tube selected from the group consisting of a finned tube and a corrugated tube,

arranging a lead portion of said second length of tube abutting against said spacing means,

causing relative rotation of first helical coil and said lead portion of said second length of tube such that said second length of tube is helically wound on said spacing means to form a second helical coil radially spaced from said first helical coil.

42. A method according to claim 40 and comprising the further steps of:

fixating said helical coil relative to said body, and

subjecting said body and said coil to annealing heat treatment.

43. A method according to claim 41 and comprising the further steps of:

fixating said second helical coil relative to at least one of said body and said first helical coil, and

subjecting said body and said first and second coils to annealing heat treatment.