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Woebcke

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[54] **COOLING APPARATUS AND PROCESS**

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[21] Appl. No.: **72,765**

Related U.S. Application Data

[60] Continuation-in-part of Ser. No. 802,790, Feb. 27, 1969, abandoned, and a continuation-in-part of Ser. No. 877,575, Nov. 26, 1969, which is a division of Ser. No. 802,790, Feb. 27, 1969, abandoned, and a continuation-in-part of Ser. No. 729,878, May 10, 1968, abandoned, which is a division of Ser. No. 557,005, June 13, 1966, Pat. No. 3,403,722.

[52] **U.S. Cl.** .... **165/142;** 165/147; 165/169; 23/277 R
[51] **Int. Cl.** **F28d 7/12;** F28f 13/08
[58] **Field of Search** 165/142, 1, 157, 158, 141, 165/155, 135, 169, 146, 147, 40, 159, 143, 7; 23/284, 292, 288.9

[56] **References Cited**

UNITED STATES PATENTS

779,741	1/1905	Scheubner	165/156
1,884,583	10/1932	Lucke et al.	165/157
1,884,778	8/1965	Hood, Jr. et al.	165/135
2,904,400	9/1959	Asendorf et al.	23/288 X

FOREIGN PATENTS OR APPLICATIONS

184,231	5/1907	Germany	165/158

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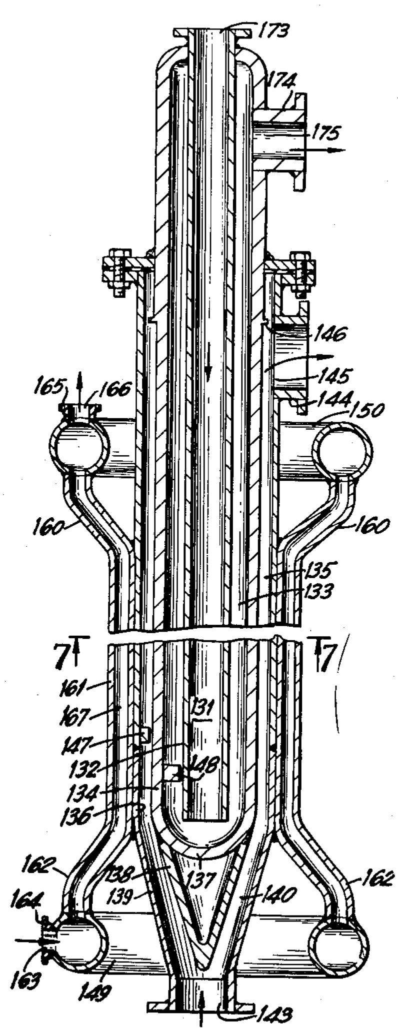
[57] **ABSTRACT**

An apparatus and process for effecting heat exchange between hot effluent and a coolant. The heat exchange apparatus is substantially tubular in shape and is provided with a divergent inlet section having an angle of divergence less than 10°, and preferably 4° to 7°.

18 Claims, 9 Drawing Figures



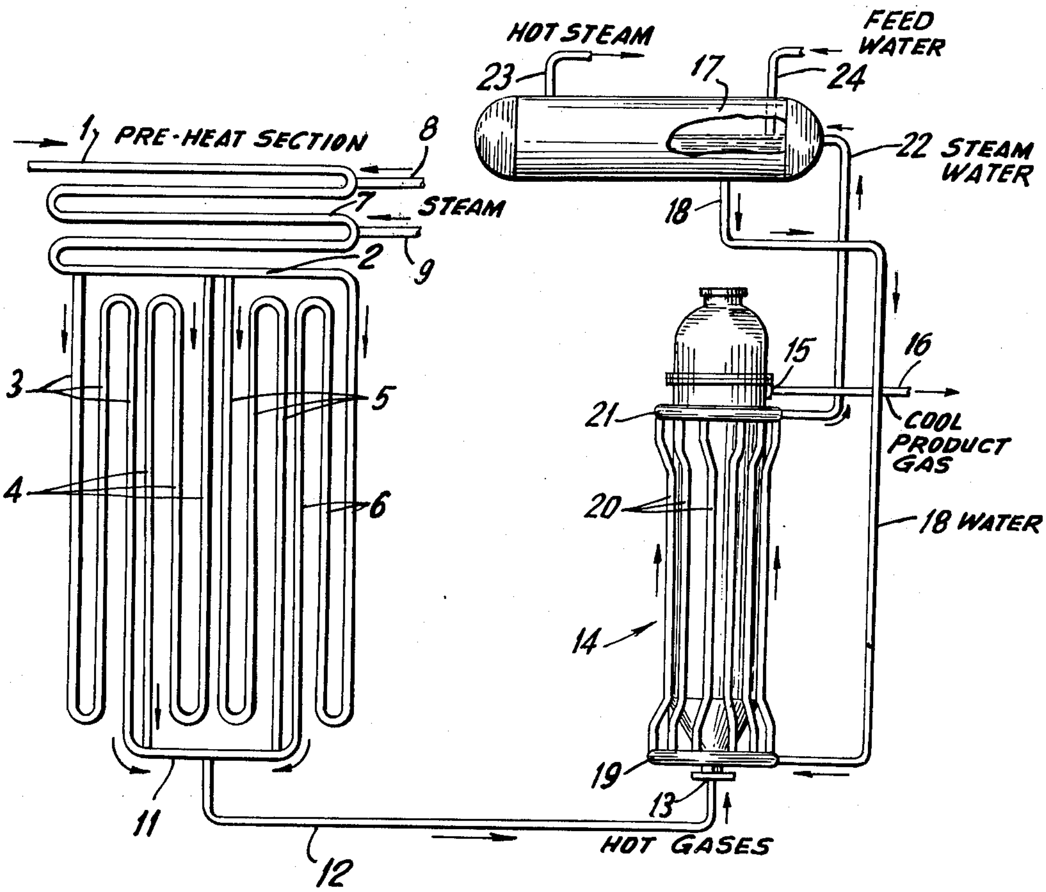


FIG. 1

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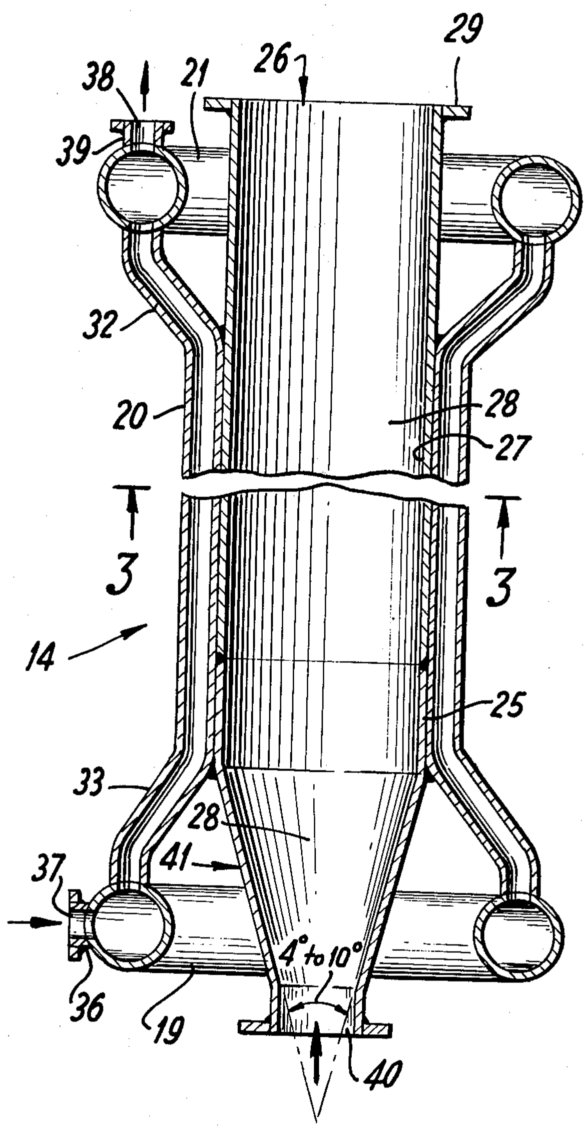

FIG. 2

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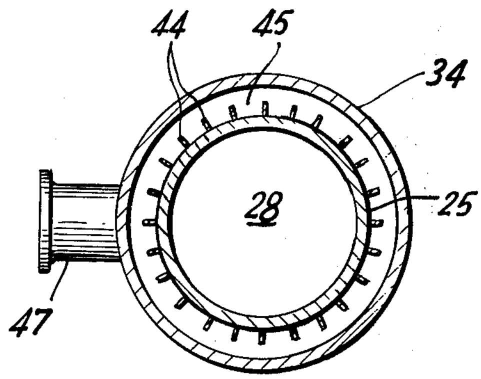

FIG. 5

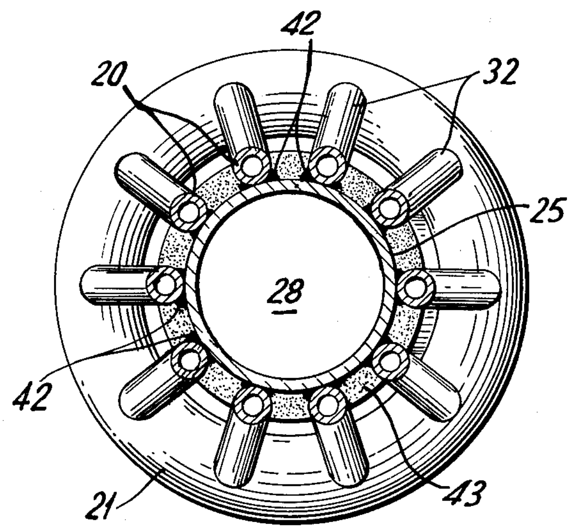

FIG. 3

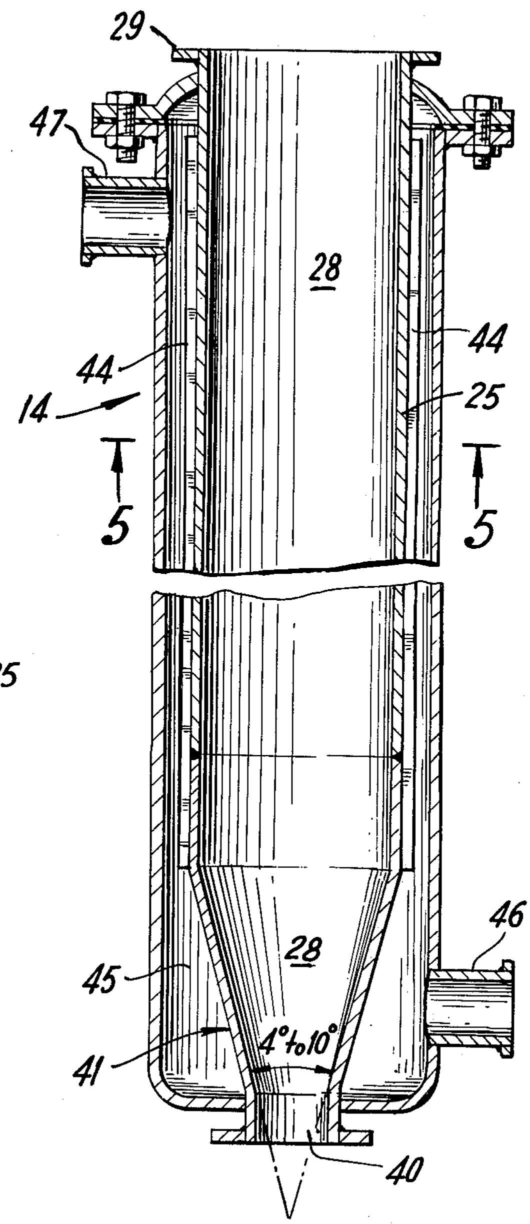

FIG. 4

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FIG. 6

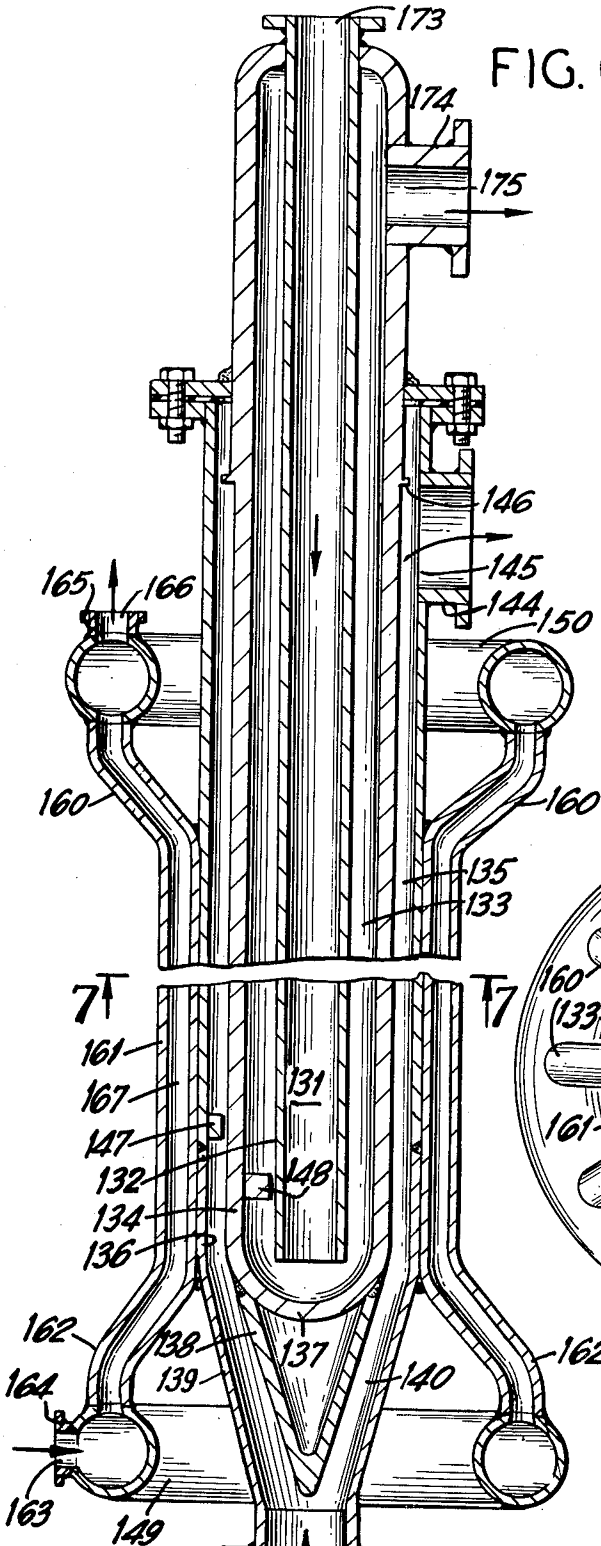
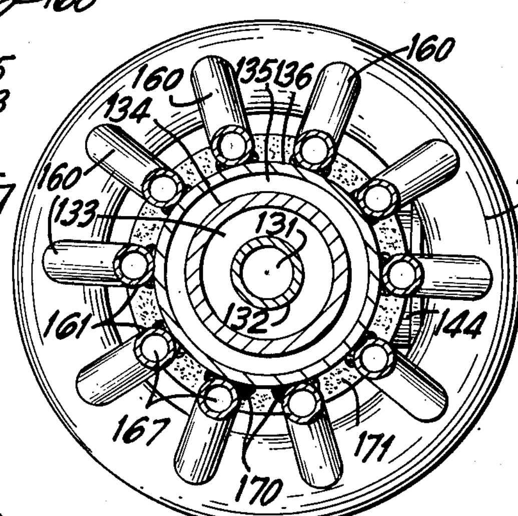


FIG. 7



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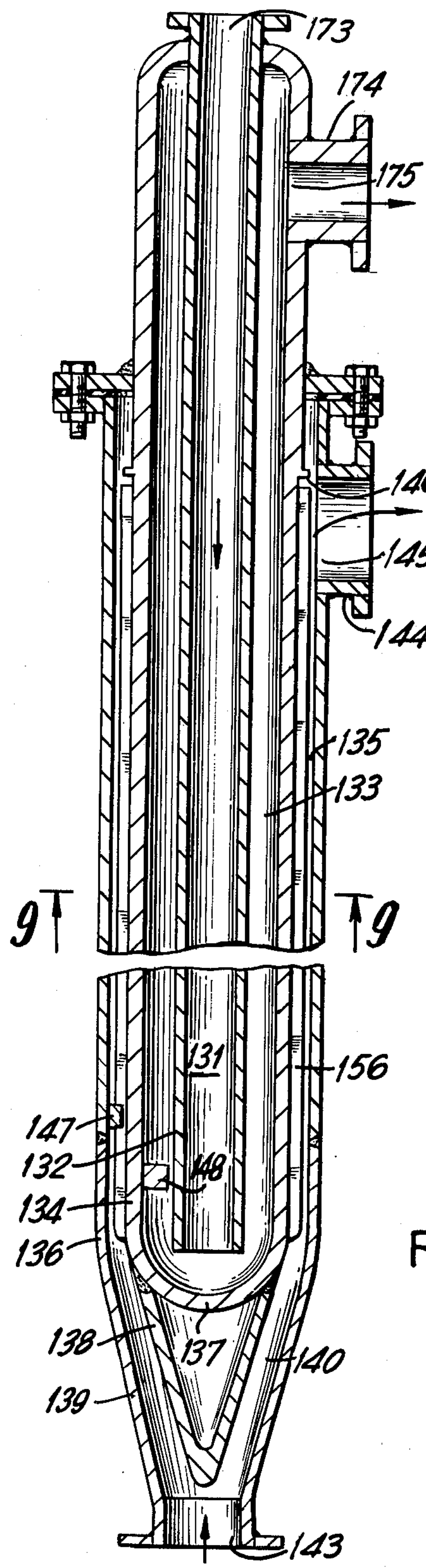

FIG. 8

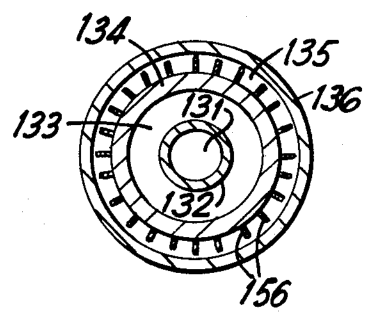

FIG. 9

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COOLING APPARATUS AND PROCESS

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of applications Ser. No. 802,790 filed Feb. 27, 1969 and Ser. No. 877,575 filed Nov. 26, 1969 as a divisional application of Ser. No. 802,790, now abandoned. Application Ser. No. 802,790 is a continuation-in-part of application Ser. No. 729,878 filed May 10, 1968 now abandoned which is a divisional application of application Ser. No. 557,005 filed June 13, 1966 now U.S. Pat. No. 3,403,722 granted Oct. 1, 1968. Additional applicants and patents which are relevant to the subject matter of the present invention and which have a common assignee therewith are: HEATING APPARATUS AND PROCESS, U.S. Pat. No. 3,407,789 filed June 13, 1966 granted Oct. 29, 1968 COOLING APPARATUS AND PROCESS, U.S. PAT. No. 3,403,722 filed June 13, **1966** granted Oct. 1, 1968; and COOLING APPARATUS AND PROCESS U.S. Pat. No. 3,583,476 filed Feb. 27, 1969 granted June 8, 1971.

The present invention relates generally to an apparatus and process for cooling a fluid and, in particular, to an apparatus and process for rapidly cooling a fluid. The apparatus and process of the present invention are especially suitable for rapidly cooling furnace effluent issuing from a hydrocarbon cracking furnace.

The present invention comprises an apparatus and process which is used to rapidly cool hot fluids. The apparatus comprises a means whereby a hot fluid is contacted on cooling surfaces to provide rapid decrease in the temperature of the hot fluid. The cooling means is suitable for cooling fluids at elevated pressures. The apparatus of the present invention can be used to rapidly cool hot gases without substantial pressure change.

The cooling means has particular and advantageous application when used in conjunction with a process for the production of olefins by cracking hydrocarbon feeds at high temperature and short residence time, using a high radiant heat furnace having relatively short conduits of small diameter. The cooling means is used to provide rapid reduction in the effluent product gas temperature from the furnace without substantial pressure drop.

Cracking furnace effluent gas temperatures are very high, and at these high temperatures the cracking reactions proceed at a rapid rate. In order to substantially stop the reactions in the effluent gas and to minimize the production of undesirable by-products, it is necessary to rapidly cool the effluent gas after it leaves the reactor to a temperature at which the reactions substantially cease. There are several means available for doing this, most of which have one or more drawbacks. Conventional means of cooling, e.g., a shell and tube heat exchanger, result in substantial pressure loss of the effluent gas. This type of heat exchanger employs multiple tubes and is fitted with an inlet head. The residence time of the hot gases in this head alone at the temperatures employed is significant and results in product degradation and the formation of coke precursors and coke, either of which can accumulate in the heat exchanger.

In cooling high temperature hydrocarbon gas effluents from a hydrocarbon cracking process used to produce olefins, the temperature of the cooling means be sufficiently low to cool the gases the desired amount and sufficiently high to prevent condensation of high boiling hydrocarbon by-products on the cooling surfaces.

Cooling techniques and apparatus of the present invention are particularly useful in cooling the effluent gases from a process for the thermal cracking of hydrocarbons. In the thermal cracking of hydrocarbons, in the process described hereinafter, the hydrocarbon feed can be heated to high temperature, maintained at high temperature for a short residence time and selectively converted to desired products. In accordance with the present invention, the hot gas reaction products are rapidly quenched or cooled in such a manner that the conversion is substantially stopped after the desired residence time.

The quenching apparatus and process of cooling of the present invention is particularly suitable for use in cooling the hot gas effluent issuing from a pyrolysis furnace. However, the concept used can be readily applied to other processes for cooling hot product streams, for heat recovery and/or for heating fluids. The cooling means and process can be used for rapidly cooling hot gaseous products from other cracking processes. The quenching apparatus provides indirect cooling on surfaces. The apparatus is simple in design and easy to operate. The apparatus can be of any size and is normally designed for a specified service. The apparatus can be horizontally or vertically disposed. The cooling unit rapidly cools hot fluilds while not substantially changing the pressure of the fluid. That is, the pressure of the cooled fluid at the outlet of the cooling unit is substantially the same as the inlet pressure. The material to be cooled can be upflow or downflow. The operation of the unit can be such that the coolant circulation rate can be self-regulating and within limits adjust itself to the heat load. Alternatively, the coolant circulation rate can be controlled by suitable auxiliary pumping means.

SUMMARY OF THE INVENTION

Basically, the heat exchanger of the present invention is comprised of a passage for the flow of hot fluid therethrough and at least one coolant passage. The hot fluid passage and the coolant passage or passages are arranged with common walls through which indirect heat exchange occurs. The inlet of the hot fluid passage is configured in the form of a diverging nozzle having an angle of divergence of from 4° to 10°, and preferably 4° to 7°.

A variation of the basic heat exchanger design consists essentially of three concentric pipes,, pipes, walls of which form two annular chambers and one central chamber. The cooling fluid can be fed into the top of the unit and flow into the central chamber. The central chamber at the end opposite from the inlet thereof is in communication with the first annular chamber. The cooling fluid can flow downwardly in the central chamber and upwardly in the first annular chamber and exit through an opening at or near the top of the first annular chamber. The outer wall of the second concentric pipe forms a cooling surface. The hot gaseous material to be cooled can enter at the bottom of the cooling device through an opening in the third concentric pipe and pass upwardly through the second annular chamber and be cooled by direct contact with the cooling surface. The cooled material can pass out of the cooling device through an outlet located near the top of the second annular chamber.

The invention will be better understood and made more apparent when considered in conjunction with the accompanying drawings wherein:

FIG. **1** is a schematic flow diagram of an overall thermal cracking system with the gas cooling apparatus of the present invention embodied therein;

FIG. **2** is a cross-sectional elevational view of an embodiment of the cooling or quench apparatus;

FIG. **3** is a cross-sectional view of the cooling apparatus of FIG. **2** taken through line **3—3** showing a cross section of the concentric pipes and cooling tubes;

FIG. **4** is a cross-sectional elevational view of another embodiment of the cooling or quench apparatus of the present invention;

FIG. **5** is a cross-sectional view of the cooling apparatus of FIG. **4** taken through line **5—5** showing the concentric pipes and cooling fins;

FIG. **6** is a cross-sectional elevational view of another embodiment of the cooling or quench apparatus of the present invention;

FIG. **7** is a cross-sectional view of the cooling apparatus of FIG. **6** taken through line **7—7**;

FIG. **8** is a cross-sectional elevational view of another embodiment of the cooling or quench apparatus of the present invention;

FIG. **9** is a cross-sectional view of the cooling apparatus of FIG. **8** taken through line **9—9**;

The heat exchanger of the present invention will be described as part of a system for thermally cracking hydrocarbons to produce olefins. Basically, the heat exchanger of the present invention is an indirect heat exchanger having a passage for the flow effluent therethrough and at least one coolant chamber with a common wall therebetween.

The cooling apparatus can use any desired cooling fluid. The cooling fluid can be a liquid that, on heating, partially or completely vaporizes. The preferred cooling fluids are liquids. Suitable liquids are Dowtherm, water, etc.

The preferred cooling liquid is water. In the present embodiment, the cooling apparatus is used to produce high temperature, high pressure steam. The heat energy recovered in cooling can be used for power generation or heating service.

A typical reactor furnace and cooling unit will be described with reference to FIG. **1** of the drawings. A petroleum naphtha fraction boiling in the range of 90° to 375° F. is fed through line **1** into convection preheat section 7 wherein it is heated from about ambient temperature to a temperature of about 1000° to 1100° F. Steam, at a ratio of steam to hydrocarbon of about 0.4 to 0.8 by weight, is introduced into preheat section 7 through lines **8** and/or **9** at a point where the naphtha feed is approximately 80% vaporized. The preheated hydrocarbon and steam and steam mixture at about 1000° to 1100° F. is then fed to manifold **2** and subsequently into the inlets of coils **3–6.** The feed is heated in the coils from about 1000° to 1100° F. to a coil outlet temperature of about 1650° F. Under the recited conditions the hydrocarbon partial pressure at the coil outlet is about 12 to 14 PSIA. The residence time of the fluid in the radiant section of the furnace is about 0.20 to 0.25 seconds. The mass velocity of the hydrocarbon and steam in the coils is about 18 to 26 pounds per second, per square foot of cross-sectional area of the coil.

The radiant coil inlet pressure is about 45 PSIA and the coil outlet pressure of the effluent gases is about 25 PSIA. The hot effluent gases are fed from the outlet manifold **11** through line **12** to the cooling apparatus **14** at a gas velocity of about 800 ft./sec. The hot gases are introduced into the cooler through inlet **13** at a temperature of about 1650° F. The cooled gases are withdrawn from the cooler through outlet **15** which is in communication with line **16.** The gases are cooled rapidly in about 10–20 milliseconds to a temperature of about 1200° to 1400° F. and may be conveyed to a conventional cooling means for further cooling and to a conventional olefin separation plant for separation and recovery of ethylene. The gas pressure in line **16** is about 25 PSIA.

Basically, the heat exchanger **14** of the present invention can be adapted to rapidly cool the furnace effluent by 100° to 600° F.; that is, from about 1500° to 1650° F. down to about 1000° to 1400° F. The cooling step is carried out very rapidly after the effluent leaves the radiant section of the furnace in about 1 to 30 milliseconds, preferably in about 5 to 20 milliseconds. The rapid cooling step is critical in the high temperature, short residence time process for cracking hydrocarbons to produce olefins. It is found that if the cooling step takes substantially more than about 30 milliseconds, there may be substantial coke deposits in interior passages of the cooling unit and downstream equipment.

When high temperature and short residence time are used to crack hydrocarbon to form olefins, it is necessary to rapidly cool the furnace effluent sufficiently below the reaction temperature to substantially stop the reaction. If this is not done, the reaction continues after the effluent has left the reaction zone and can result in degradation of product, reduction of ethylene yield, and increased production of polynuclear aromatics and/or compounds of low volatility. Such products tend to cause deposition of coke on the walls of the downstream equipment. At 1600° F. reaction rates are so high that the residence time in a quench zone at times as short as 50 milliseconds results in a significant amount of reaction taking place. It is, therefore, important to quench the effluent very soon after it leaves the furnace to a temperature at which substantially no deleterious reaction takes places, e.g. below 1100° to 1400° F.

FIG. **1** of the drawing illustrates the thermosiphon cooling embodiment of the present invention. Coolant water from steam drum **17** is introduced through line **18** at a temperature of about 600° F. and a pressure of about 1600 PSIA. The coolant flows through line **18** into a torus **19** and upwardly in tubes **20,** in which tubes the water is partially converted to steam. The steam and water mixture flows into torus **21** and through line **22** back to steam drum **17.** The water being more dense than the mixture of steam and water sets up a thermosiphon flow of coolant water through the cooling apparatus. Within design limits the cooling apparatus is self-regulating and the higher the temperature and flow rate of gases into the cooling unit the faster will be the coolant liquid circulation rate.

Saturated steam at a temperature of about 600° F. and a pressure of about 1600 PSIA can be withdrawn from steam drum **17** through line **23** and the heat energy recovered. Boiler feed water is fed to steam drum **17** through line **24.**

The heat exchanger of the present invention can be used in other known processes but it is particularly suitable for service in a hydrocarbon cracking system. However, it will be obvious that the cooling apparatus has many uses for cooling process streams, heat exchange, and other uses that will appear to those skilled in the art.

The heat exchange apparatus of the present invention comprises a means whereby the hot furnace effluent is cooled in a heat exchanger passage. If the heat exchanger passage is annular, either or both of the surfaces comprising the annular passage can be a heat transfer surface. This cooling apparatus is particularly adapted to rapid quench of hot gas with a small decrease or substantially no change in the pressure of the fluid being cooled while generating high pressure steam economically.

One basic embodiment of the present invention is depicted in FIGS. **2** and **3**. Basically, the heat exchanger **14** is an indirect heat exchange apparatus which cools furnace effluent or similar hot fluid and generates high pressure steam. Also, the inlet end of the heat exchanger is designed to gradually lower the velocity of the furnace effluent steam so that the velocity head or kinetic energy is converted to static pressure. The pressure recovery realized can partially or entirely offset the friction pressure drop through the device depending upon the specific dimensions of the apparatus and the conditions under which it is operated. Rapid cooling of the gas if effected by passing the gas through a tubular passage which is cooled.

The heat exchanger **14** is comprised of a centrally disposed pipe **25** that extends about the length of the apparatus and terminates in an outlet **26.** The inner wall **27** of the pipe **25** defines the passage or chamber **28** through which the effluent passes to be quenched. At the top of the pipe **25** there is provided connecting means **29** to connect the heat exchanger **14** to the transfer line pipe.

The wall of pipe **25** can be provided with a multiplicity of equally spaced tubes **20** which tubes are connected to and are in close contact with the outer wall **31** of the pipe **25.** These tubes run the approximate length of the wall and, at the upper and lower ends, flare outwardly by curved portions **32** and **33** respectively, and are in communication with torus **21** at their upper end and torus **19** at their lower end. Torus **19** has a connecting conduit **36** through which coolant fluid passes through inlet **37** into the torus **19** and flows upwardly through tubes **20.** Tubes **20** are in communication with upper torus **21** and the cooling fluid flows out of torus **21** through outlet **38** and conduit **39.**

Pipe **25** at a position proximate to the end at which effluent enters the quench apparatus tapers inwardly to form inlet opening **40.** The cross-sectional area of inlet **40** is such that the passage **28** gradually increases in cross-sectional area from inlet **40** to the quench chamber to form an inlet diffuser section **41.**

The cooling apparatus can be disigned and sized to accommodate any desired cooling service. Suitable apparatus for use in the present invention can have an overall length of the cooling apparatus from gas outlet **26** to hot gas inlet **40** of 10 to 50 feet. The inside diameter of the pipe **25** can be 2.5 to 5 inches. Tubes **20** can be about 1 to 2 inches in inside diameter. The inside diameter of tori **19** and **21** can be about 3 to 6 inches. The cross-sectional area of gas inlet **40** can be about 3 to 14 square inches, gradually increasing in cross-sectional area to about 4 to 20 square inches in the straight portion of pipe **25.** The total coolant flow through tubes **20** can be about 10 times the flow of hot effluent gases based on weight.

Hot gases at a velocity of 700 to 800 ft./sec. enter the cooling apparatus through inlet **40** and pass into chamber **28** where they are slowed to about 400 to 500 ft./sec. and pass out of the apparatus at the end of the chamber through outlet **26.** Coolant water enters the bottom torus **19** through inlet **37** and flows upwardly in tubes **20** providing indirect contact cooling for the hot furnace effluent gases at the inner wall surface **27** of pipe **25.** The inner surface **27** of pipe **25** provides the cooling surface for the hot gas.

The mixture of steam and water moves upwardly in tubes **20** into torus **21** and through outlet **38.**

The inlet diffuser section **41** provides for gradual increase in cross-sectional area of the gases entering through inlet **40** which gradually increases the pressure of the hot gases as the gas velocity is reduced. The diffuser section **41** insures uniform gas distribution over the cooling surface **27** without the production of large eddy currents in the gas flow. In accordance with the present invention, the pressure increase in the gas caused by the gradual increase in cross-sectional area in the inlet compensates for a substantial portion of the pressure loss in the gas due to friction. The cooled outlet gas pressure will be about the same as the hot inlet gas pressure. Passage **28** is sized to provide the gradual increase in cross-sectional area through which the hot gases flow. The gradual increase is provided by the tapered shape of the wall of diffuser section **41.**

The gradual increase in cross-sectional area provides a gradual decrease is gas velocity which is accompanied by an increase in gas pressure to conserve total energy.

The total angle of divergence of the entering pipe of the diffuser section **41** is in the range of 4° to 10°, preferably 4° to 7°, e.g. 5°.

FIG. **3** shows a cross section of the cooling apparatus taken through line **3—3** of FIG. **2.** FIG. **3** shows an end section of tubes **20** and the manner in which they are connected by welds **42** to the outer wall of pipe **25.** A suitable heat transfer material **43** can be used to fill the space between tubes **20** in order to improve the heat transfer between the hot gases and coolant.

Another embodiment of the cooling apparatus is illustrated by FIGS. **4** and **5** of the drawings. In this embodiment cooling of the hot gases is provided by direct contact with the outer wall of the concentric pipe **25.** In order to improve the heat transfer between pipe **25** and the cooling fluid, pipe **25** can possess a multiplicity of cooling fins **44** which project into the coolant passage **45.**

The diffuser section **41** immediately adjacent the cooling chamber inlet **40** is again formed of an entering pipe section which makes a total divergence angle of between 4° and 10°, preferably 4° to 7°.

The coolant chamber **45,** however, completely surrounds the inner quenching chamber **28** thereby providing direct exposure of the tube **25** with the fluid passing through the cooling chamber or jacket **45.** Coolant enters inlet **46** which is near the hot effluent inlet **40,** passes through chamber **45** and discharges through outlet **47** thereby providing cooling of the chamber **28** from the inlet **40** to the discharge opening **26.**

Another embodiment of the cooling apparatus is depicted in FIGS. 6 and 7 of the drawings. Referring to FIG. 6 of the drawings, the cooling device can comprise three concentric cylinders or pipes which are vertically disposed, the outer cylinder of which is provided with a multiplicity of equally spaced tubes. The hot effluent gases are introduced into the coolant apparatus and rapidly cooled by indirect heat exchange by contact with two cooling surfaces.

The central concentric pipe **132** has an inlet **173** at its upper end and depends downwardly to form the central passage **131.** The second concentric pipe **134** at its upper end just short of inlet **173** curves inwardly and abuts and terminates at the wall of central pipe **132.** The outer wall of pipe **132** and the inner wall of pipe **134** form annular space **133.** Spacers **148** maintains pipe **132** equidistant from the inner wall of pipe **134.** Pipe **134** at its lower end forms a rounded chamber terminating in rounded end member **137.** The third concentric pipe **136** extends about the length of the apparatus and terminates short of the top of pipe **134.** Above the point at which pipe **136** terminates, conduit **174** is in communication with annular space **133** through outlet opening **175.** The inner wall of pipe **136** and the outer wall of pipe **134** form the second annular chamber **135.** Near the top of annular passage **135** there is provided baffle ring **146** which prevents stagnant product gases from accumulating in the upper end of the annular chamber. Also near the top of annular chamber **135** there is provided connecting means **144** which is in communication with annular passage **135** through outlet opening **145.** Baffle ring **146** and spacers **147** maintain concentric pipe **134** in the center of annular chamber **135.**

An important feature of the cooling apparatus is the nose cone **138.** The nose cone **138** is arranged axially with the pipe **134,** the base of the nose cone **138** being attached to the rounded end member **137** and the apex extending in the direction of the inlet opening **143.** The concentric pipe **136** at a position proximate to the end of the straight portion of concentric pipe **134** tapers inwardly in the general direction of the nose cone **138** to form inlet opening **143.** The cross-sectional area of inlet **143** is such that the annular passage **140** gradually increases in cross-sectional area from inlet **143** to the annular space formed by the walls of pipes **134** and **136.**

The outer wall of concentric pipe **136** can be provided with a multiplicity of equally spaced tubes **161** defining passages **167,** which tubes are connected to and are in close contact with outer wall **136.** These tubes run the approximate length of outer wall **136** from about the bottommost portion of wall **136** up to conduit **144.** Tubes **161** at the upper and lower ends flare outwardly by curved portions **160** and **162,** respectively and are in communication with torus **150** at their upper end and torus **149** at their lower end. Torus **149** has a connecting conduit **164** through which coolant fluid passes through inlet **163** into the torus **149** and flows upwardly through tubes **161.** Tubes **161** are in communication with upper torus **150** and the cooling fluid flows out of torus **150** through outlet **166** and conduit **165.**

The cooling apparatus can be designed and sized to accommodate any desired cooling service. Suitable apparatus for use in the present invention can have an overall length of the cooling apparatus from coolant inlet **173** to hot effluent gas inlet **143** of 20 to 24 feet. The inside diameter of the third concentric pipe **136** can be 8 to 10 inches. Tubes **161** can be about one to two inches in inside diameter. The inside diameter of tori **149** and **150** can be about 3 to 4 inches. The cross-sectional area of central chamber formed by pipe **132** can be 7 square inches. The length of the central chamber can be 18 to 20 feet. The cross-sectional area of the first annular chamber **33** can be about 12 square inches and can have a length of about 18 to 20 feet. The cross-sectional area of the second annular chamber **135** can be about 20 square inches and the chamber can have a length of about 16–18 feet, excluding the inlet section. The cross-sectional area of gas inlet **143** can be about 12 to 13 square inches, gradually increasing in cross-sectional area to about 19 to 20 square inches in the straight portion of pipe **134.** Tapered nose cone **138** can have an angle at its apex of about 28° to 30°. The total cross-sectional area of tubes **161** can be about 10–11 square inches. The total coolant flow through tubes **161** and first annular passage **133** can be about 10 times the flow of hot effluent gases based on weight.

Hot gases at a velocity of 700 to 800 ft./sec. enter the cooling apparatus through inlet **143** and pass into second annular chamber **135** where they are slowed to about 400 to 500 ft./sec. and pass out of the apparatus at the end of the chamber through outlet **145.** The coolant water is introduced through inlet **173** and flows downwardly in the central chamber **131** of concentric pipe **132** and a mixture of water and steam flows upwardly in first annular passage **133** and passes out near the top of the first annular passage through outlet opening **175.** Coolant water enters the bottom torus **149** through inlet **163** and flows upwardly in tubes **161** providing indirect cooling for the hot furnace effluent gases at the inner wall surface of pipe **136.** The inner surface of pipe **136** and the outer surface of pipe **134** provide the two cooling surfaces for the hot gas.

The mixture of steam and water move upwardly in tubes **161** into torus **150** and through outlet **166.**

The inlet diffuser **140** formed by wall **139** and nose cone **138** provides for gradual increase in cross-sectional area of the gases entering through inlet **143** which gradually increases the pressure of the hot gases as the gas velocity is reduced. The diffuser **140** ensures uniform gas distribution between cooling surfaces **136** and **134** without the production of large eddy currents in the gas flow which would reduce the extent of pressure increase. In accordance with the present invention, the pressure increase in the gas caused by the gradual increase in cross-sectional area in the inlet compensates for a substantial portion of the pressure loss in the gas due to friction. The cooled outlet gas pressure will be about the same as the hot inlet gas pressure. Passage **140** is sized to provide the gradual increase in cross-sectional area through which the hot gases flow. The gradual increase is provided by the tapered shape of nose cone **138** and the converging wall **139** of pipe **136.**

The gradual increase in cross-sectional area provides a gradual decrease in gas velocity which is accompanied by an increase in gas pressure to conserve total energy.

The angle of the nose cone **138** and the entering pipe **139** are selected so that the increase in cross-sectional area of the annular space formed between cone **138** and pipe **139** per unit length is equal to the increase in cross-sectional area per unit length of a conical pipe having an angle of divergence of 4° to 10°, preferably 4° to 7°, e.g. 5°. The angle of the cone **138** and extent to which converging wall **139** corresponds to the angle of cone **138** provide the necessary gradual increase in cross-sectional area. The nose cone angle can be 25° to 30°. The angle of converging wall **139** if taken to an apex can be 20° to 25°. The length of cone **138** can be 8 to 12 inches. The cooling chamber that is the second annular chamber **135** has the same cross-sectional area throughout its length.

FIG. **7** shows a cross section of the cooling apparatus taken through line **7**—**7** of FIG. **6**. FIG. **7** shows an end section of tubes **161** and the manner in which they are connected by welds **170** to the outer wall of concentric pipe **136**. A suitable heat transfer material **171** can be used to fill the space between tubes **161** and to improve the heat transfer between the hot gases and coolant.

Another embodiment of the cooling apparatus is illustrated by FIGS. **8** and **9** of the drawings. In this embodiment cooling of the hot gases is provided primarily by direct contact with the outer wall of concentric pipe **134**. In order to improve the heat transfer between pipe **134** and the hot gases, pipe **134** can contain a multiplicity of cooling fins **156** which project into the hot gases in annular space **135**.

The cooling apparatus or quenching unit of the present invention provides rapid cooling for hot fluids by indirect heat exchange on cooling surfaces. The heat exchanger can be used to cool liquids or gases and/or for heat recovery and generation of steam. Typically, when used to cool a hot gaseous hydrocarbon effluent from a cracking furnace, the inlet gas temperature to the quench unit will be about 1350° to 1650° F. While in the heat exchanger the effluent will be cooled by 100° to 600° F. The hot gases are fed to the quench unit at a velocity of 350 to 1000 ft./sec., and preferably at 500 to 900 ft./sec. The heat flux at the inlet to the cooling apparatus can be as high as 80,000 BTU/hr./sq. ft. and the cooling apparatus can have an average heat flux of about 40,000 BTU/hr./sq. ft. In the operation of the unit, at the pressures described below, about 10 to 15 lbs. of water are circulated for each pound of steam produced. The design and operation of the unit can provide that there be substantially no decrease in pressure between the hot gas inlet and the quenched gas outlet. The pressure decrease of the fluid to be cooled can be kept down to 3 PSI and preferably less than 1 PSI. The water is introduced to the unit at a pressure of 200 to 2000 PSIA and at a temperature of about 388° to about 635° F. and preferably, the coolant water is introduced at a pressure of 1500 to 1800 PSIA and at a temperature of about 595° to 620° F. In the embodiment of the invention where the coolant circulation is provided by thermosiphon effect, the circulation rate can be self-regulating within design limits and automatically adjusts for variations in cooling service required.

When cooling high temperature hydrocarbon streams which contain some relatively high boiling constituents, it is necessary to maintain the cooling surfaces at a temperature high enough to prevent condensation and deposition of the high boiling constituents on the cooling surfaces, but it is also necessary to maintain the cooling surfaces cold enough to carry out the rapid cooling of the effluent stream that is required.

I claim:

1. A heat exchange apparatus comprising:

a divergently shaped inlet section for the flow of hot fluid therethrough configured with a total divergence angle between 4° and 7°;

a downstream section for the flow of hot gases passing from the inlet section which downstream section extends from the downstream end of the inlet section and has a constant cross-sectional area equal to the cross-sectional area of the downstream end of the divergently shaped inlet section;

means for cooling the hot fluid flowing through the heat exchanger apparatus;

whereby the flow of the hot gases is substantially turbulence-free during the passage thereof through the heat exchange apparatus.

2. The apparatus of claim **1** wherein the total angle of divergence of the inlet section is 5°.

3. The apparatus of claim **1** wherein the passage for the flow of hot fluid is a centrally disposed tubular structure and the means for cooling the hot fluid flowing therethrough is a cooling chamber arranged therearound.

4. The apparatus of claim **1** wherein the passage for the flow of hot fluid is a centrally disposed tubular structure and the means for cooling the hot fluid flowing therethrough is comprised of an annular array of tubes arranged in direct contact with the outer surface of the centrally disposed chamber.

5. The apparatus of claim **4** further comprising cooling manifolds at each end of the heat exchanger and wherein the annular array of tubes arranged in direct contact with the surface of the centrally disposed chamber communicate with the manifolds.

6. The apparatus as in claim **5** where the cooling manifolds arranged to communicate with the annular array of tubes are toroidal in configuration.

7. The apparatus as in claim **3** wherein the cooling chamber has a coolant inlet located in proximity to the inlet of the centrally disposed chamber for hot fluid and an outlet located in proximity to the outlet of the centrally disposed chamber for hot fluid.

8. The apparatus of claim **7** wherein the cooling chamber surrounds the entire centrally disposed chamber for hot fluid.

9. The apparatus of claim **1** wherein the passage for the flow of hot fluid is annular.

10. The apparatus of claim **9** wherein the increase in cross-sectional area of the divergent inlet section is equivalent to the increase in cross-sectional area per unit length of a conical pipe having an angle of divergence of 5°.

11. The apparatus of claim **9** wherein the means for cooling the hot fluid flowing through the annular passage is a cooling passage arranged concentrically with and interiorly of the inner wall of the annular passage.

12. The apparatus of claim **11** wherein the cooling passage arranged concentrically with and interiorly of the inner wall of the annular passage is comprised of a tubular central cooling chamber arranged axially in the heat exchanger, which central cooling chamber has an inlet at one end and an outlet at the opposite end; an annular cooling chamber defined by the outer wall of the tubular central chamber and the inner wall of the annular hot fluid passage; and communication means between the tubular central chamber and the annular cooling chamber.

13. The apparatus of claim 12 wherein the diverging inlet for the annular hot fluid passage is defined by a cone extending from the end of the inner wall of the annular hot fluid passage near the hot fluid inlet and a converging wall surrounding the cone, which converging wall extends from the outer wall of the annular hot fluid passage to the hot fluid inlet.

14. The apparatus of claim 13 wherein the cone has an angle of 25° to 30° and the converging wall extending from the outer wall of the annular hot fluid passage surrounding the cone has an angle of 20° to 25°.

15. The apparatus of claim 9 wherein the cone has an angle of 25° to 30° and the converging wall extending from the outer wall of the annular hot fluid passage surrounding the cone has an angle of 20° to 25°.

16. The apparatus of claim 14 further comprising cooling means arranged around the outer wall of the annular hot fluid passage.

17. The apparatus of claim 16 wherein the cooling means arranged around the outer wall of the annular hot fluid passage is a cooling chamber.

18. The apparatus of claim 17 further comprising cooling fins extending from the outer wall of the annular hot fluid passage into the outer cooling chamber.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,910,347

DATED : October 7, 1975

INVENTOR(S) : Herman N. Woebcke

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 13, "applicants" should be -- application --; line 67, between "means" and "be" insert -- must -- .

Column 2, line 52, delete second ",pipes,".

Column 3, line 34, between "flow" and "effluent" insert -- of hot -- .

Column 5, line 29, change "if" to -- is -- ; and line 67, after "3" insert -- to 6 inches. The cross-sectional area of gas inlet 40 can be about 3 -- .

Column 6, line 35, change "is"to -- in -- .

Signed and Sealed this

Twenty-first Day of June 1977

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks