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71 Applicant: **Lummus Crest, Inc.**
1515 Broad Street
Bloomfield New Jersey 07003(US)

72 Inventor: **Fernandez-Baujin, Jorge Moises**
702-73 Street
North Bergen New Jersey 07047(US)
Inventor: **Albano, John Vincent**
768 Glenside Court East
Oradell New Jersey 07649(US)
Inventor: **Rhoe, Andrei**
539 Hartung Drive
Wyckoff New Jersey 07481(US)
Inventor: **Sundaram, Kandasamy Meenakshi**
157-H Meriline Avenue
West Patterson New Jersey 07424(US)
Inventor: **Sumner, Charles**
3 Stratford
Livingston New Jersey 07039(US)

74 Representative: **Gross, Gernot K.**
Kleiberweg 5
D-6200 Wiesbaden(DE)

54 **Pyrolysis heater.**

57 The first half and preferably only the first quarter of a pyrolysis coil (31,32) for treating hydrocarbons is provided with extended heating surface (52) for increasing the adsorption of radiant heat. The extended heating surface may be on the inside or the outside of the tubes and may be in the form of studes (54) or fins or ribs (56).

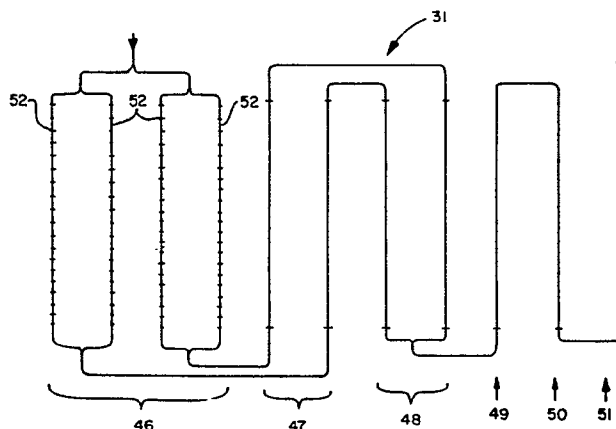


Fig. 2

PYROLYSIS HEATER

BACKGROUND OF THE INVENTION

The production of light olefins (ethylene, propylene, butadiene and butylenes) and associated aromatics (benzene, toluene, ethylbenzene, xylenes and styrene) is usually carried out by the thermal cracking of hydrocarbon feedstocks in the presence of steam. This process is known as the steam pyrolysis of hydrocarbons for the production of olefins.

The hydrocarbon feedstocks used for the production of olefins range from essentially pure ethane to vacuum gas oils and any combination thereof. Hydrogen and methane are impurities found in the feed. The process consists of a pyrolysis section and a recovery section. The feedstock preheating system, the steam pyrolysis coils and the exchangers to cool the coil effluent are included in the pyrolysis section of the plant. The majority of the feed preheating system and the pyrolysis coils are contained in the pyrolysis furnace or reactor. The chemical reactions of this process take place in the pyrolysis coils in the absence of catalyst.

Approximately 30 to 40 percent of the total plant capital investment is required in the pyrolysis section. Furthermore, the economics of the process, i.e. feedstock consumption and byproducts produced for a fixed ethylene production, are determined by the design of the pyrolysis section. Thus, traditionally, improvements in the design of the pyrolysis section of the plant have resulted in dramatic impact on the economics of the steam pyrolysis process.

The pyrolysis furnaces consist of a convection section and a radiant section or any combination thereof. The hydrocarbon feed is first preheated in the convection section of the furnace. Dilution steam is then added and the steam-hydrocarbon mixture is further preheated in the mixed preheat coil of the convection section. In some designs, the dilution steam is also preheated prior to addition to the hydrocarbon stream. The mixture is preheated up to the required transition temperature for pyrolysis in the radiant section. This temperature is identified as the crossover temperature between the convection and the radiant sections.

This temperature varies with the type of feedstock and with the specific coil design.

With liquid hydrocarbon feedstocks, vaporization of the feed takes place in the mixed preheat coil and/or at the point where the dilution steam is injected. In some designs, the vaporization of the feedstock is external to the convection section coils to avoid potential coke laydown. Furthermore, boiler feedwater, saturated steam and dilution steam may also be heated in the convection section. It should be noted that this description is only typical. The requirements for the heating services described above, as well as their locations and sizes in the convection section of a pyrolysis furnace, depend upon the specifications of each plant's requirements.

The pyrolysis coils, where the hydrocarbon feed in the presence of dilution steam is pyrolyzed, are contained in the radiant section of the pyrolysis furnace or reactor. The number of pyrolysis coils per radiant section is a function of the required ethylene capacity per pyrolysis furnace, the desired pyrolysis yields, the coil configuration and dimensions, the feedstock type and the terminal operating conditions such as coil outlet pressure. Transferline exchangers, followed by direct quenching with oil, are used to cool the effluent coming out from the coils. For a fixed ethylene capacity per furnace, pyrolysis yields, feedstock type and terminal operating conditions, the pyrolysis coils based on small diameter tubes have less capacity per coil than those based on large diameter tubes. Therefore, the number of pyrolysis coils with small diameter tubes required to meet the specified ethylene production per furnace is larger than the number required with coils of large diameter tubes.

The current practice in the design of pyrolysis coils includes three basic types. One type employs small to moderate tube diameters (1 to 4 inches) with a single tube per pass and one or more passes per pyrolysis coil (1 to 8). The second type employs large tube diameters (4 to 7 inches) also with a single tube per pass and several passes per coil (2 to 12). The third type uses a combination of small and large tube diameters (1 to 7 inches) and multiple tubes per pass toward the front end of the coil and single tube per pass toward the back end of the pyrolysis coil, and several passes per coil (2 to 12).

It should be noted that, for the first two types, the tube diameter could be constant throughout the coils or could be increasing from the first pass to the last pass of the pyrolysis coils.

The pyrolysis coils are located in a longitudinal plane in the radiant section of the pyrolysis furnaces. The pyrolysis coils could be staggered or located in a single row or multiple rows. The radiant heat source is provided by firing either burners from the lateral walls of the radiant section, or burners from the floor (hearth) of the radiant section or a combination thereof.

For designs with a single diameter tube throughout the coil, it is obvious that the ratio of the metal

surface to the coil volume per pass remains constant from the beginning to the end of the pyrolysis coils. In these designs, the axial temperature profile of the gases reacting in the pyrolysis coil approaches a straight line with a positive slope.

Pyrolysis coils with small diameter tubes, although having better heat transfer characteristics, result in smaller capacity per coil when compared to the other two design types because of the faster coking rate observed during the cycle, and the increase in coil pressure drop due to the coke deposited on the coil inner walls during the run. This increase has a detrimental effect on the pyrolysis yield (decreasing olefins production and increasing fuel oil byproduct at constant feedstock conversion with cycle time) produced by the first design mentioned above.

By enlarging the diameters of the tubes from the beginning to the end of the pyrolysis coil, the surface to volume ratio is also reduced along the direction of the flow in the pyrolysis coil. The larger tube diameters in the second half of the pyrolysis coil reduce the coking rate and, thus, the effect of the deposited coke on the coil pressure drop and the concomitant detrimental effect on the pyrolysis yields. Also, the larger tubes ultimately result in a larger capacity coil. However, the axial temperature profile of the reacting gases still approaches a straight line with a positive slope. The drawback of the larger diameter tubes is the lower heat transfer coefficient resulting in higher metal temperatures.

Since the surface to volume ratio of a coil with enlarged tube diameter toward the outlet is smaller than that of a coil with constant diameter, the coil must be longer to achieve a higher average ethylene production per coil. Both coils can be designed to achieve essentially identical yields by trading increments in residence time against reductions in hydrocarbon partial pressure. An obvious limitation with the enlargement of the tube diameter toward the outlet section of the pyrolysis coil is the poorer heat transfer coefficient since, for a given throughput, the coefficient is inversely proportional to $D^{1.8}$ where D is the diameter.

To significantly increase the ethylene production per pyrolysis coil, thus reducing the required number of coils per pyrolysis furnace, the ultimate objective is to develop an axial gas temperature profile that maximizes the utilization of the metal surface available in the pyrolysis coil. In general, the target temperature profile is concave down and as close as possible to an isothermal profile instead of the almost straight line with positive slope or concave up profile achieved with the first two coil design types mentioned earlier. The isothermal axial gas temperature profile represents the best heat utilization of the metal in the pyrolysis coil, i.e., for a given yield and run length, the maximum capacity per unit weight of pyrolysis coil metal and, thus, the least expensive pyrolysis coil.

One design approach is to use zone firing which requires the partitioning of the firebox into several compartments. In addition, the firing system has to be properly controlled to achieve the zone firing effect. The operating principle behind this design approach is to initiate the cycle with a straight line or a concave up temperature profile by firing uniformly throughout the pyrolysis coil or shifting the intensity of the firing more toward the outlet section of the pyrolysis coil. Gradually, during the progress of the run or as coking of the coil takes place, the firing is shifted from more intensity toward the outlet section of the coil to more intensity toward the inlet section of the coil. Ultimately, toward the end of the cycle, an isothermal or concave down axial temperature profile is used to operate the coil.

The zone firing approach permits the utilization of higher capacity per coil at constant running time. However, due to the complexities in the construction of the firebox of the pyrolysis furnace and in the firing control system, this approach has not been too widely practiced in the industrial production of ethylene. Furthermore, it should be noted that the metal in the pyrolysis coil is fully utilized only when the temperature profile approaches isothermal conditions which, in this type of design, occurs only during a fraction of the running time.

The coil type three mentioned above which uses multiple parallel tubes of small diameter in the passes of the inlet section of the coil and large diameter single tubes in the passes of the outlet section of the coil is discussed next. This design is commonly referred to as the swage coil and that term will be used herein.

The swage coil design approach has been utilized in a large number of worldwide ethylene plants since the seventies. Instead of using a firebox of complex construction and a very sophisticated and expensive firing control system, it relies on the coil configuration to achieve the concave down axial gas temperature profile during the entire running time. Because of this efficient utilization of the metal in the pyrolysis coil, the coil is characterized by larger production capacity at equal average yields and constant running time. The swage coil has a higher capacity and a lower coking rate resulting in a longer running time per cycle.

The technical advantages of the large diameter pyrolysis tubes in the outlet section outweigh its poor heat transfer characteristics. Designers have tried to compensate for this drawback by installing inserts inside the outlet tubes and/or installing studs or longitudinal fins on the outer walls of the outlet tubes with the objective to improve the heat transfer rate in that section of the pyrolysis coil. However, the pyrolysis

conditions are more intense in the last half of the coil. The coke forms predominantly in this location of the coil during the pyrolysis of the feedstock and the coke deposits on the inner walls of the pyrolysis tubes. The coke deposition is responsible for the increase in metal temperature with days on stream. Due to the mild pyrolysis conditions in the first half of the pyrolysis coil, the coke formation in this inlet region is significantly less than in the second half of the coil. In this inlet region of the coil, the increases in metal temperature due to coke deposition on the walls are only moderate.

Because of the above characteristics of pyrolysis coils, inserts located inside the outlet tubes are expected to act as nucleus for the growth of the coke formed during pyrolysis. Thus, the utilization of inserts in this region would result in shorter than desirable run lengths, higher than desirable pressure drops, poor operating reproducibility of conditions and significant losses in olefins yields.

In principle, because the equivalent outside heat transfer coefficients of the outlet tubes are lower than the inside heat transfer coefficients, it appears attractive to utilize extended surfaces in the form of studs or fins in the outlet portion of the coil. However, the utilization of the extended surfaces in the outlet position of the coil is not effective because the temperature of the stud or fin tip will limit the run length as a result of the coke deposition on the inner walls of this section of the pyrolysis coils.

SUMMARY OF THE INVENTION

The present invention relates to the incorporation of extended surfaces on the inlet portion of a pyrolysis coil in order to make the axial gas temperature profile even closer to an isothermal profile than it has been possible to achieve with uniform firing in the pyrolysis coils currently used in the olefins production industry. This permits higher production capacity per unit weight of pyrolysis coil while preserving the desired pyrolysis yields and on-stream time in between decoking cycles. Conversely, this invention, at constant ethylene production per pyrolysis coil, permits longer on-stream time and/or somewhat higher ethylene yields. More specifically, the invention involves the placing of the extended surface in the first half and preferably the first quarter of the coil and preferably involves the use of studs or longitudinal straight fins or ribs on either the outside or the inside of the tubes or both locations.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified schematic representation of a pyrolysis furnace which can employ the present invention;

Figure 2 is a schematic presentation of an arrangement of the tubes in one coil of a pyrolysis furnace employing the present invention; and

Figure 3 shows a short section of a tube with the studs of the present invention thereon.

Figure 4 illustrates a cross-section of a tube with longitudinally extending fins or ribs around the inside circumference.

Figure 5 is a graph illustrating the temperature profile through a coil of the prior art as compared to a coil of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1, there is provided a vertical tube type pyrolysis heater supported on structural steel framework generally indicated as 10. The heater is comprised of outer walls 11 and 12, inner walls 13 and 14, end walls 15 and floors 16 and 17. The outer walls 11 and 12 are substantially parallel to inner walls 13 and 14 with the height of outer walls 11 and 12 extending above the height of inner walls 13 and 14. Mounted in outer walls 11 and 12 and inner walls 13 and 14 are a plurality of vertical rows of high intensity radiant type burners, generally indicated at 18. The floors 16 and 17 extend between the outer walls 11 and 12 and inner walls 13 and 14, respectively. The floors 16 and 17 are provided with floor burners, generally indicated as 19 which are preferably of the flame type.

The outer wall 11, inner wall 13 and floor 16 together with end walls 15 form a radiant heating zone, generally indicated as 20, while outer wall 12, inner wall 14 and floor 17 together with end walls 15 form a second radiant heating zone, generally indicated as 21. End walls 15 are in the shape of an inverted U thereby forming an open area 22 permitting access to the burners 18 mounted in the inner walls 13 and 14.

Horizontally positioned and mounted on inner walls 13 and 14 is inner roof 25. Horizontally positioned

and extending inwardly from outer wall 11 is upper roof 26 mounted on outer wall 11 and end walls 15. Similarly, upper roof 27 is horizontally positioned and extends inwardly from outer wall 12 and is mounted on outer wall 12 and end walls 15. Mounted on upper walls 26 and 27 are upper walls 28 and 29 which form with the upper extending portions of end walls 15, a convection zone generally indicated as 30. All of the walls, floors and roofs are provided with suitable refractory material.

In the radiant heating zones 20 and 21, there is provided a plurality of vertical tubes forming process coils 31 and 32 suitably mounted from supporting structure 10 by hangers 33. The process coils 31 and 32 are positioned intermediate the outer and inner walls 11 and 13 and 12 and 14, respectively. The configuration of these process coils will be described in more detail hereinafter. Mounted within the convection zone 30 are horizontally disposed conduits, schematically illustrated and generally indicated as 35. The conduits 35 are in fluid communication with the process coils 31 and 32 through crossovers 36. Also positioned within the convection section 30 is a second section of horizontally disposed conduits generally indicated as 38. Inlet and outlet manifolds 38A and 38B are in fluid communication with the conduits 38.

The burners 18 are supplied with the fuel through lines 40 from a plurality of manifolds 39. The fuel is introduced into manifolds 39 through a manifold 41 under control of valves 42. The flow of fuel to burners 18 may be varied in vertical rows depending on the described severity of firing of the process coils 31 and 32. Individual burners may be further adjusted by valves 44 in lines 40 with the total flow of fuel to the heater being controlled by valve 45. It is understood that the burners mounted in outer walls 11 and 12 and inner walls 13 and 14 have similar manifold means which is not shown. Similarly, lines 46 carry the fuel to the floor burners.

Referring now to Figure 2, there is schematically illustrated a layout of the process coil 31 and it is to be understood that the process coil 32 would be similar. This general type of pyrolysis heater is described in U.S. Patent 3,274,978. However, the present invention is also applicable to pyrolysis coils that can be installed in other types of heaters currently used in industry.

Referring now to Figure 2, there is illustrated a schematic arrangement of the process coil 31 of the present invention and it is to be understood that the process coil 32 would be similar. This process coil 31 is generally of the swage type previously discussed and consists of a first pass 46, a second pass 47, a third pass 48, a fourth pass 49, a fifth pass 50 and a sixth pass 51. As can be seen, the first pass 46 comprises four tubes, the second pass 47 and the third pass 48 each comprise two tubes, and the passes 49, 50 and 51 each comprise one tube. However, this coil should be considered typical only and not limiting the present invention. The present invention is applicable to pyrolysis coils of any configuration and tube dimensions.

The following table sets forth the details of the coil configuration:

Pass No.	No. of Tubes	Inside Diameter, Inches
1	4	3.5
2	2	5
3	2	5
4	1	7.5
5	1	7.5
6	1	7.5

As depicted in Figure 2, extended heating surface 52 is located on the four tubes of first pass 46. This extended heating surface can be in the form of studs or straight longitudinal fins or ribs. The studs may be of any desired shaped but they are preferably cylindrical. The size and number of studs or fins per unit length of pyrolysis tubing are selected according to the process parameters of any particular installation. As an example, the studs may be 0.5 inches in diameter with a length ranging from 0.5 to 0.75 inches. There may be 8 to 12 studs around the circumference of the tube at any one plane. Figure 3 illustrates a short section of tube with studs. Studs are applicable to the outside of the tubes. Straight longitudinal fins or ribs are preferred for the inside of the tubes. For example, the fins may be 0.2 inches in height having 6 to 10 fins around the circumference of the tubes. Figure 4 illustrates a cross-section of a tube with straight longitudinal fins or ribs around the inside circumference thereof. Also, the extended heating surface is installed in the first half of the pyrolysis coil and preferably in the first quarter. As indicated, the embodiment illustrated in Figure 2 has the studs only in the first pass.

The effect of the extended heating surface on the first pass can be seen in Figure 5 which compares the temperature profile for a conventional pyrolysis coil and the same coil with extended heating surface. In this Figure 5, it can be seen that the temperature in the first part of the coil is significantly increased over the temperature in a conventional coil while the temperature in the outlet portion is only slightly affected.

With this higher temperature at the inlet portion, pyrolysis severity and coil capacity are increased without increasing the maximum outlet temperature or greatly increasing the temperature in the outlet portion where coking would otherwise take place.

Following is a comparison of the calculated process characteristics of a conventional swage coil design with two different designs incorporating the present invention. In each case, the coil configuration is four tubes in the first pass, two tubes in each of the second and third passes, and one tube in each of the fourth, fifth and sixth passes:

	Conventional Swage Coil	Coil A	Coil B
Length/pass, ft.	31	33	31
Capacity per coil tons HC/hr.	5.756	7.212	6.577
Capacity increase, %	basis	24.4	13.5
Heat duty, MMBTU/hr.	16.07	20.1	18.41
Run length, days	60	60	60
Ethylene yield, wt %			
Once through	28.9	28.7	28.7
Ultimate	32.9	32.9	32.9
Operating Coils	30	24	26.3
Stud Addition, % effective surface area increase			
Pass No. 1	None	50	100
Other Passes	None	None	None

To make the most effective use of the metal in the first half of the coil, an isothermal gas temperature profile would be desired. The use of zone firing and the prior art swage coil design both bring the temperature profile closer to the isothermal. The use of the internal and/or external extended heating surface of the present invention in the first half or quarter of the coil brings the temperature profile even closer to the isothermal. Use of extended heating surface in the last part of the coil would tend to take the temperature profile further away from a isothermal profile as well as create the coking previously mentioned. The use of the extended surface in the first part of the coil maintains or enhances the run length or cycle time, maintains or enhances pyrolysis selectively toward olefins and enhances ethylene capacity per unit weight of tube metal and any combination thereof.

Although the temperature profiles in Figure 5 appear to be very close together, the temperature difference in favor of the coil with extended surface results in an increase in the capacity of the coil of approximately 10%. Since the kinetic reaction velocities vary exponentially with changes in temperature, small differences in gas temperature have a pronounced effect on the pyrolysis reactions.

Claims

1. A pyrolysis heater for the pyrolysis of hydrocarbons comprising:
 - a) a radiant heating chamber,
 - b) at least one tubular processing coil including a first half and a second half for processing fluid in said heating chamber,
 - c) a plurality of radiant burners for heating the at least one tubular processing coil, and
 - d) said at least one tubular processing coil including, within at least a portion of the first half thereof only, extended heating surface for increasing the adsorption of radiant heat.
2. A pyrolysis heater for the pyrolysis of hydrocarbons as recited in claim 1 wherein said extended heating surface comprises heating surface attached to and extending outwardly from the external surface of said tubular processing coil.

3. A pyrolysis heater for the pyrolysis of hydrocarbons as recited in claim 2 wherein said extended heating surface comprises studs.

5 4. A pyrolysis heater for the pyrolysis of hydrocarbons as recited in claim 1 wherein said extended heating surface comprises longitudinally extending heating surface attached to and extending inwardly from the internal surface of said tubular processing coil.

5. A pyrolysis heater for the pyrolysis of hydrocarbons as recited in claim 4 wherein said extended heating surface comprises straight longitudinal fins or ribs.

6. A pyrolysis heater for the pyrolysis of hydrocarbons as recited in claim 1 wherein said extended heating surface is located only in the first quarter of said processing coil.

10 7. A pyrolysis heater for the pyrolysis of hydrocarbons as recited in claim 1 wherein said extended heating surface is located only on said first pass of the said tubular processing coil.

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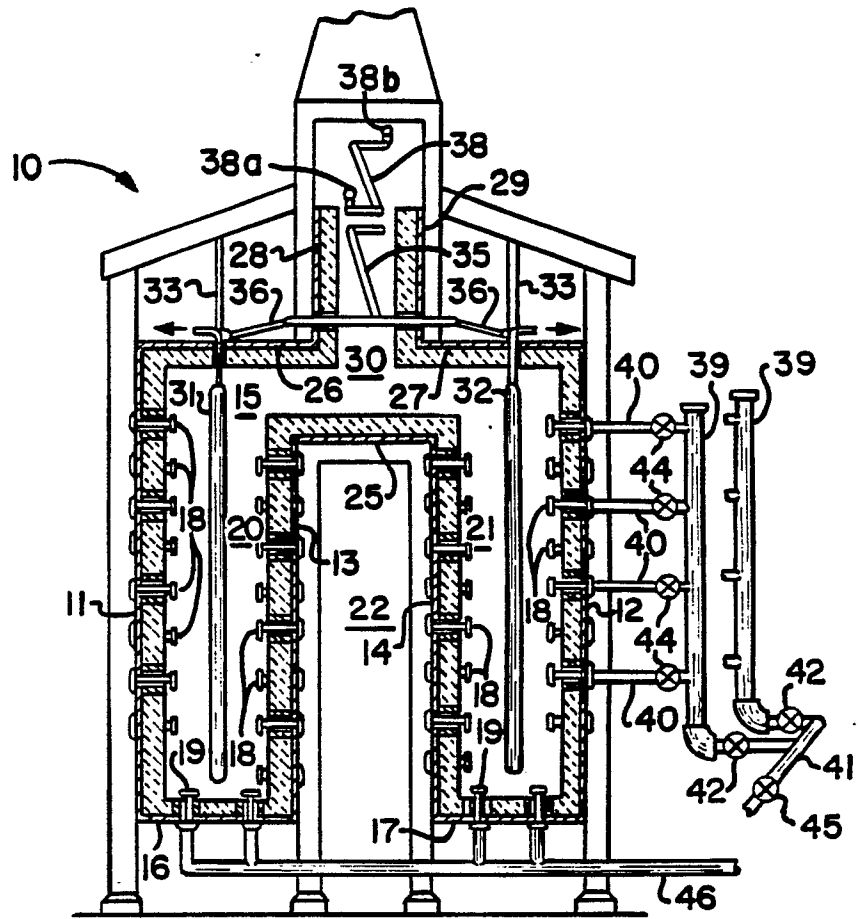


Fig. 1

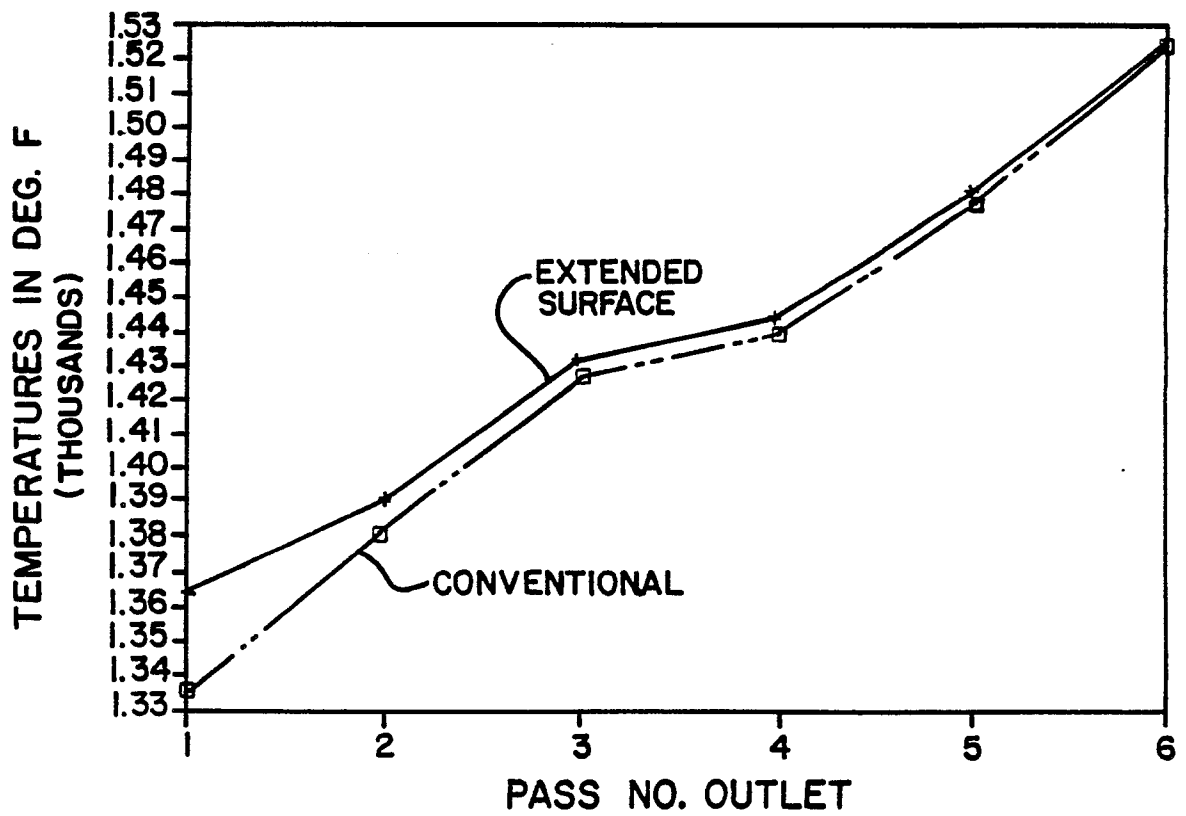


Fig. 5

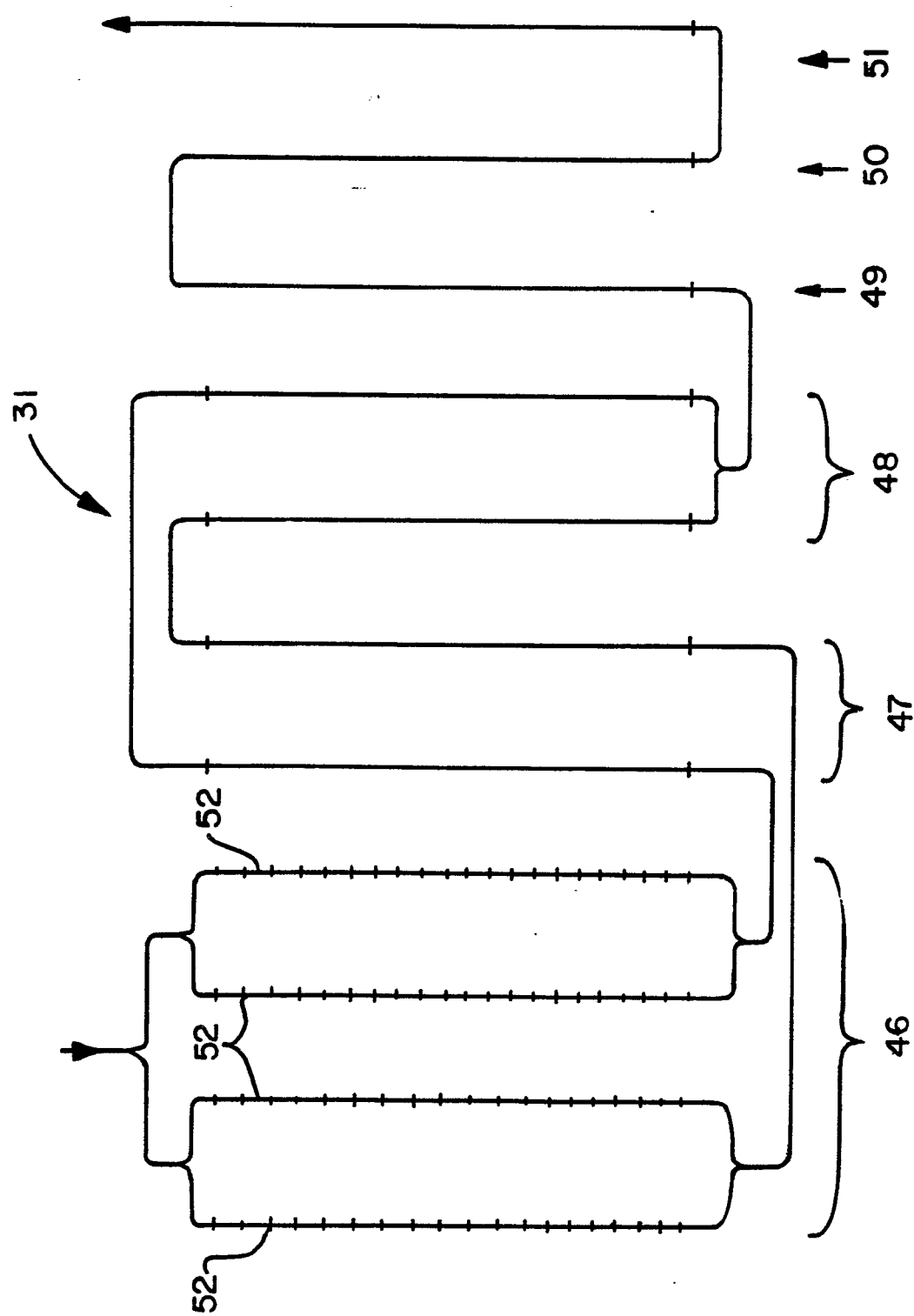


Fig. 2

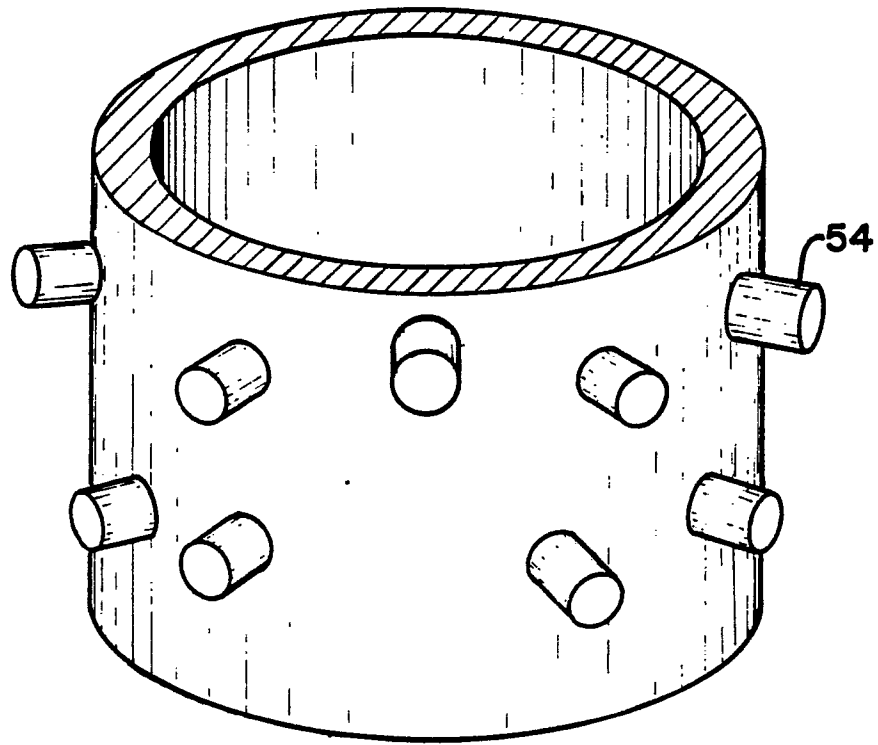


Fig. 3

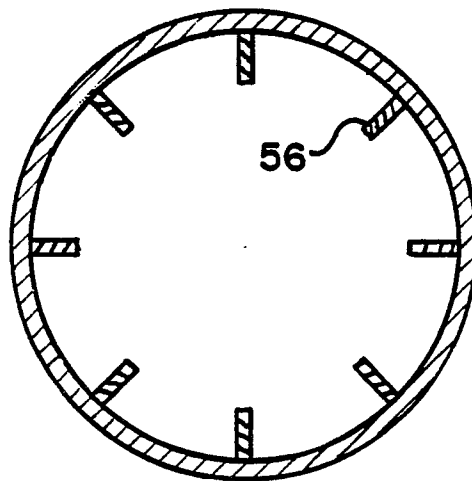


Fig. 4



DOCUMENTS CONSIDERED TO BE RELEVANT			EP 88113240.1
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	GB - A - 2 021 632 (LUMMUS) * Claims; fig. * --	1,4,5	C 10 G 9/14
X	US - A - 4 342 642 (BAUER) * Claims; fig. * --	1,4,5	
D,X	US - A - 3 274 978 (PALCHIK) * Claims; fig. 1 * ----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			C 10 G F 28 F C 07 C 4/00
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 05-12-1988	Examiner BECKER
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	