



(22) Date de dépôt/Filing Date: 2010/05/06

(41) Mise à la disp. pub./Open to Public Insp.: 2011/11/06

(51) Cl.Int./Int.Cl. *F28D 7/00* (2006.01)

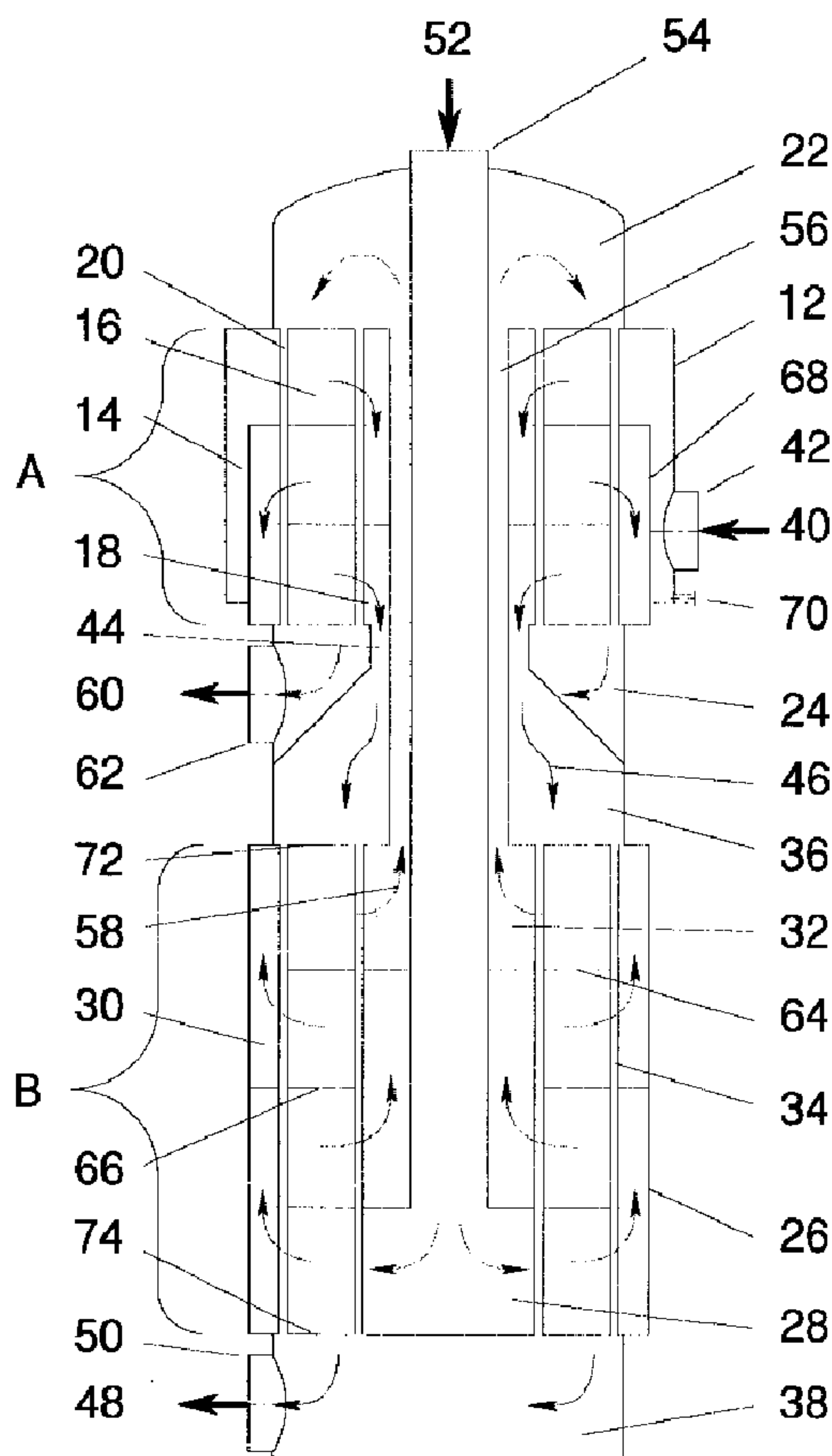
(71) Demandeur/Applicant:
AKER SOLUTIONS CANADA INC., CA

(72) Inventeurs/Inventors:
PEREZ, ORLANDO G., CA;
NORTON, DANIEL S., CA

(74) Agent: GOWAN INTELLECTUAL PROPERTY

(54) Titre : ECHANGEURS DE CHALEUR A TUBES ET CALANDRE

(54) Title: SHELL AND TUBE HEAT EXCHANGERS



(57) Abrégé/Abstract:

A process for exchanging heat in a shell and tube gas-to-gas heat exchanger between a plurality of gases, said process comprising passing a cold first gas in parallel flow to a second hot gas to provide a warmer first gas; and passing said warmer first gas in

(57) **Abrégé(suite)/Abstract(continued):**

counter-current flow to a hot third gas to provide a cooler said third gas. The invention provides increased minimum tube wall temperature within the exchanger for given process conditions while maintaining a high log mean temperature differential allowing for the prevention of corrosion from entrained corrosive vapours or entrained corrosive mist with a minimal increase in effective area.

ABSTRACT OF THE DISCLOSURE

5

A process for exchanging heat in a shell and tube gas-to-gas heat exchanger between a plurality of gases, said process comprising passing a cold first gas in parallel flow to a second hot gas to provide a warmer first gas; and passing said warmer first gas in counter-current flow to a hot third gas to provide a cooler said third gas. The invention provides increased minimum tube wall temperature within the exchanger for given process conditions while maintaining a high log mean temperature differential allowing for the prevention of corrosion from entrained corrosive vapours or entrained corrosive mist with a minimal increase in effective area.

15

20

25

0

SHELL AND TUBE HEAT EXCHANGERS

5

FIELD OF THE INVENTION

This invention relates to shell and tube heat exchangers, more specifically to exchangers operating in service where a standard counter flow shell and tube heat exchanger would not be able to meet the required process conditions without experiencing dew point corrosion, more specifically to exchangers using a combination of counter flow and parallel flow throughout the exchanger to reduce the potential for dew point corrosion while being able to maintain a high thermal efficiency with only a minimal increase in effective area, and most specifically to gas to gas heat exchangers used to cool hot gases containing sulphur trioxide and/or acid vapour or heating cold gases containing sulphur dioxide and/or entrained acid mist.

BACKGROUND OF THE INVENTION

20 The invention relates to heat exchangers operating in potentially corrosive or high fouling conditions where said corrosion or fouling rates are highly dependent upon the tube wall temperature throughout the exchanger. Shell and tube exchangers are generally the preferred layout of exchangers when fouling is expected.

Dew point corrosion is a well known phenomenon in heat exchangers dealing with a condensable corrosive vapour. When the shell or tube wall temperature on the corrosive side of the heat exchanger falls below said corrosive vapour's dew point, there is a potential for corrosion. This can lead to fouling which causes a decrease in performance, an increase in pressure drop, and premature failure of the heat exchanger.

In sulphuric acid manufacturing, both gas streams in a heat exchanger are often potentially corrosive. The hot gas stream typically contains sulphur trioxide (SO₃) and acid vapour which will rapidly corrode carbon steel if the walls drop below the acid vapour dew point temperature. The cold gas stream may be composed of various gas streams, including but not limited to ambient air, dried air, dried air containing sulphur dioxide (SO₂) gas, or SO₂ gas. The cold gas stream may also contain entrained acid mist from the upstream

30

process. This entrained acid mist can rapidly corrode the heat exchanger when it comes into direct contact with the tube walls, especially when said tube walls are directly impacted with droplets of entrained acid mist within the cold inlet gas.

In hydrocarbon power plants, it is beneficial to recover as much heat as possible from tail gas before releasing it to atmosphere. This is done through the use of preheat exchangers which transfers residual heat from combustion gas to preheat the combustion air or other fluids. The waste gas contains, amongst other gases, moisture and small quantities of SO₃ which combine to form sulphuric acid. Therefore, these preheat exchangers often experience dew point corrosion issues similar to those in the production of sulphuric acid.

Counter-flow exchangers are widely preferred due to their high Log Mean Temperature Differential (LMTD). These exchangers transfer heat from a hot fluid to a cold fluid, with the hot fluid flowing longitudinally along the effective length of the exchanger a cold fluid flowing in the opposite direction along the longitudinal length of the exchanger, the two fluids separated by a barrier or barriers, generally with said barrier being a tube wall or tube walls. Counter flow exchangers have the highest LMTD of the standard heat exchanger arrangements and therefore require less effective heat transfer area to attain an equivalent heat duty to other heat exchanger designs with equivalent process requirements.

Counter flow exchangers have traditionally been designed to prevent dew point corrosion by limiting the exchanger's heat duty. Limiting the heat duty can prevent the minimum tube wall temperature from falling beneath the dew point but may prevent the exchanger from being able to meet its process requirements. An alternative to limiting the effectiveness of the exchanger is to increase the gas inlet temperature, although for process reasons this may not be desirable or feasible.

Various prior art exchangers have attempted to overcome the difficulties with corrosion associated with the standard counter flow design while maintaining a high LMTD. Many of these will be familiar to a person skilled in the art and are discussed in standard sources of heat exchanger literature.

Corrosion resistant materials of construction are commonly used when there is a potential for dew point corrosion. Use of these materials reduces the effects of corrosion but does not prevent the formation of dew within the exchanger. The capital cost of the exchanger can increase significantly by using corrosion resistant materials depending on the materials required, and yet the material may still experience a considerable amount of corrosion and fouling.

Some counter flow exchangers contain a separate sacrificial tube bank on the cold side. These exchangers are designed so that any expected acid mist and dew point corrosion is contained to the sacrificial region. The use of a sacrificial tube bank does not inhibit corrosion and instead attempts to limit its long term effects by having a separate replaceable
5 section.

Parallel flow exchangers are able to maintain more consistent tube wall temperatures than counter flow exchangers for equivalent inlet and outlet conditions. These exchangers transfer heat from a hot fluid to a cold fluid, with the hot fluid flowing longitudinally along the effective length of the equipment and exchanging heat indirectly with a cold fluid flowing
10 in a generally parallel direction to the hot fluid, the two fluids separated by a barrier or barriers, generally with said barrier being a tube wall or tube walls. The temperatures of the two streams approach asymptotically and converge towards a common temperature which in turn limits the maximum heat duty and exit temperatures. A parallel flow exchanger will always have a lower LMTD than a comparable counter flow exchanger. There is also a
15 potential for significant thermal differential stresses in the inlet region where the temperature difference between the hot and cold gases is greatest. Because of these traits, pure parallel flow exchangers are not preferable when there is a requirement for high heat duties or where there is a large inlet temperature differential.

The herein disclosed invention offers a novel improvement over the prior art through
20 a unique combination of counter flow and parallel flow sections with other additional features, whose design and use will become apparent after a full review of this disclosure.

SUMMARY OF THE INVENTION

25 The present invention provides a shell and tube heat exchangers utilizing an improved flow combination of parallel flow and counter flow to retain a high LMTD and increase the minimum tube wall temperature in comparison to a counter flow heat exchanger operating under identical process conditions. This exchanger is particularly well suited for the prevention of dew point corrosion and damage from entrained acid mist.

30 The exchanger generally comprises two main sections with one section having a generally parallel flow arrangement and the other having a generally counter flow arrangement between the two fluids. Partially cooled hot gas transfers heat in a generally parallel flow manner to a cold gas through the tube walls in the colder of the two sections, while hot gas transfers heat in a generally counter flow manner to a partially heated cold gas

through the tube walls in the hotter of the two sections. These two sections may be separated by a transition section where the flows alternate between shell side and tube side. This transition is particularly beneficial in plants that have unsteady process conditions. Dividing the exchanger into two sections allows for full control over the thermal design of the system, the inclusion of a partial gas by-pass or intermediate gas addition, and easier repairs if necessary. By alternating the shell side and tube side gas streams the overall difference in thermal growth between the shell and tubes is reduced, which in turn reduces the stresses caused by differential thermal growth and reduces fatigue stresses from thermal cycling.

Accordingly, in one aspect the invention provides a process for exchanging heat in a shell and tube gas-to-gas heat exchanger between a plurality of gases,

said process comprising

passing a cold first gas in parallel flow to a second hot gas to provide a warmer first gas; and

passing said warmer first gas in counter-current flow to a hot third gas to provide a cooler said third gas.

Preferably, said second hot gas comprises said cooler said third gas.

In alternative embodiments, the invention as hereinabove defined provides a process comprising passing said cold first gas as a shell-side gas, and said warmer said first gas as a tube-side gas or a shell-side gas.

In further embodiments, the invention as hereinabove defined provides a process comprising passing said cold first gas as a tube-side gas and said warmer said first gas as a tube-side gas or a shell-side gas.

In yet further embodiments, the invention as hereinabove defined provides a process comprising removing a portion of said warmer said first gas from said heat exchanger.

In still yet further embodiments, the invention as hereinabove defined provides a process comprising removing a portion of said cooler said third gas from said heat exchanger.

In yet further embodiments, the invention as hereinabove defined provides a process comprising feeding a portion of said hot third gas in admixture with said cooler said third gas in parallel flow to said cold first gas.

In yet further embodiments, the invention as hereinabove defined provides a process comprising feeding a portion of said cold first gas in admixture with said warmer said first gas in counter-current flow to said hot third gas.

In yet further embodiments, the invention as hereinabove defined provides a process comprising said hot first gas comprises sulphur trioxide.

In yet further embodiments, the invention as hereinabove defined provides a process comprising hot first gas further comprises entrained corrosive liquid droplets.

In yet further embodiments, the invention as hereinabove defined provides a process wherein said hot first gas comprises entrained corrosive liquid droplets.

5 In yet further embodiments, the invention as hereinabove defined provides a process wherein said cold first gas comprises entrained corrosive liquid droplets.

In further embodiments, the invention as hereinabove defined provides a process wherein said second cold gas comprises air.

10 In a further aspect, the invention provides a process for the manufacture of sulphuric acid by the contact process comprising a process as hereinabove defined.

In a further aspect, the invention provides a process for exchanging heat in a shell and tube gas-to-gas heat exchanger between a first hot gas and a cold second gas as hereinabove defined in hydrocarbon power generation plants.

15 In a further aspect, the invention provides a gas-to-gas heat exchanger comprising a shell and tube first section comprising means for receiving a cold first gas; means for receiving a hot second gas; and means for passing said cold first gas in parallel flow to said hot second gas to provide a warmer said first gas;

20 a shell and tube second section comprising means for receiving a hot third gas; means for receiving said warmer said first gas; and means for passing said hot third gas in counter-current flow to said warmer said first gas to provide a cooler said third gas.

25 In further embodiments, the invention provides a heat exchanger as hereinabove defined wherein said means for receiving said hot second gas comprises means for receiving said cooler said third gas.

In yet further embodiments, the invention provides a heat exchanger as hereinabove defined wherein said cooler said third gas constitutes said hot second gas.

30 Having the cold inlet gas flow in parallel to partially cooled hot gas maintains a higher LMTD throughout the exchanger and reduces thermally induced differential stresses when compared to a standard parallel flow design. Additional uses of this exchanger design including alternating the hot and cold gas streams to prevent against high temperature

corrosion will become apparent to a person skilled in the art of exchanger design and operation following a review of this disclosure.

5 The parallel flow section maintains a more consistent tube wall temperature than the counter flow section, which allows for further heat to be transferred between the two gas streams while maintaining the tube wall temperature above the dew point. Maintaining the tube wall temperature above the dew point prevents corrosive vapours present in the hot gas stream from condensing. This in turn allows for the use of standard materials of construction as opposed to corrosion resistant materials, thus reducing the capital cost of the exchanger while simultaneously extending its expected life.

10 In the counter flow section the two gases flow in a generally opposite direction to maximize heat transfer efficiency. By partially heating the cold gas in the parallel flow section, the counter flow section can be designed so that the tube wall temperatures remain above the dew point temperature of the potentially corrosive vapours. In a heat exchanger designed according to this invention, the coldest temperature within the counter-flow section
15 will always be greater than the hottest tube wall temperature within the parallel section. Therefore, dew point corrosion is inhibited in the counter flow section if it is also inhibited in the parallel flow section.

Some heat exchangers of prior art have an initial parallel flow section, with the hot inlet gas flowing first in parallel with the cold inlet gas, and the remaining heat exchange
20 occurring in a counter flow fashion. This design maintains an unnecessarily high tube wall temperature and LMTD within the parallel flow section. This limits the LMTD of the counter flow section to less than that of the parallel flow section, therefore requiring the exchanger to have a larger effective area in order to reach the required heat duty than an exchanger designed according to the invention. Finally, the lowest tube wall temperature
25 within this prior art exchanger does not occur within the parallel flow section and instead occurs at the cold end of the counter flow section. Therefore, even if no dew point corrosion occurs within the parallel flow section, it is still possible to have dew point corrosion within the counter flow section. These shortcomings are overcome by the disclosed invention.

An exchanger designed according to the invention may be designed to have the gases
30 alternate sides of the tube wall during the transition between the parallel flow and counter flow sections. Doing so maintains the average shell wall temperature of the exchanger closer to the average tube wall temperature, thus reducing differential thermal growth. Dividing the tubes into two separate sections allows for the differential growth between the shell and tubes to be absorbed in stages, which reduces the forces on the tube sheets. The combined

reduction in differential growth and thermally induced stresses from alternating the shell side and tube side flows can be substantial in exchangers with a high temperature differential between their hot and cold gas streams, especially in plants with fluctuating process conditions; however, this is not required to realize the corrosion resistance benefits and relatively high heat duty capabilities of the exchanger design.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be better understood, preferred embodiments will now be described by way of example only with reference to the accompanying drawings wherein:

Fig. 1 represents a diagrammatic cross-sectional picture of a heat exchanger according to the invention;

Fig. 2 represents a diagrammatic cross-sectional picture of an alternate arrangement of a heat exchanger according to the invention;

Fig. 3 represents a diagrammatic cross-sectional picture of an alternate arrangement of a heat exchanger according to the invention which utilizes two separate hot gas streams;

Fig. 4 represents a diagrammatic cross-sectional picture of an alternate arrangement of a heat exchanger according to the invention which utilizes an alternate inlet vestibule design;

Fig. 5 represents a plot of temperatures across the length of a heat exchanger according to the invention; and wherein the same numerals denote like parts.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 shows a typical arrangement of a heat exchanger according to the invention comprised of two heat exchange sections, being parallel-flow section **A** and counter-flow section **B**.

Parallel flow section **A** is comprised of parallel flow shell **12**, contained within which is parallel flow shell side inlet vestibule **14**, parallel flow shell side **16**, and parallel flow shell side outlet vestibule **18** where through said parallel flow shell side **16** there passes parallel flow section tubes **20** connecting parallel flow tube side inlet vestibule **22** and parallel flow tube side outlet vestibule **24**.

Counter flow section **B** is comprised of counter flow shell **26**, contained within which is counter flow shell side inlet vestibule **28**, counter flow shell side **30**, and counter flow shell

side outlet vestibule **32** where through said counter flow shell side **30** there passes counter flow section tubes **34** connecting counter flow tube side inlet vestibule **36** and counter flow tube side outlet vestibule **38**.

Cold gas **40** enters the exchanger through parallel flow shell side inlet **42** into parallel flow shell side inlet vestibule **14** passing through parallel flow shell side **16** into parallel flow shell side outlet vestibule **18** followed by parallel flow to counter flow transition duct **44** into counter flow tube side inlet vestibule **36** as partially heated cold gas **46** passing through counter flow section tubes **34** into counter flow tube side outlet vestibule **38** before exiting the exchanger as heated cold gas **48** through counter flow tube side outlet **50**.

Hot gas **52** enters the exchanger through counter flow shell side inlet **54** into counter flow shell side inlet vestibule **28** passing through Section B counter flow shell side **30** into counter flow shell side outlet vestibule **32** followed by counter flow to parallel flow transition upper duct **56** into parallel flow tube side upper inlet vestibule **22** as partially cooled hot gas **58** passing through parallel flow section tubes **20** into parallel flow tube side outlet vestibule **24** before exiting the exchanger as cooled hot gas **60** through parallel flow tube side outlet **62**. Disk baffles **64** and donut baffles **66** located throughout parallel flow shell side **16** and counter flow shell side **30** direct the shell side fluid flow across the tubes to increase the heat transfer rate between the fluids. Alternate baffle arrangements including, but not limited to, segmental baffles, double segmental baffles or an absence of baffles may also be used; however, disk and donut baffles combined with an axisymmetric donut tube layout is preferred for its uniformity of heat transfer rates and thermal growth between tubes.

Separating parallel flow section **A** and counter flow section **B** while alternating the shell-side and tube-side gas flows reduces the difference in thermal growth between the combined growth of parallel flow shell **12** and counter flow shell **26** and the combined growth of parallel flow tubes **20** and counter flow tubes **34**. Thus, thermal cycling loads and fatigue stresses are reduced on an exchanger according to the invention.

Cold gas **40** may contain entrained liquid droplets as it enters the exchanger through parallel flow shell side inlet **42** which can rapidly corrode the exchanger. Parallel flow shell side inlet vestibule **14** is designed such that droplets impinge on vestibule inner wall **68** where they accumulate harmlessly and can be drained through liquid drain **70**. Parallel flow shell side inlet vestibule **14** reduces the potential for and severity of corrosion as well as the amount of fouling on the exterior of parallel flow section tubes **20** due to the previously mentioned entrained liquid droplets when compared to allowing cold gas **40** to directly enter parallel flow shell side **16** of the exchanger.

The coldest tube wall temperature in the exchanger occurs within parallel flow section **A** and, thus, this section is designed to maintain a tube wall temperature above the dew point of the corrosive liquids. A parallel flow exchanger has a higher minimum tube wall temperature than a counter flow exchanger with identical inlet and outlet conditions; therefore, parallel flow section **A** allows for additional heat transfer while maintaining the tube wall temperature above the dew point when compared to a standard counter flow exchanger. The coldest tube wall temperature within counter flow section **B** occurs at counter flow cold tube sheet **72** at the intersection of partially heated cold gas **46** and partially cooled hot gas **58**. The hottest tube wall temperature in the exchanger is found at counter flow hot tube sheet **74** where hot gas **52** and heated cold gas **48** intersect.

The overall length of parallel section **A** and counter flow section **B**, along with the relative number of disk baffles **64** and donut baffles **66** within each section can be varied to modify the relative heat duties of each section. This can be used during design to alter the heat duty of the exchanger while maintaining control over the minimum tube wall temperatures. The number and diameter of the parallel flow section tubes **20** and counter flow section tubes **34** can be varied to further alter the heat duty of each section.

Fig. 2 shows an alternate arrangement of a heat exchanger according to the invention.

Parallel flow section **A** is comprised of parallel flow shell **12**, contained within which is parallel flow shell side inlet vestibule **14**, parallel flow shell side **16** and parallel flow shell side outlet vestibule **18** where through said parallel flow shell side **16** there passes parallel flow section tubes **20** connecting counter flow section tubes **34** and parallel flow tube side outlet vestibule **24**. Counter flow section **B** is comprised of counter flow shell **26**, contained within which is counter flow shell side inlet vestibule **28**, counter flow shell side **30** and counter flow shell side outlet vestibule **32** where through said counter flow shell side **30** there passes counter flow section tubes **34** connecting counter flow tube side inlet vestibule **36** and parallel flow section tubes **20**. Cold gas **40** enters the exchanger through parallel flow shell side inlet **42** into parallel flow shell side inlet vestibule **14** passing through parallel flow shell side **16** into parallel flow shell side outlet vestibule **18** followed by parallel flow to counter flow transition duct **44** into counter flow shell side inlet vestibule **28** as partially heated cold gas **46** passing through counter flow section shell side **30** into counter flow shell side outlet vestibule **32** before exiting the exchanger as heated cold gas **48** through counter flow shell side outlet **74**. Hot gas **52** enters the exchanger through counter flow tube side inlet **76** into counter flow tube side inlet vestibule **36** passing through counter flow section tubes **34** continuing into parallel flow section tubes **20** as partially cooled hot gas **58** continuing into

parallel flow tube side outlet vestibule **24** before exiting the exchanger as cooled hot gas **60** through parallel flow tube side outlet **62**. In this arrangement, parallel flow section tubes **20** are a continuation of counter flow section tubes **34**. Disk baffles **64** and donut baffles **66** located throughout parallel flow shell side **16** and counter flow shell side **30** direct the shell side fluid flow across the tubes to increase the heat transfer rate between the fluids.

An exchanger arrangement as shown in Fig. 2 has an identical temperature profile to an exchanger arrangement as shown in Fig. 1 when the thickness and heat resistance of the tubes are negligible. The arrangement shown in Fig. 2 maintains the shell-side and tube side flows on their respective sides throughout the length of the exchanger, which reduces the capital cost and the initial overall pressure drop of the exchanger. It is most preferred to have an identical number and diameter of tubes in parallel flow section **A** and counter flow section **B** as the tubes run the entire length of the exchanger. This limits the overall flexibility of the initial design of the exchanger in comparison to an arrangement as shown in Fig. 1. The differential thermal growth between the shell and tubes of the exchanger in Fig. 2 is on a similar scale to that of standard counter flow exchanger. It is also not possible to replace only the parallel flow section of the exchanger arrangement shown in Fig. 2 in contrast the arrangement shown in Fig. 1. Therefore, an exchanger arrangement as shown in Fig. 2 is better suited for steady operating conditions, while an exchanger arrangement as shown in Fig. 1 is better suited for use in unsteady operating conditions.

Fig. 3 shows an alternate arrangement of a heat exchanger according to the invention wherein two hot gases are used in series to warm a single cold gas. Parallel flow section **A** comprises of parallel flow shell **12**, contained within which is parallel flow shell side inlet vestibule **14**, parallel flow shell side **16**, and parallel flow shell side outlet vestibule **18** where through said parallel flow shell side **16** there passes parallel flow section tubes **20** connecting parallel flow tube side inlet vestibule **22** and parallel flow tube side outlet vestibule **24**. Counter flow section **B** is comprised of counter flow shell **26**, contained within which is counter flow shell side inlet vestibule **28**, counter flow shell side **30**, and counter flow shell side outlet vestibule **32** where through said counter flow shell side **30** there passes counter flow section tubes **34** connecting counter flow tube side inlet vestibule **36** and counter flow tube side outlet vestibule **38**. Cold gas **40** enters the exchanger through parallel flow shell side inlet **42** into parallel flow shell side inlet vestibule **14** passing through parallel flow shell side **16** into parallel flow shell side outlet vestibule **18** followed by parallel flow to counter flow transition duct **44** into counter flow tube side inlet vestibule **36** as partially heated cold gas **46** passing through counter flow section tubes **34** into counter flow tube side outlet

vestibule **38** before exiting the exchanger as double heated cold gas **78** through counter flow tube side outlet **50**. Hot gas **52** enters the exchanger through counter flow shell side inlet **54** into counter flow shell side inlet vestibule **28** passing through counter flow shell side **30** into counter flow shell side outlet vestibule **32** before exiting the exchanger as counter flow cooled hot gas **80** through counter flow shell side outlet **74**. Second hot gas **82** enters the exchanger through parallel flow tube side inlet **84** into parallel flow tube side inlet vestibule **22** passing through parallel flow section tubes **20** into parallel flow tube side outlet vestibule **24** before exiting the exchanger as parallel flow cooled hot gas **86** through parallel flow tube side outlet **62**. Disk baffles **64** and donut baffles **66** located throughout parallel flow shell side **16** and counter flow shell side **30** direct the shell side fluid flow across the tubes to increase the heat transfer rate between the fluids.

The separation between parallel flow section **A** and counter flow section **B** allows for the intermediate removal of counter flow cooled hot gas **80** and addition of second hot gas **82**. In a similar manner two cold gas streams could be used to cool a single hot gas. Modifying the gas flow rates of hot gas **52** and second hot gas **82** alters the heat duty of the exchanger in each section independently. Other benefits will be apparent to a person skilled in the art of heat exchanger design or fabrication.

Fig. 4 shows an alternate arrangement of an exchanger similar to that shown in Fig. 2. In this arrangement, cold gas **40** enters the exchanger through alternate parallel flow shell side inlet **88** into alternate parallel flow shell side inlet vestibule **90** passing through parallel flow shell side **16** into parallel flow shell side outlet vestibule **18** followed by alternate parallel flow to counter flow transition duct **92** into counter flow shell side inlet vestibule **28** as partially heated cold gas **46** passing through counter flow section shell side **30** into counter flow shell side outlet vestibule **32** before exiting the exchanger as heated cold gas **48** through counter flow shell side outlet **74**. Hot gas **52** follows an identical flow path to that described in Fig. 2 and exits the exchanger as cooled hot gas **60**. Alternate parallel flow shell side inlet vestibule **90** provides improved mist elimination capabilities in comparison to parallel flow shell side inlet vestibule **14** as previously shown in Figs. 1 through 3. Numerous similar alternate variations are apparent to a person skilled in the art of heat exchanger design or fabrication.

Fig. 5 shows a temperature profile for an exchanger designed according to the invention as shown in Fig. 1, Fig. 2 or Fig. 4. This temperature profile will be identical for an exchanger as shown in Fig. 1, Fig. 2 or Fig. 4 when the tube wall thickness and resistance are negligible. The temperature profile for an exchanger as shown in Fig. 3 will also be

identical provided that additionally said second hot gas **82** is composed of counter flow cooled hot gas **80**. The process conditions used are arbitrary but representative of those found in a cold reheat exchanger in a sulphuric acid plant. This process has a minimum allowable tube wall temperature **94** of 300 F for the prevention of dew point corrosion. Cold gas **40** enters the exchanger at a temperature of 165 F and is heated in parallel flow section **A** to partially heated cold gas **46** at a temperature of 224 F. Following parallel flow section **A** partially heated cold gas **46** is heated in counter flow section **B** to heated cold gas **48** at a temperature of 680 F and exits the exchanger. Hot gas **52** enters the exchanger at a temperature of 860 F. It is cooled in counter flow section **B** to partially cooled hot gas **58** at a temperature of 435 F. Following counter flow section **B** partially cooled hot gas **58** is cooled in parallel flow section **A** to cooled hot gas **60** at a temperature of 380 F and exits the exchanger. The minimum tube wall temperature **96** within the exchanger is 300 F. This is equivalent to minimum allowable tube wall temperature **94** of 300 F for the prevention of dew point corrosion. The relative heat duties of parallel flow section **A** and counter flow section **B** can be adjusted to optimize the exchanger for its desired service. Increasing the relative heat duty to parallel flow section **A** will increase the minimum tube wall temperature, while increasing the relative heat duty to counter flow section **B** will increase the overall LMTD of the exchanger which in turn decreases the required effective area to meet the exchanger's heat duty. A prior art counter flow exchanger operating under equivalent process conditions would have a minimum tube wall temperature of approximately 272 F, which is less than minimum allowable tube wall temperature **94**. It is, therefore, expected that condensation would form within the prior art exchanger, causing dew point corrosion.

Although this disclosure has described and illustrated certain preferred embodiments of the invention, it is to be understood that the invention is not restricted to those particular embodiments. Rather, the invention includes all embodiments which are functional or mechanical equivalence of the specific embodiments and features that have been described and illustrated.

30

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A process for exchanging heat in a shell and tube gas-to-gas heat exchanger between a
5 plurality of gases,
said process comprising
passing a cold first gas in parallel flow to a second hot gas to provide a warmer first
gas; and
passing said warmer first gas in counter-current flow to a hot third gas to provide a
10 cooler said third gas.
2. A process as claimed in claim 1 wherein said second hot gas comprises said cooler
said third gas.
3. A process as claimed in claim 1 or claim 2 comprising passing said cold first gas as a
shell-side gas, and said warmer said first gas as a tube-side gas or a shell-side gas.
- 15 4. A process as claimed in claim 1 or claim 2 comprising passing said cold first gas as a
tube-side gas and said warmer said first gas as a tube-side gas or a shell-side gas.
5. A process as claimed in any one of claims 1 to 3 further comprising removing a
portion of said warmer said first gas from said heat exchanger.
6. A process as claimed in any one of claims 1 to 3 further comprising removing a
20 portion of said cooler said third gas from said heat exchanger.
7. A process as claimed in any one of claims 1 to 3 further comprising feeding a portion
of said hot third gas in admixture with said cooler said third gas in parallel flow to said cold
first gas.
8. A process as claimed in any one of claims 1 to 4 further comprising feeding a portion
25 of said cold first gas in admixture with said warmer said first gas in counter-current flow to
said hot third gas.
9. A process as claimed in any one of claims 1 to 8 wherein said hot first gas comprises
sulphur trioxide.
10. A process as claimed in any one of claims 1 to 9 wherein said hot first gas comprises
30 entrained corrosive liquid droplets.
11. A process as claimed in any one of claims 1 to 10 wherein said cold first gas
comprises entrained corrosive liquid droplets.
12. A process as claimed in any one of claims 1 to 11 wherein said second cold gas
comprises air.

13. A process for the manufacture of sulphuric acid by the contact process comprising a process as claimed in any one of claims 1 to 12.

14. A process for exchanging heat in a shell and tube gas-to-gas heat exchanger between a first hot gas and a cold second gas as claimed in any one of claims 1 to 12 in hydrocarbon power generation plants.

15. A gas-to-gas heat exchanger comprising
a shell and tube first section comprising
means for receiving a cold first gas;
10 means for receiving a hot second gas; and
means for passing said cold first gas in parallel flow to said hot second gas to provide a warmer said first gas;
a shell and tube second section comprising
means for receiving a hot third gas;
15 means for receiving said warmer said first gas; and
means for passing said hot third gas in counter-current flow to said warmer said first gas to provide a cooler said third gas.

16. A heat exchanger as claimed in claim 15 wherein said means for receiving said hot second gas comprises means for receiving said cooler said third gas.

17. A heat exchanger as claimed in claim 16 wherein said cooler said third gas constitutes said hot second gas.

25

30

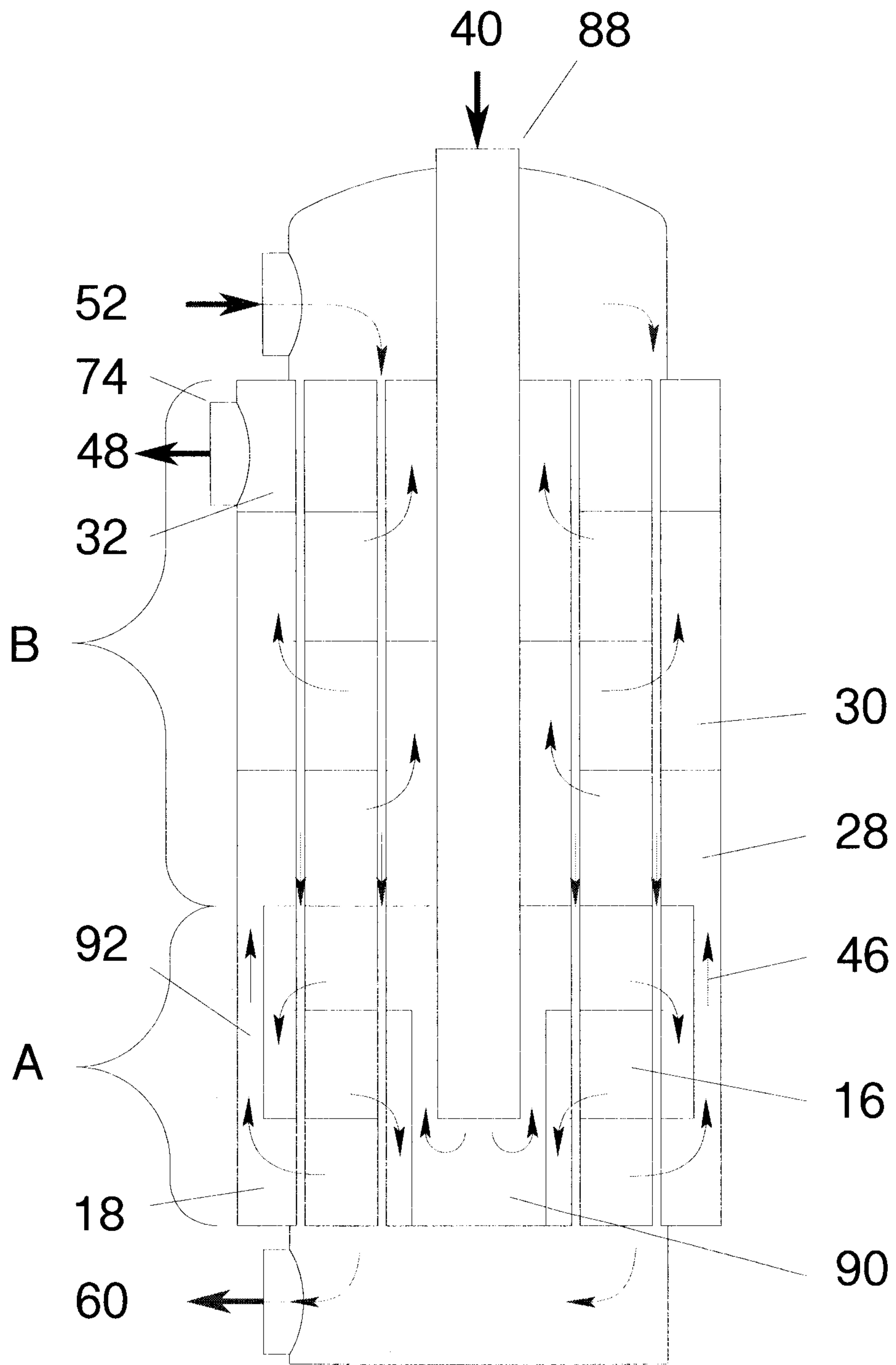


Fig. 4

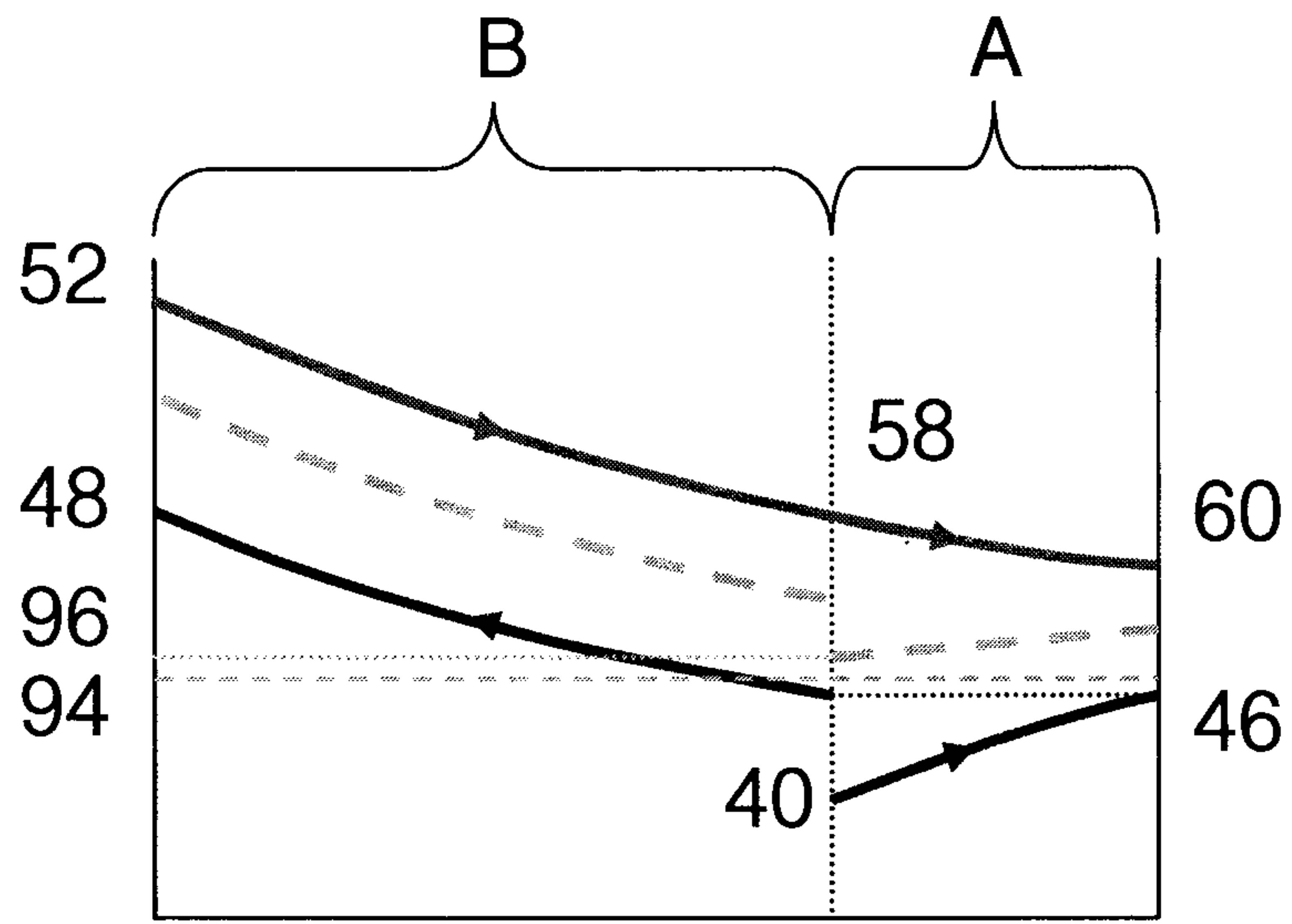


Fig. 5

