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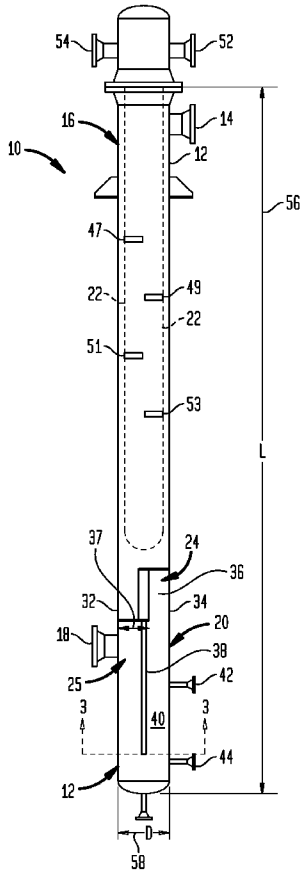
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(54) Title: VERTICAL COOLER WITH LIQUID REMOVAL AND MIST ELIMINATOR

(57) Abstract: A vertical gas cooler suitable for use as an intercooler in a multi-stage compressor includes an inlet at its upper portion, a tube bundle, a centrally disposed mist eliminator assembly and a side-draw outlet. Optionally provided is a drain pipe from the mist eliminator assembly to a sump located below the side- draw outlet.

FIG. 1



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VERTICAL COOLER WITH LIQUID REMOVAL AND MIST ELIMINATOR

Claim for Priority

This application is based on United States Provisional Patent Application No. 61/657,074, filed June 8, 2012, the priority of which is hereby claimed and the disclosure of which is incorporated herein by reference.

Technical Field

The present invention relates generally to coolers with liquid and mist removal. The device is particularly useful as an intercooler for a multi-stage compressor.

Background Art

Conventionally, a gas cooler and mist eliminator are provided in separate vessels which adds bulk and introduces pressure drop into a system due to gas exiting and entering the various units. Such configuration is disclosed, for example, in United States Patent Application Publication No. US 2008/0008602 of *Pozivil et al.*; *note* **Figure 6** thereof.

Conventional mist removal systems include particulate and/or fibrous coalescers as is seen in Kirk-Othmer, Encyclopedia of Chemical Technology, 3rd ed., Vol. 14, page 389 (Wiley 1981). The use of coalescing filters is also described in United States Patent No. 6,139,747 to *Rotzheim et al.*, which refers to the removal of organic impurities in the course of waste-water treatment in connection with an aldolization process.

WO 2010/081526 discloses treating exhaust gas through a coalescing filter to remove water and other impurities.

United States Patent No. 4,087,197 to *Haugen* discloses a multi-stage compressor with a horizontal intercooler provided with a mist eliminator pad **86** in **Figure 3**. In this system, it appears difficult to drain off condensed liquid effectively. Moreover, liquid accumulating on a mist eliminator pad disengages as large droplets in a gas stream and the droplets are entrained in flowing gas and propelled downstream, causing damage to components such as pump impellers. In this regard, the system disclosed in the '197 patent may be undesirable in manufacturing operations with extended manufacturing campaigns between turn-arounds because impeller wear is detrimental to performance and requires expensive and time consuming maintenance.

Summary of Invention

There is provided in accordance with the present invention a vertical cooler with liquid removal and a mist eliminator configured such that the cooled gas is taken as side-draw in order to avoid entrained droplets in the gas stream as it exits the device. In a preferred construction, there is provided a tortuous flow path between the mist eliminator assembly and a side-draw exit over a disengaging portion of the intercooler.

Further features and advantages will become apparent from the discussion which follows.

Brief Description of Drawings

The invention is described in detail below with reference to the drawings, wherein like numerals designate similar parts. In the drawings:

Figure 1 is a schematic view in elevation and section illustrating construction and operation of a vertical cooler with liquid removal and mist eliminator in accordance with the invention;

Figure 2 is a view in perspective illustrating construction of a mist eliminator assembly disposed in the housing of the device of **Figure 1**; and

Figure 3 is a bottom sectional view along line 3-3 of **Figure 1** further illustrating construction of the mist eliminator assembly, especially the drain pipe of the cooler's mist eliminator assembly.

Detailed Description

The invention is described in detail below in connection with the **Figures** for purposes of illustration, only. The invention is defined in the appended claims.

As used herein, terminology is given its ordinary meaning as supplemented by the following discussion.

"Mist eliminator medium" or like terminology refers to any conventional porous material used to coalesce and remove mist from a gas including particulate containing cartridges, fibrous composites and so forth. Particularly preferred are fine metal mesh, co-knit metal and glass mesh or combinations of such materials.

Unless otherwise indicated, "orientation" generally refers to the direction perpendicular to a cross section of a part or assembly and refers to direction when referring to flow of a fluid. The orientation of a tube, for example, is the direction along its axis and the orientation of flow though an outlet, for example, is usually substantially perpendicular to the outlet.

"Vertically oriented" and like terminology used throughout this description and claims refers to construction and placement of the inventive device for flow generally perpendicular to the plane of the horizon; that is, a generally upright orientation as opposed to a generally horizontal orientation. Vertical orientation thus refers to having the inlet and outlet of the device at different levels and preferably having the outlet of the cooler at a level of the device below the inlet. While the device is illustrated in orientation 90° from horizontal, one of skill in the art will appreciate that the device of **Figure 1** might be substantially inclined from that position without changing its mode of operation or that the device is configured for vertically oriented flow.

Referring to **Figure 1**, there is illustrated schematically in elevation and section a vertical cooler **10** with an elongated vertical oriented housing **12**

provided with an inlet **14** at its upper portion indicated generally at **16** and a side-draw outlet **18** at its lower portion indicated generally at **20**.

A plurality of cooling tubes **22** are secured with housing **12** adjacent upper portion **16** of the housing; while a mist eliminator assembly **24** is located within housing **12** between tubes **22** and outlet **18.** The housing further defines a disengaging portion indicated generally at **25** between assembly **24** and side-draw outlet **18**.

Referring to **Figures 1** and **2**, mist eliminator assembly **24** includes an upper baffle plate **26** and a lower baffle plate **28** which operate to position mist eliminator medium **30** generally centrally within the housing and define a tortuous flow pattern whereby flowing gas is directed from a first side **32** of the housing to a second side **34** of the housing upon exiting the mist eliminator medium. It will be appreciated from **Figures 1** and **2** and the discussion hereinafter that assembly **24** is positioned, configured and dimensioned such that gas flowing through the device flows through mist eliminator assembly **24** and flows through mist eliminator medium **30**. The baffle plates are disposed such that the side-draw outlet **18** is located on first side **32** of the housing, away from outlet **36** of assembly **24**, at a level below lower baffle plate **28** and below the level of outlet **36** of mist eliminator assembly **24**.

The disengaging portion of the cooler is the portion of the device between outlet **36** of the mist eliminator assembly and outlet **18** of the cooler. The flow path involves a change in flow direction such as shown where outlet **36** of the mist eliminator assembly is oriented perpendicular to side-draw outlet **18** of the device. Most preferably, the side draw outlet is located on the opposite side of the housing from the side where the mist eliminator outlet is located, involving a horizontal disengaging distance **37** between outlet **36** of the mist eliminator assembly and draw outlet **18** of the device. Most preferably, distance **37** is at least 3-4 inches and preferably 6 inches or more. Any other suitable configuration

which provides for allowing the momentum of entrained droplets to carry them away from the device outlet such as vertical acceleration distances of an inch or two before a change in flow direction is likewise suitable. The disengaging portion of the device thus spans between an outlet of the mist eliminator assembly having a different orientation than the orientation of the outlet of the cooler and includes that portion of the interior of the device separating those respective outlets of differing orientation.

Figure 3 is a view along line **3-3** of **Figure 1** illustrating placement of a drain pipe **38** which extends from mist eliminator medium **30** to a sump **40** where condensed liquid is accumulated after it is derived from medium **30** via pipe **38**. The level of liquid in sump **40** is monitored via upper and lower ports **42, 44**, which may include optical sensors or other sensors, if so desired. During operation, it is desirable to maintain some liquid in the sump to maintain pressure in cooler **10**.

Various materials may be used to fabricate mist eliminator medium **30**. Particularly preferred are fine metal mesh, co-knit metal and glass mesh or combinations of such materials. The cooling tubes are perhaps most preferably a U-tube bundle as is well known in the art and which may be provided with a plurality of baffle plates indicated at **47, 49, 51, 53**. This baffled construction is likewise well known. Coolant is fed to the U-tube bundle via inlet **52** and exits at **54** during operation of the device.

The dimensions of the cooler/mist eliminator of the invention will vary depending upon its application. A length **56** to diameter **58** ratio is suitably from 5 to 30; typically, 8.5 to 20 and from 12.5 to 17.5 in many cases.

The vertical cooler with liquid removal and mist eliminator described and shown in **Figures 1-3** is especially useful as an intercooler for a multi-stage compressor used for compressing hydrogen gas, for example. During use, the

device is operated by way of circulating coolant via inlet **52**, outlet **54** and feeding compressed gas from a first compressor stage to vertical gas intercooler **10** via inlet **14** at upper portion **16** of the device such that the gas stream contacts a plurality of cooling tubes **22** located adjacent the upper portion of the cooler housing **12**. After cooling, the gas is fed downwardly to mist eliminator assembly **24** disposed between the cooling tubes and the side-draw outlet **18** of the housing, the mist eliminator assembly being positioned, configured and dimensioned such that gas flowing between the inlet and outlet of the housing flows through a mist eliminator medium **30**. The housing further defines a disengaging portion **25** between the mist eliminator element and side-draw outlet of the housing. During operation, the gas flows generally downwardly and is cooled which promotes condensation of liquid contained in the gas. Condensed liquid, typically water, is removed from the flowing gas by medium **30**. Medium **30** is drained of condensed liquid by way of gravity flow through pipe **38** and accumulates in sump **40**. A liquid level is maintained by monitoring liquid level in the sump at ports **42** and **44** and draining the sump periodically in response to those measurements so that a predetermined level of liquid in the sump prevents pressure loss during draining of the device under elevated pressure, that is, when the device is utilized between stages of a multi-stage compressor.

Any droplets of condensed liquid which are entrained from mist eliminator medium **30** are propelled downwardly from exit **36** of the mist eliminator assembly by the downwardly flowing gas, away from side-draw outlet **18**.

Cooled gas is withdrawn from the cooler via outlet **18** and fed forward to another stage of a multi-stage compressor.

While the invention has been described in detail, modifications within the spirit and scope of the invention will be readily apparent to those of skill in the art. Such modifications are also to be considered as part of the present invention. In view of the foregoing discussion, relevant knowledge in the art and references discussed above in connection with the Background of the Invention, the disclosures of which are all incorporated herein by reference, further description is deemed unnecessary. In addition, it should be understood that aspects of the invention and portions of various embodiments may be combined or interchanged either in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to limit the invention.

WHAT IS CLAIMED IS:

1. A vertical gas cooler with liquid removal and mist eliminator comprising:

(a) an elongated vertically oriented housing provided with an inlet at its upper portion and a side-draw outlet at its lower portion;

(b) a plurality of cooling tubes located adjacent the upper portion of the housing;

(c) a mist eliminator assembly disposed between the cooling tubes and the outlet of the housing, the mist eliminator assembly being positioned, configured and dimensioned such that gas flowing between the inlet and outlet of the housing flows through the mist eliminator assembly and contacts a mist eliminator medium, the mist eliminator assembly having an outlet with a different orientation than the orientation of said outlet of said housing; and

(d) the housing further defining a disengaging portion between the mist eliminator assembly outlet and side-draw outlet of the housing.

2. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the mist eliminator assembly includes upper and lower baffle plates which position a mist eliminator medium centrally within the housing and define a tortuous flow pattern whereby flowing gas is directed from a first side of the housing to the mist eliminator medium and to a second side of the housing upon exiting the mist eliminator medium.

3. The vertical gas cooler with liquid removal and mist eliminator according to Claim 2, wherein the side-draw outlet is disposed on the first side of housing at a level below the lower baffle plate.

4. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the side-draw outlet is disposed at a level below the outlet of the mist eliminator assembly.

5. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the mist eliminator assembly includes a drain pipe.

6. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the housing defines a sump located below the side-draw outlet for collecting liquid removed from a cooled gas, and the sump includes upper and lower sensor ports for monitoring liquid level in the sump.

7. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the mist eliminator assembly includes a drain pipe and the drain pipe extends to a sump defined by the housing below the side-draw outlet.

8. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the mist eliminator assembly includes a mist eliminator medium selected from metal mesh, co-knit metal and glass mesh and combinations thereof.

9. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein said plurality of cooling tubes comprises a U-tube bundle.

10. The vertical gas cooler with liquid removal and mist eliminator according to Claim 9, wherein the U-tube bundle is a baffled U-tube bundle.

11. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the housing has a length to diameter ratio of from about 5 to about 30.

12. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the housing has a length to diameter ratio of from about 8.5 to about 20.

13. The vertical gas cooler with liquid removal and mist eliminator according to Claim 1, wherein the housing has a length to diameter ratio of from about 12.5 to about 17.5.

14. A method of intercooling gas between compressor stages in a multistage compressor comprising:

(a) feeding compressed gas from a first compressor stage to a vertical gas intercooler with liquid removal and mist eliminator, the intercooler including :

(i) an elongated vertically oriented housing provided with an inlet at its upper portion and a side-draw outlet at its lower portion;

(ii) a plurality of cooling tubes located adjacent the upper portion of the housing;

(iii) a mist eliminator assembly disposed between the cooling tubes and the outlet of the housing, the mist eliminator assembly being positioned, configured and dimensioned such that gas flowing between the inlet and outlet of the housing flows through the mist eliminator assembly and contacts a mist eliminator medium, the mist eliminator assembly having an outlet with a different orientation than the orientation of said outlet of said housing; and

(iv) the housing further defining a disengaging portion between the mist eliminator element and side-draw outlet of the housing;

(b) cooling the gas in the intercooler and removing condensed liquid therefrom;

(c) withdrawing the cooled gas from the intercooler and

(d) feeding the withdrawn gas to a second compressor stage of a multistage compressor.

15. The method of intercooling gas between compressor stages in a multistage compressor according to Claim 14, wherein the gas comprises hydrogen.

FIG. 1

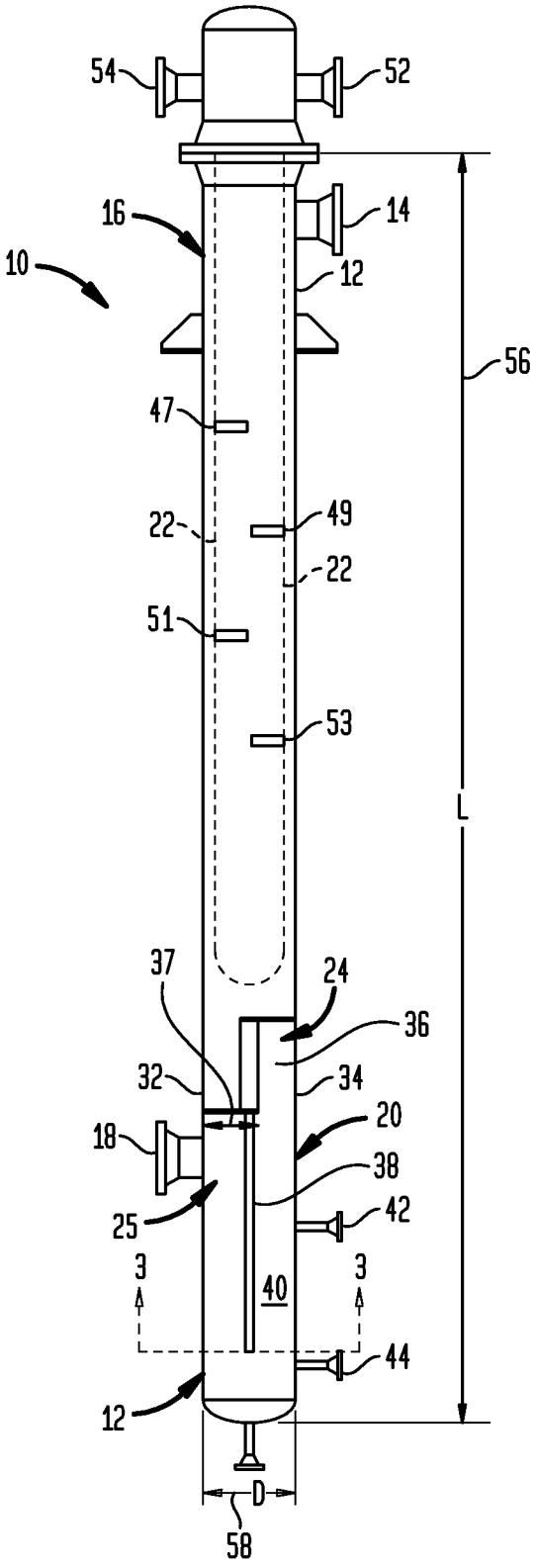


FIG. 2

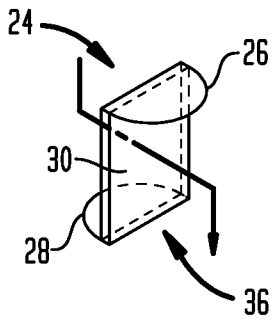
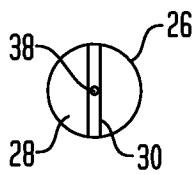


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/042334

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D53/00 F04D29/58
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	column 3, line 52 - column 55; figure 3	2,3,6-15
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 September 2013	23/09/2013

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International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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