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(54) **BAR AND PLATE AIR-OIL HEAT EXCHANGER**

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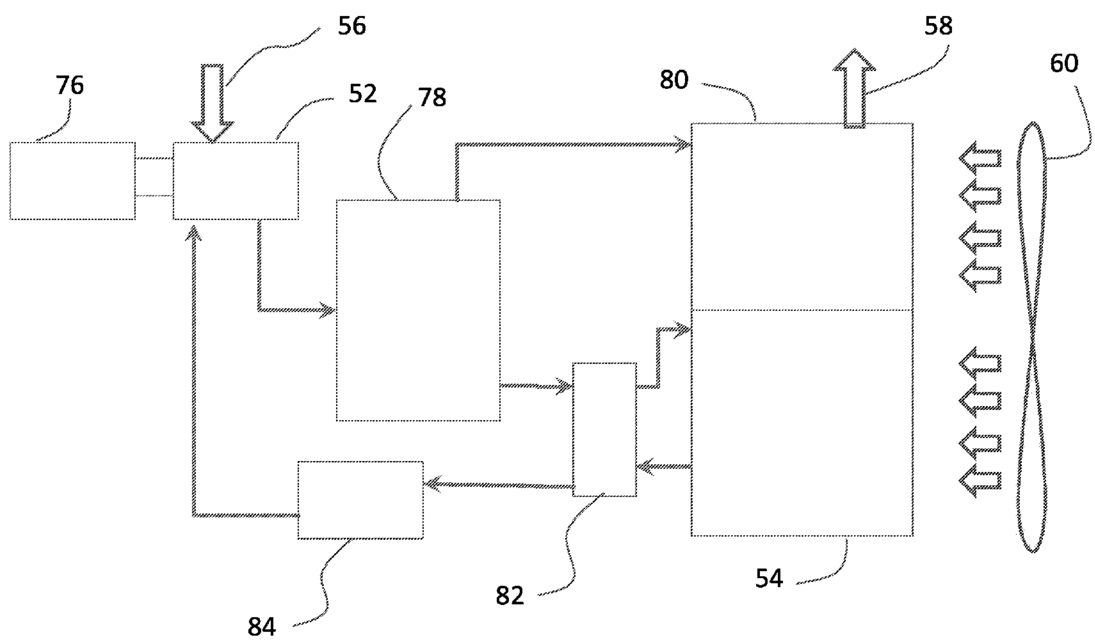
(57) **ABSTRACT**

An air-oil heat exchanger used in a compression system that includes a compressor is disclosed. The heat exchanger can be used to cool oil in one embodiment which is used in a compression process. The heat exchanger can be a bar-and-plate type heat exchanger having a number of external fins, internal fins, parting sheets, and header bars. The external fins can include louvers formed therein. An arrangement of multiple unrelated components can be provided that improves pressure loss and reduces weight.



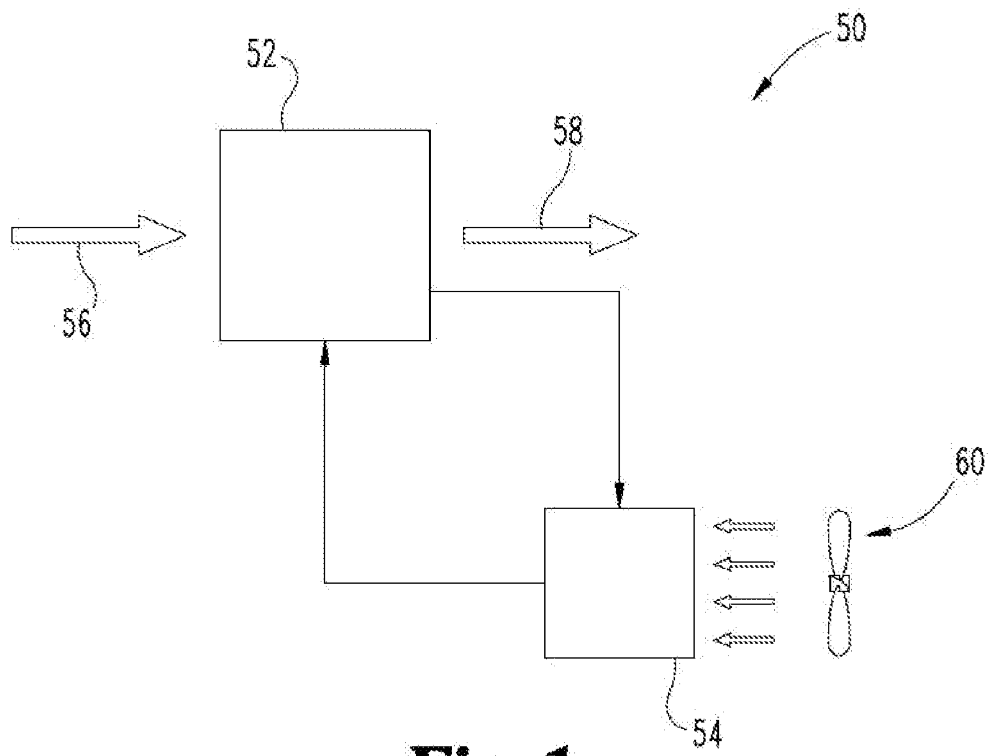


Fig. 1

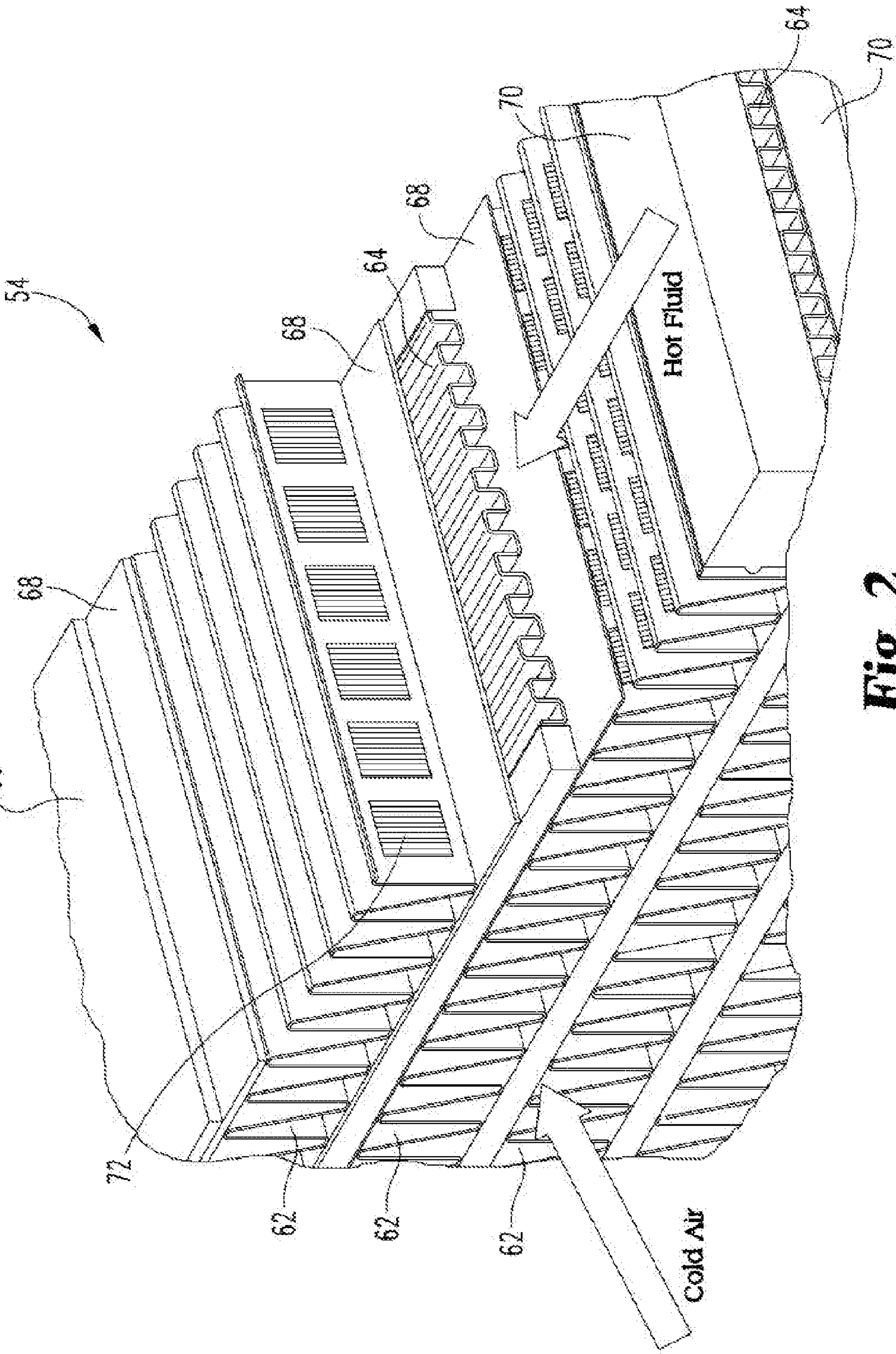


Fig. 2
(PRIOR ART)

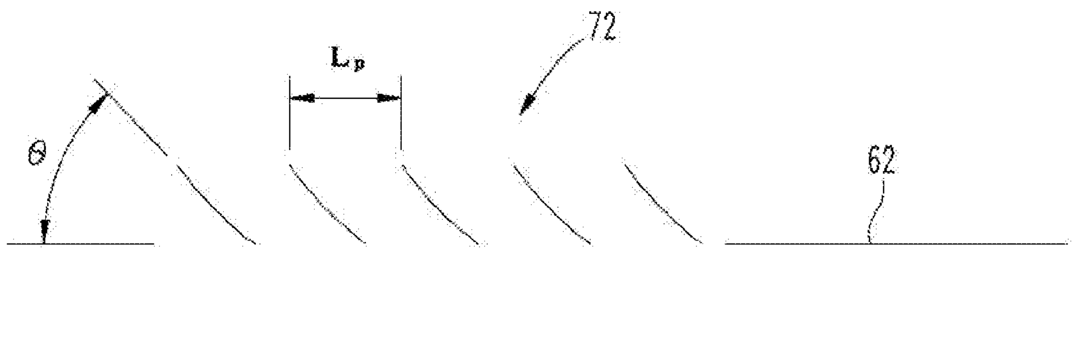


Fig. 3

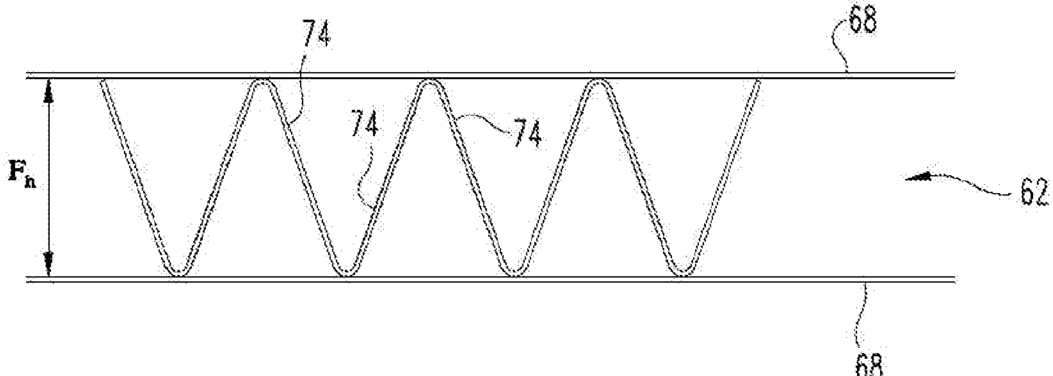


Fig. 4

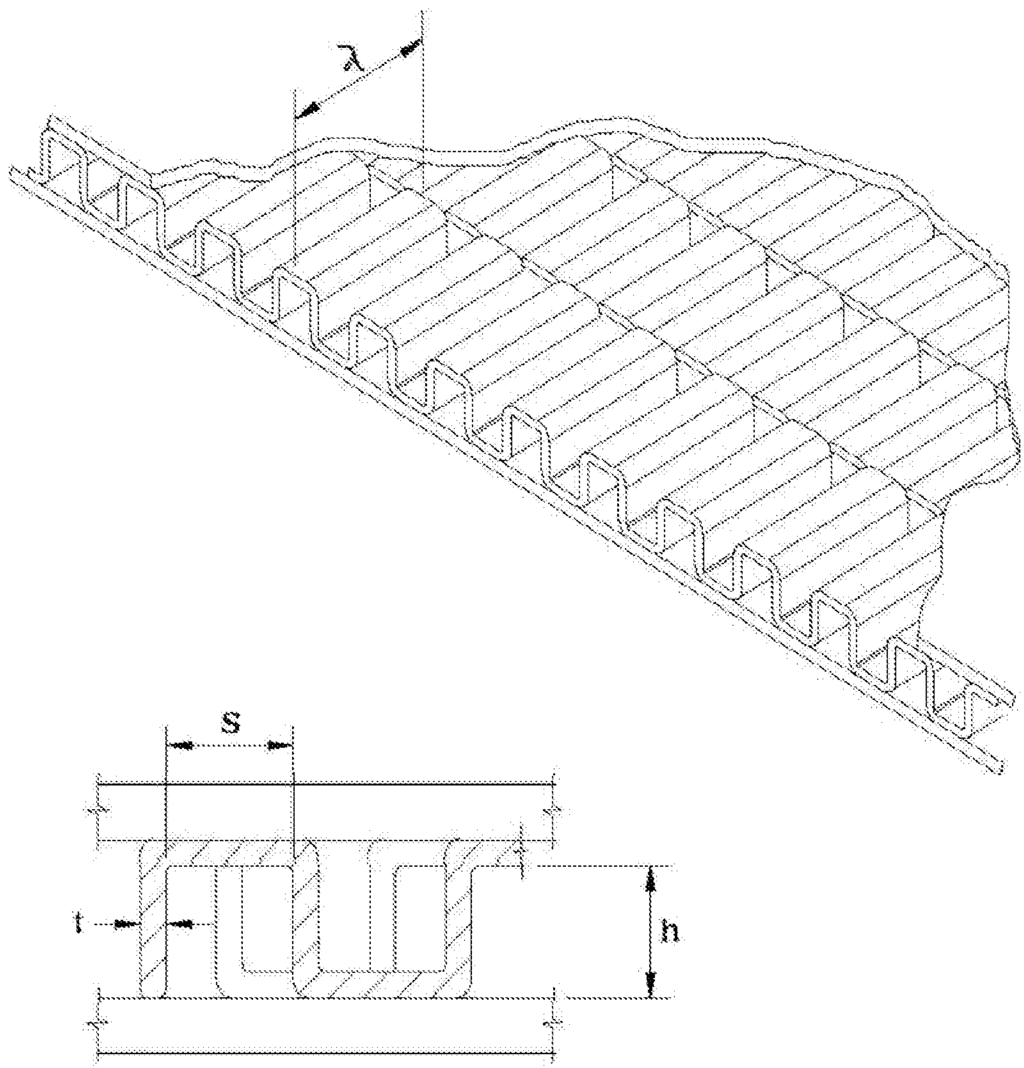


Fig. 5

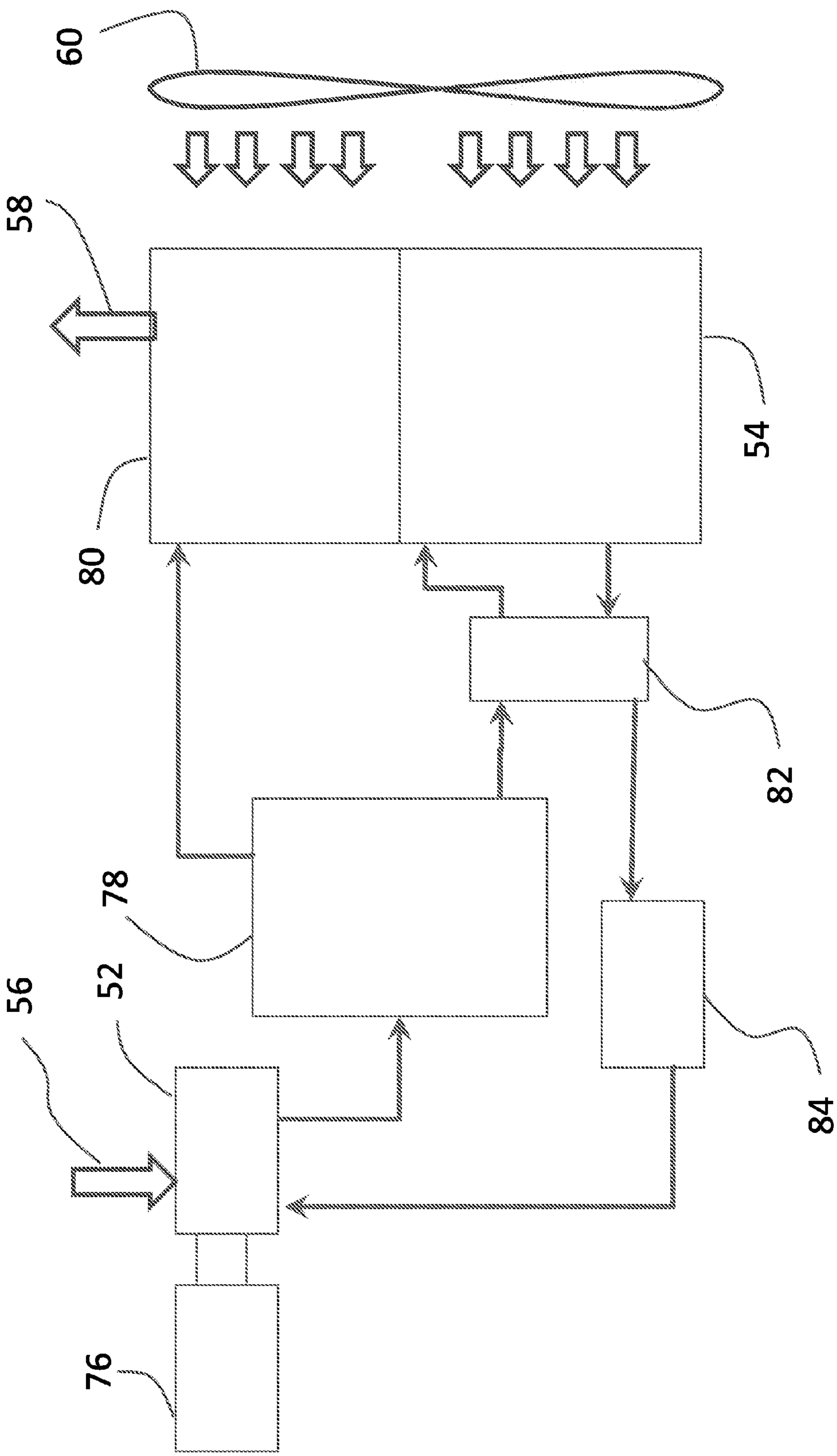


FIG. 6

BAR AND PLATE AIR-OIL HEAT EXCHANGER

TECHNICAL FIELD

[0001] The present invention generally relates to compression system heat exchangers, and more particularly, but not exclusively, to particular arrangement of bar and plate heat exchanger.

BACKGROUND

[0002] Providing improvements in bar and plate heat exchangers used in compression systems remains an area of interest. Some existing systems have various shortcomings relative to certain applications. Accordingly, there remains a need for further contributions in this area of technology.

SUMMARY

[0003] One embodiment of the present invention is a unique heat exchanger for use with a compression system. Other embodiments include apparatuses, systems, devices, hardware, methods, and combinations for reduced pressure loss and low weight heat exchangers. Further embodiments, forms, features, aspects, benefits, and advantages of the present application shall become apparent from the description and figures provided herewith.

BRIEF DESCRIPTION OF THE FIGURES

[0004] FIG. **1** depicts a schematic of a compression system having an air-oil heat exchanger.

[0005] FIG. **2** depicts a prior art example of a bar and plate heat exchanger.

[0006] FIG. **3** depicts an embodiment of an external fin.

[0007] FIG. **4** depicts an embodiment of an external fin.

[0008] FIG. **5** depicts an embodiment of an internal fin.

[0009] FIG. **6** depicts an alternative embodiment to that shown in FIG. **1**.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

[0010] For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Any alterations and further modifications in the described embodiments, and any further applications of the principles of the invention as described herein are contemplated as would normally occur to one skilled in the art to which the invention relates.

[0011] With reference to FIG. **1**, a compressor system **50** is disclosed having a compressor **52** and oil cooler **54**. Although only the compressor **52** and oil cooler **54** is depicted, other components may also be included in any given embodiment of the compressor system **50**, including, but not limited to, a compressor dryer, oil sump, etc. The compressor dryer can be a refrigerated dryer or a desiccant based dryer, among potential others. The compressor **52** is used to compress a compressible fluid **56**, such as air, and deliver a compressed air **58** to an end user, customer, reservoir, or other suitable destination. The compressor **52** can take on a variety of forms. For example, in one non-limiting embodiment the compressor **52** is an oil filled screw compressor, but other forms are also contemplated herein.

[0012] The oil cooler **54** is used to cool oil or other fluid used in conjunction with operation of the compressor **52**. The oil, or other suitable fluid, can be used for lubrication and cooling purposes within the compressor **52**, among other uses. The oil cooler **52** can structured as an air-oil heat exchanger and in the illustrated embodiment includes a fan **60** or other suitable fluid moving devices which provides a stream of moving air useful in exchanging heat with oil routed through the oil cooler **54**.

[0013] Yet another embodiment is shown in FIG. **6** of a compressor system **50** that includes additional components such as a motor **76**, separator tank **78**, combined air cooler **80** and oil cooler **54** (in which the coolers are connected and cooled by a common fan), combi block with thermal valve **82**, and oil filter **84**. The route of mixed oil/air, separated oil and air, as well as the hot and cold sides of oil and air should be readily apparent from the figure.

[0014] A prior art embodiment of an oil cooler is shown in FIG. **2**. Shown in the illustration is a cutaway view of a bar and plate type of heat exchanger **54**. The heat exchanger **54** includes a number of external fins **62**, internal fins **64**, a side bracket **66**, parting sheets **68**, and header bar **70**. In general, the bar and plate heat exchanger **54** shown in FIG. **2** includes a stack of alternating flat plates (e.g. the parting sheets **68**) and fins (e.g. the internal fins **64** and external fins **62**) that are brazed together to form a single solid unit, though other manufacturing techniques may also be used. Though only a limited number of each of these components are illustrated in FIG. **2**, it will be understood that other numbers of components can also be present. To set forth just one non-limiting example, although the header bars **70** are shown on only one lateral side of the heat exchanger **54**, the other side of the heat exchanger **54** can also include additional header bars **70**.

[0015] The external fins **62** can be formed of any heat conductive material, and can be triangular shaped as illustrated in FIG. **2**. Such materials that the external fins **62** can be made out of include metal, which may be aluminum or aluminum alloy in many embodiments, but other metals and/or metal alloys are also contemplated herein. The external fins **62** can be described as fin members that are shaped in a triangular pattern that alternatingly extends between parting sheets located on either side of the external fins **62**. Each of the fin members can include a plurality of louvers (described further below) formed as openings with an angled hood or vent which is useful to direct a passing fluid such as cooling air. The plurality of louvers can be assembled in small groupings that are distributed along the length of the external fins **62**, as can be seen by the groupings illustrated in FIG. **2**.

[0016] FIG. **3** depicts one embodiment of the louvers **72**. The louvers **72** can be set at a louver angle θ which is an acute angle formed between the louver **72** and surface of the external fin **62**. The acute angle θ of the louvers **72** can all be oriented in the same direction along the length of the external fins **62** and on the same side of the fins **62**, but in some embodiments other variations are possible. For example, in some embodiments the louvers **72** can be formed with an acute angle pointing in a direction against a flow of cooling air over a first half of the length of the external fins **62**, while the second half of the length of the external fins **62** can have louvers pointing in an equivalent acute angle but oriented in a direction along the flow of cooling air. The louvers **72** can also have a louver pitch L_p which can be described as the distance between the tips of the louvers measured along the direction of the fin **62**.

[0017] FIG. **4** depicts some geometric details of the external fins **62**. The external fins **62** can have individual fins **74** which are distributed along the length of the external fins **62**. The number of individual fins **74** can be counted over a given length and a quantification can be made of the frequency of fins. For example, the number of fins per inch can be counted and a "fin per inch" quantity can be used to describe the density of individual fins **74** over the length of the external fins **62**. The F_h or fin height shown in FIG. **4** is the height of the fins **62** as they reach between adjacent walls (e.g. the parting sheets **68**).

[0018] Turning now to FIG. **5**, certain geometric details of the internal fins **64** are illustrated. The internal fins **64** can be of the offset strip fin type having a length λ, height h, and pitch s. The height of the internal fins **64** can be described as the open space between parting sheets **68** less the material thickness of the sheet that makes up the internal fins **64**. The pitch can be the open space within the internal fins **64** between upright wall sections of the fins **64**.

[0019] The external fins **62** and/or the internal fins **64** can be made using a variety of approaches, which include forming a unitary member, coupling separate components together to form the member, etc. To set forth just a few examples, the external fins **62** can be stamped into shape to form the triangular shape as depicted in the illustrated embodiment. The offset strip type of the internal fins **64** as illustrated can include a number of separate strips that are individually stamped, which are then brought together in an offset configuration before being consolidated into an internal fin construction.

[0020] It will be appreciated that in highly complex, multi-variate systems, it is not always clear which combination of parameters provide for improvements. The instant application has discovered heretofore unappreciated arrangement of multiple and unrelated components in the heat exchanger **54** which unexpectedly provided for an appreciable degree in reduced pressure loss and weight. Prior to their discovery as disclosed in the instant application, it was unknown which combination and degree of factors in the aggregate provided the best solution. As a result of the inventive concepts described herein, it was discovered that at least one potential candidate, internal strip length, was deemed to either not impact the overall study or minimally impact the study, while other parameters were changed quite significantly from the conventional baseline indicating that the state of the art was unaware of the combination and degree of changes required to provide a better solution.

[0021] The combination of parameters that have led to unexpected improvements are as follows (listing the known baseline prior system for comparison):

Parameter	Baseline	Option 1 Low air side pr. Drop	Option 2 Low weight
External FIN HEIGHT	0.375	0.438	0.488
Internal FIN HEIGHT	0.125	0.098	0.100
Internal FIN PITCH	0.074	0.069	0.081
External FIN PER INCH	12	11	12
Internal strip length	0.14	0.14	0.14
External LOUVER ANGLE	23.0	25.2	23.5
External LOUVER PITCH	0.045	0.035	0.035
Output			
Air side pr. Drop (Pa)	493.7	386.5	430.7
Heat transfer (W)	251317	253002	252603
Oil outlet temperature (deg C.)	76.0	75.8	75.9
Coil weight (Kg)	105.0	89.6	85.9
Oil side pr. Drop (Pa)	38895	56993	50198

[0022] The dimensions quoted herein regarding various geometries of the heat exchanger need not always be precisely exact as is well understood. Manufacturing tolerances permit some degree of dimensional variation.

[0023] Of the parameters listed above, the first four listed in the chart (external fin height, internal fin height, internal fin pitch, and external fin per inch) where surprisingly found to be most important in achieving the desired objectives, while the remaining parameters (internal strip length, external louver angle, and external louver pitch) were deemed to be less important.

[0024] The arrangement of components as described above was determined assuming that a core face area of 15.39 square feet, core depth of 6 inches, blower air flow of 14,145 cubic feet per minute, air inlet temperature of 120 degrees F., oil inlet temperature of 212 degrees F., and an oil flow rate of 42,900 lb/hr.

[0025] It is possible to construct a heat exchanger using values that are between the numbers listed above in Option 1 and Option 2, which will provide for a tradeoff between low pressure loss and low weight.

[0026] The oil cooler **54** embodiments disclosed herein could be used for an air-to-air heat exchanger as well, such as might be used in interstage cooling of a multi-stage compressor system, or as an aftercooler in other embodiments, to set forth just a few non-limiting examples.

[0027] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiments have been shown and described and that all changes and modifications that come within the spirit of the inventions are desired to be protected. It should be understood that while the use of words such as preferable, preferably, preferred or more preferred utilized in the description above indicate that the feature so described may be more desirable, it nonetheless may not be necessary and embodiments lacking the same may be contemplated as within the scope of the invention, the scope being defined by the claims that follow. In reading the claims, it is intended that when words such as "a," "an," "at least one," or "at least one portion" are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. When the language "at least a portion" and/or "a portion" is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

[0028] Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings.

What is claimed is:

1. An apparatus comprising:

a bar and plate heat exchanger having an arrangement of external fins disposed in a first flow path separated from an arrangement of internal fins disposed in a second flow path by a parting sheet, the first flow path distinct from the second flow path, wherein the arrangement of external fins and the arrangement of internal fins are structured according to the following:

external fin height of about 0.438";

internal fin height of about 0.098";

internal fin pitch of about 0.069"; and

external fin per inch of about 11.

2. The apparatus of claim **1**, wherein the second flow path within which the internal fins are disposed is structured to contain oil.

3. The apparatus of claim **2**, which further includes a compressor and an oil sump, the second flow path including a passage to convey oil between the oil sump and the internal fins.

4. The apparatus of claim **3**, which further includes another arrangement of external fins, the arrangement of internal fins disposed between the arrangement of external fins and the another arrangement of external fins, which further includes another parting sheet between the internal fins and the another arrangement of external fins, and wherein internal strip length is about 0.14".

5. The apparatus of claim **4**, which further includes another arrangement of internal fins structured to flow oil and in fluid communication with the oil sump, and wherein the external fins includes a plurality of groupings of louvers defined by the external louver angle.

6. The apparatus of claim **5**, which further includes a header bar disposed at an end of the arrangement of external fins, and wherein at least one of the plurality of groupings of louvers is oriented in a direction that opposes a direction of at least another one of the plurality of groupings of louvers.

7. The apparatus of claim **1**, wherein the first flow path is constructed to convey a flow of air and is oriented transverse to the second flow path, and wherein the arrangement of internal fins further include an external louver angle of about 25.2 degrees, and an external louver pitch of about 0.035", and wherein the arrangement of internal fins are offset strip fins.

8. An apparatus comprising:

a compressor system heat exchanger having a first external fin construction fluidly separated from a first internal fin construction by a parting sheet, wherein the arrangement of external fins and the arrangement of internal fins are structured according to the following:

external fin height of about 0.488";

internal fin height of about 0.1"; and

internal fin pitch of about 0.081".

9. The apparatus of claim **8**, wherein the heat exchanger is an air/oil heat exchanger, with the first internal fin is structured to flow oil in a flow path that includes an oil sump.

10. The apparatus of claim **9**, wherein the compressor system includes a rotatable compressor element structured to pressurize a flow of air, and wherein the first external fin is structured to flow air in a flow path for the air/oil heat exchanger.

11. The apparatus of claim **10**, wherein the compressor system includes a second and third external fin construction, wherein the first, second, and third external fin construction are each a single unitary fin member constructed to be disposed within a fluid oil flow path, wherein external fin per inch is 12, and internal strip length is 0.14".

12. The apparatus of claim **11**, which further includes a header bar disposed at each end of the first, second, and third external fin construction, and which further includes a second and third internal fin construction.

13. The apparatus of claim **12**, which further includes a plurality of parting sheets, each neighboring pair of external fin constructions and internal fin constructions having a parting sheet disposed therebetween.

14. The apparatus of claim **13**, wherein each of the first, second, and third external fin constructions include a plurality of groupings of louvers.

15. The apparatus of claim **8**, wherein the internal fin constructions are offset strip fins, and wherein the first flow path is transverse to the second flow path, and wherein the arrangement of external fins and the arrangement of internal fins are further structured according to: an external louver angle of about 23.5 degrees; and an external louver pitch of about 0.035".

16. An apparatus comprising:

a heat exchanger of the bar and plate type for use with an air compressor system includes an plurality of external fins and a plurality of internal fins, and a parting plate disposed between the external fin device and the internal fin device, the parting plate separating a first flow path in which the external fin device is disposed and a second flow path in which the internal fin device is disposed, the external fin device and the internal fin device having an arrangement as follows:

external fin height between about 0.438" and about 0.488";

internal fin height between about 0.098" and about 0.100";

internal fin pitch between about 0.069" and about 0.081";

external fin per inch of between 11 and 12; and

internal strip length of about 0.14".

17. The apparatus of claim **16**, wherein the first flow path is transverse to the second flow path, the first flow path is an air flow path, and the second flow path is an oil flow path.

18. The apparatus of claim **17**, which further includes an oil sump in fluid communication with the second flow path.

19. The apparatus of claim **18**, wherein the plurality of internal fins includes a first set of internal fins offset and separate from a second set of internal fins, wherein the plurality of external fins includes a first set of external fins offset and separate from a second set of external fins, the heat exchanger having an alternating stacked pattern which includes the first set of internal fins, then the first set of external fins, then the second set of internal fins, then the second set of external fins.

20. The apparatus of claim **19**, wherein the plurality of internal fins are offset strip fins, which further includes a header bar disposed at the end of each of the first and second set of external fins, and wherein the first set of external fins has separate groupings of louvers; and wherein the external fin device and the internal fin device having a further

arrangement of: an external louver angle between about 23.5 degrees and about 25.2 degrees, and an external louver pitch of about 0.035".

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