MULTI-STAGE CENTRIFUGAL COMPRESSOR

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References Cited

UNITED STATES PATENTS

1,837,873 12/1931 Macmechen 415/108
2,165,741 7/1939 Wolfert 62/196
2,428,128 9/1947 Shepard 74/421 R
2,700,311 1/1955 Bade 74/801
2,888,809 6/1959 Rachfal 62/196
3,214,990 1/1965 Jekat 415/122
3,680,973 8/1972 Pilarczyk 415/116
3,717,418 2/1973 Pilarczyk 415/199 A
3,736,074 5/1973 Kilbane et al. 417/312

FOREIGN PATENTS OR APPLICATIONS

262,458 2/1928 Great Britain 415/201
563,532 8/1944 Great Britain 415/199 A
838,317 6/1960 Great Britain 415/201

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ABSTRACT

A low weight compact assembly consisting of a multi-stage in-line centrifugal compressor with driving means including, a compound epicyclic gear train having three double star gears and a multi-cooler housing which acts as a support base for the compressor, gear train, driving means and accessories therefor and as an intercooler for the first and intermediate compression stages of the compressor, an aftercooler and has cooling means for lubricant more particularly lubricant used in the compressor.

Additionally, a multi-stage in-line centrifugal compressor having a casing with a cylindrical bore for mounting a cartridge assembly, the casing having annular channels in the wall to serve as flow passages between the cartridge and the multi-stage cooler, each of the annular channels ending in a rectangular slot provided in a mounting flange on the casing which serves to connect the compressor to the multi-cooler housing.

Additionally, a compressor having a casing and a cartridge to be mounted in said casing wherein the cartridge has a rotor supported by a single line and thrust bearing at one end and by three double star gears of the compound epicyclic gear train which engage a sun gear at the end of the rotor remote from the main bearing, the three double star gears being formed so as to distribute the load equally between the three double star gears. The rotor may have a guide bearing outboard of sun gear for assemblies at higher capacities.

Additionally, a compound epicyclic gear train having three double star gears wherein the three double star gears are specially formed and indexed to the low speed internal ring gear and to the sun gear connected to the rotor shaft so that the compound epicyclic gear train is adapted to provide gear rotors in excess of 1:11—which is the approximate limit for simple three star gear trains—and is capable of taking reasonable misalignment between the drive motor and the driven compressor without interfering with the required alignment of the remaining elements of the epicyclic gear and the rotor mounted and/or centered in the cartridge.

13 Claims, 43 Drawing Figures
MULTI-STAGE CENTRIFUGAL COMPRESSOR

BACKGROUND OF THE INVENTION

A multi-stage compression assembly directly coupled with a standard motor through a speed increasing gear for independently driving each stage of compressor and having an intercooler housing with also acts as the base for the compressor and the speed increasing gear is shown in the U.S. Pat. Nos. 3,001,692 and 3,476,485.

Although at the time of its introduction, the assembly shown in U.S. Pat. Nos. 3,001,692 and 3,476,485 were considered relatively simple, compact and efficient, it soon becomes clear that the large helical gear required to directly couple the motor to the pinion gears for independently driving the respective stages of compression at the required rotational speeds, as well as the size of the independent stages of compression and the associated accessory equipment made these units not only heavy but required that they have a large independent space and they will be supported independently of the intercooler housing.

Additionally, such prior art devices required additional time for installation of the foundation, the piping in of process air and water, electrical conduits, etc. connecting of accessories for example, the motor starter, inlet filter, after cooler, blow off valve and silencer, a discharge check valve etc., all of which entail extra expense in addition to the first time cost for the particular unit.

These prior art designs are particularly directed to providing oil free compressed air for industrial use. Proper assembly and use of suitable accessories are important and necessary to their operation.

The compression assembly of the present invention accomplishes the same results as prior art devices by providing in a single combined, easy to install, compact unit the centrifugal compressor, its driver, cooler and accessory equipment in which the compressor by contrast is small light and compact.

This is accomplished by utilizing an in-line type centrifugal compressor with epicyclic gearing to assure a collinear arrangement for the axis of the compressor and its driving means.

The compact unit of the present arrangement eliminates the need for a special foundation. Further, since all normally required components and accessories are incorporated into the one unit or package, only the simplest of air, water and electrical connections are made after the unit is delivered at the site where it will be used.

Thus, the present invention meets and overcomes the problems of the prior art compression systems by modifying the construction of an in-line multi-stage centrifugal compressor first to enable the compressor to be driven through the improved epicyclic gear train at gear ratios in excess of those available from known simple type gear trains and second to permit the compressor, its gear train and the associated driving means to be mounted on an improved multi-cooler housing with which the compressor coacts to provide for the compression system the advantages of intercooling between the stages of compression, the end conditioning of the compressed air or gas before it is delivered to use and the cooling of the lubricant used in the system.

Other objects and advantages of the present invention will be better understood by reference to one of the preferred forms as hereinafter described and claimed and shown in the accompanying drawings wherein:

FIG. 1 is a front isometric view showing the inlet end of an assembly in accordance with the present invention.

FIG. 2 is a rear isometric view from the driving end of the assembly shown in FIG. 1.

FIG. 3 is a front elevational view of the assembly shown in FIG. 1.

FIG. 4 is a rear elevational view of the assembly shown in FIG. 1.

FIG. 5 is a top elevational view of the assembly shown in FIG. 1.

FIG. 6 is a right side elevational view of the assembly shown in FIG. 1.

FIG. 7 is a left side elevational view of the assembly shown in FIG. 1.

FIG. 8 is a right side elevational view of one form of gas inlet, filter, noise suppressor and blow off device partly in vertical section in assembled position on the multi-stage cooler and connected to inlet of the compressor.

FIG. 9 is a front elevation of the inlet, filter, noise suppressor and blow off device shown in FIG. 8 taken at line 9—9 and partly in vertical section.

FIG. 10 is a horizontal section taken on line 10—10 of FIG. 9.

FIG. 11 is an enlarged fragmentary view of the blow off pipe and blow off muffler.

FIG. 12 is a cross section taken on line 12—12 of FIG. 11.

FIG. 13 is a vertical section taken through the compressor illustrated in FIGS. 1 through 7 showing the compound epicyclic gear train partly in side elevation in communication with the shaft of the driving element, the main line and thrust bearing housing assembly in side elevation to show generally how the rotor of the compressor is supported and driven.

FIG. 14 is a vertical section taken through the main line bearing and thrust bearing housing assembly shown in FIG. 13.

FIG. 15 is a front view of the inlet of the first stage compressor insert showing a front elevational view of the main line and thrust bearing housing assembly in assembled position.

FIG. 16 is a side view of the first compression stage insert unit partly in section.

FIG. 17 is a vertical section taken on line 17—17 of FIG. 15.

FIG. 18 is a rear view of the second compression stage insert unit.

FIG. 19 is a vertical section taken on line 19—19 of FIG. 18.

FIG. 20 is a cross section taken on line 20—20 of FIG. 19.

FIG. 21 is a side view of the third stage compressor insert unit partly in section.

FIG. 22 is a vertical section of the compound epicyclic gear train shown in FIG. 13 with one double star gear removed to show the sun gear and partly modified to illustrate the addition of a guide bearing for higher capacity assemblies.

FIG. 23 is a cross section taken on line 23—23 of the FIG. 22.
FIG. 24 is a cross section taken on line 24—24 of FIG. 22.

FIG. 25 is a view taken on line 25—25 of FIG. 22.

FIG. 26 is a perspective view of the compound epicyclic gear train shown in FIGS. 13, 22, 23, 24 and 25.

FIG. 27 is a front view of the compressor casing partly broken away in vertical section.

FIG. 28 is a side elevational view of the compressor casing shown in FIG. 27 partly broken away in vertical section.

FIG. 28A is a cross sectional view taken at line 28A—28A of FIG. 28.

FIG. 29 is a top view of the compressor casing.

FIG. 30 is a bottom view of the compressor casing.

FIG. 31 is a horizontal section taken on line 31—31 of FIG. 28.

FIG. 32 is a front perspective view of the multi-cooler housing partly broken away to show the first stage inter-cooler section.

FIG. 33 is a front elevational view of the multi-cooler housing shown in FIG. 32.

FIG. 34 is a rear elevational view of the multi-cooler housing shown in FIG. 32.

FIG. 35 is a top elevational view of the multi-cooler housing shown in FIG. 32.

FIG. 36 is a right side elevational view of the multi-cooler housing shown in FIG. 32 partly broken away to show the first stage inter-cooler passage from the multi-stage compressor to the multi-cooler and the second stage return passage from the multi-cooler housing to the multi-stage compressor.

FIG. 37 is a left side elevational view of the multi-cooler housing shown in FIG. 32 partly broken away to show the first stage inter-cooler passage from the multi-stage compressor to the multi-cooler housing, the second stage return passage from the multi-cooler housing to the multi-stage compressor, the third stage inlet passage from the multi-stage compressor to the multi-cooler and the discharge outlet for the assembly.

FIG. 38 is a vertical section taken on line 38—38 of FIG. 37.

FIG. 39 is a vertical section taken on line 39—39 of FIG. 37.

FIG. 40 is a vertical section taken on line 40—40 of FIG. 35.

FIG. 41 is a vertical section taken on line 41—41 of FIG. 35.

FIG. 42 is a horizontal section taken on line 42—42 of FIG. 40.

DESCRIPTION OF GENERAL ARRANGEMENT

Referring to FIGS. 1 to 7 of the drawings one preferred form of the composite assembly is shown as including a multi-stage in line centrifugal compressor generally designated 1 connected through a compound epicyclic gear train section generally designated 2 to the shaft 3 of a suitable driving means generally designated 4 which is enclosed in a substantially sound-proof housing 5.

Driving means such as a standard induction motor is used for driving the compressor however it will be understood that turbines and internal combustion engines could be utilized for this purpose without departing from the scope of the present invention.

The compressor 1 receives its air or other gas to be compressed through an inlet, filter and noise suppressor assembly generally designated 6 and the air or other gas to be compressed will be passed from the compressor to a multi-cooler housing generally designated 7. The air or gas in the compressor passes through a plurality of compression stages in the compressor and through a plurality of intercoolers and finally an end cooler in the multi-cooler housing all of which is more fully described hereinafter and from the multi-cooler is discharged through a discharge line 8 which is provided with a check valve 9 to any desired use.

Compressor 1, its associated compound epicyclic gearing and driving means connected at one end and the inlet, filter and noise suppressor assembly 6 connected to the other end are respectively mounted on top of the multi-cooler housing 7. Thus, multi-cooler housing 7 serves both as a base for the composite assembly and includes means specially arranged to coact with the compressor for interstage cooling of the air or gases being compressed from stage to stage in the compressor and for the conditioning of the air or gas being delivered from the compressor. It includes a cooling means for the lubricant which feeds the bearings and the epicyclic gearing for the compressor.

As shown in FIGS. 2, 5, 6 and 7 the discharge line is provided with a by-pass line 10 which communicates with the air inlet filter and noise suppressor assembly 6. When blow-off valve 10a is opened either manually or automatically the discharge check valve 9 will close and blow off air or gas can be by-passed through the assembly 6 back to the suction inlet of the compressor.

An enclosure 11 is provided to house and protect the controls for operating the composite system and for the various gauges which show the conditions of operation.

Air or other gas to be compressed is delivered to the compressor through the inlet, filter and noise suppressor assembly 6 more fully shown and described in co-pending application Ser. No. 245,718 filed Apr. 20, 1972, now U.S. Pat. No. 3,736,074. Assembly 6 includes a generally box-like housing 12 defining a combined inlet and by-pass chamber 13 for air or gas to be compressed and for blow-off air to be returned to the suction inlet of the compressor. In the upper portion of the combined inlet and by-pass chamber 13, a filter chamber 14 is formed having an opening as at 14a in communication with the combined inlet and by-pass chamber 13. A removable filter 15 is disposed across the opening 14a, all of which is shown in FIGS. 8, 9 and 10 of the drawings.

The walls and the removable cover 16 of the box-like housing will be made so as to suppress the propagation of noises by having any suitable type of insulation material attached as by an adhesive.

The transmission pipe 17 from the source of air or gas to be compressed is connected to the housing 12 so as to deliver the air or gas to be compressed to the filter space. This air or gas in turn is filtered as it passes through filter 15 into the chamber 13. While a transmission pipe 17 is shown it is thought clear as will be understood by those skilled in the art that housing 12 could be provided with a screen opening or an opening within a hood to draw ambient air at the point where the assembly is installed or placed.

The chamber 13 in turn communicates through the connecting pipe 18 to the inlet cone 19 on the compressor 1 defining a portion of the suction inlet of the
The by-pass conduit 10 communicates with the combined inlet and by-pass chamber 13 so that air or gas by-passed from the discharge outlet 8 will be delivered through the connecting conduit 18 to the suction inlet of the compressor 1. In order to suppress the noises normally generated by the movement of air or gas through the blow-off or by-pass line 10, a blow-off muffler 20 is mounted in the housing 12 and connects to the blow-off or by-pass conduit 10.

Muffler 20 is shown in assembled position in FIGS. 8 to 11 of the drawings. It includes an elongated body 21 which tapers as at 22 adjacent the inlet 23. The body forms a chamber or cavity which is divided transversely by a pair of spaced plates as at 24 and 25 having a multiplicity of orifices as at 26. On one side of the spaced plate 25 a passage 27 communicates with the inlet 23. and, thus, passes the blow-off or air or gas to the multi-orifice plates 24 and 25. The cavity on the side opposite passage 27 is the muffling cavity 28. Air passing through the orifices 26 is collected in the muffling cavity 28. An end wall 30 closes the muffling cavity 28. The elongated body 21 may be perforated over only part of the portion which forms the muffling cavity 28 or may be perforated in patterns as may best accomplish the desired function of abating the noises generated by the by-pass of compressed air or gas when unloading or operating at unloaded conditions.

Air or gas to be compressed is delivered to compressor 1. The disclosed compressor is particularly constructed so that all the stages of compression can be substantially assembled as a single cartridge assembly which is mounted in a specially designed casing for the compressor, is supported in that casing and will be driven by any suitable driving means through specially constructed compound epicyclic gearing which also acts or serves as a bearing support at one end of the cartridge assembly.

MULTI-STAGE IN LINE CENTRIFUGAL COMPRESSOR

Compressor 1 includes an outer casing 40 having a cylindrical bore as at 41 to receive or mount a cartridge assembly generally designated 42 which is shown as having three compression stages. It will be understood that the cartridge assembly could have two stages or more than three stages of compression without departing from the scope of the present invention.

Cartridge type multi-stage compression assemblies for rotary type fluid machines which are mounted in outer casing are a known expedient. In the conventional prior art devices the discharge of one stage either goes directly into the suction inlet of the next stage by suitable intercommunication between the discharge or volute section of one stage and the next associated suction inlet of the following stage or the discharge is connected to external piping so the air or gas being compressed can be passed to and returned from an intercooler between the stages of compression.

However, the cartridge assembly of the present invention differs in that the various stages of compression in the cartridge assembly communicate with a plurality of annular channels, or passages as at 43a, 43b, 43c, 43d and 43e disposed in the wall of the outer casing 40 so as to extend inwardly from the cylindrical bore 41 to form flow passages for the various stages of compression of the cartridge assembly to and from the associated multi-cooler housing 7.

The cartridge assembly 42 is shown in FIG. 13 as including a rotor 44 rotably supported in the main line bearing 45 which also provides one of the fixed but unloaded surfaces of a thrust bearing 110 hereinafter more fully described. At the end remote from the main bearing 45, a sun gear 47 connected to the end of the rotor 44 is supported and rotably driven by the compound epicyclic gear assembly generally designated 48 for transmitting power from the driving means 4, and drive shaft 3 to the rotor 44.

Connected to and rotatable with the rotor are a first stage impeller 51, a second stage impeller 52 and a third stage impeller 53.

The rotor 44 extends along the axial line of the cartridge assembly 42 through a plurality of diaphragm elements or stage inserts generally designated 54, 55 and 56 which are associated with the respective impellers 51, 52 and 53. The respective first stage insert 54, the second stage insert 55 and the third stage insert 56 are held in interfitting engagement by a plurality of studs 57 and nuts 58.

First stage insert 54 is shown at FIGS. 13, 15, 16 and 17; second stage insert 55 is shown at FIGS. 13, 18, 19 and 20 and third stage insert 56 is shown at FIGS. 13 and 21. These diaphragm elements or stage inserts separate the stages of compression provide flow ports or openings to the annular channels or passages 43a, 43b, 43c, 43d and 43e and mount the diffuser diaphragms, 59, 60 and 61 which form with the next associated stage insert the first stage diffuser 62, the second stage diffuser 63 and third stage diffuser 64 for the respective first, second and third stage impellers 51, 52 and 53.

First stage insert unit 54 in combination with the cover or inlet cone 19 defines the suction inlet 65 in communication with the connecting conduit 18 for delivering air or gas from the combined inlet and by-pass chamber 13 to the compressor 1. The suction inlet 65 in turn communicates at the end remote from the connecting conduit 18 with the suction eye 51a of the impeller 51 as will be clear from the description of the construction of the first stage impeller.

First stage insert unit 54 is a generally cylindrical member and includes a rim section 70 having a flange 71 at one end for connecting the cartridge assembly to the outer casing 40 and a radially inward extending disc or partition 72 which receives the first stage diffuser diaphragm 59 adjacent its inner end. The first stage diffuser diaphragm 59 surrounds and forms with the first stage impeller 51 the suction eye 51a.

In assembled position the rim 70 and disc 72 define a space which is continuous with the space defined by the cover or inlet cone 19 and this forms the suction inlet 65 which communicates with the suction eye 51 of the first stage impeller 51 and air or gas to be compressed thus flows freely from the inlet 17 to the first stage compression stage of the compressor 1.

First stage insert unit 54 further includes a plurality of radially extending ribs 73 which are connected between the rim 70 and a bearing housing 74 as shown more clearly in FIGS. 13 and 15 of the drawings so as to support and align the bearing housing 74 and the main bearing 45 mounted therein into which one end of the rotor extends as is shown in FIG. 14 of the drawings.
First stage diffuser diaphragm 54 forms the first stage diffuser 62 which discharges into the first stage volute chamber 75. The first stage volute chamber 75 in turn communicates through a plurality of passages 76 with the annular channel or passage 43a. Passages 76 as shown by FIG. 13 are formed by the first stage insert unit 54 and a portion of the third stage insert unit.

Thus, air or gas from the suction inlet 65 enters the first compression stages at impeller 51 and is discharged through diffuser 62 into the volute chamber 75. The compressed air or gas exits from the volute chamber 75 through the passages 76 into annular chamber 43a and as will be hereinafter more fully described the air or gas from the first stage of compression flows from annular chamber 43a to the multi-cooler housing 7 where it passes through the first stage intercooler loop. This first stage intercooler loop communicates on the end remote from the end communicating with the annular chamber 43a with annular chamber 43b. Annular chamber 43b in turn is associated with the second stage insert 55 of the second stage of compression in compressor 1.

FIGS. 13, 18, 19 and 20 show that the second stage insert 55 is also cylindrical in shape and includes a rim portion 100 and three spaced radially inward extending walls or partitions as at 81, 82 and 83.

Partition 81 has a gear carrier section 84 for supporting the various elements of the compound epicyclic gear 48. Gear carrier 84 includes a plurality of axially extending arms 90 connected at one end to partition 81 and provided at the end remote from partition 81 with an end cover 91 and will be referred to below in connection with the description of the compound epicyclic gear train.

Partition 82 receives the second stage diffuser diaphragm 60 to define a second stage suction inlet 85 which communicates through second stage inlet flow ports or openings 86, in the rim 80 with the annular channel 43b and the suction eye 52a of the impeller 52.

Thus, compressed air from the multi-cooler will be passed from the annular channel 43b to the suction eye 52a of the impeller 52.

An annular member 87 connects to the partition 83 at the outer end. An air seal 46 is mounted thereon in a central opening and is disposed to coat with rotor 44. Member 87 coats with the diffuser diaphragm 60 to form diffuser 63 and the member 87 and partition 83 are so spaced that they define the second stage volute 88. A plurality of outlet flow passages or openings 89 in the second stage insert unit provide communication between second stage volute 88 and the annular channel 43c.

Thus, air or gas compressed by the second stage impeller is discharged from the diffuser passage 63 into the second stage volute 88. From the volute 88, second stage compressed air or gas passes through second stage outlet flow passages or openings 89 into the annular channel or passage 43c and as will be hereinafter more fully described the air or gas from the second stage of compression flows from annular chamber 43c to the multi-cooler housing where it will pass through a second stage intercooler loop. The second stage intercooler loop communicates at the end remote from its connection with the annular chamber 43c with passage 43d associated with the third stage insert 56 of the third compression stage of the compressor 1.

The third stage insert 56 is cylindrical in shape and includes a rim portion 100 and a pair of medially disposed radially inwardly extending partitions as at 101 and 102. The third stage insert is disposed and connected intermediate the first stage insert 54 and the second stage insert 55 so that in assembled position it contacts with the first stage insert to form the first stage volute 75 and a portion of the rim adjacent the first stage insert 54 has the first stage outlet flow passages or openings 76 formed therein. Medially in the rim 100 a plurality of third stage inlet flow ports or openings 103 are formed. These ports or openings 103 connect the passage 43d to the third stage suction inlet 104 which in turn communicates with the suction eye 53a formed by the third stage diffuser diaphragm 61 which is connected to partition 102. The diffuser 63 will discharge air or gas compressed by the third stage impeller 53 to a third stage volute 105 which communicates through third state outlet flow passages or openings 106 with the annular passage 43e.

Thus, the air or gas from the second stage intercooler loop flows from the passage 43d through the third stage suction inlet 104 to the suction eye 53a of impeller 53. It is discharged from impeller 53 through diffuser 63 to the third stage volute 105 and passes from third stage volute 105 through the third stage outlet flow passages or opening 106 to the annular channel 43e. The air or gas is again passed to the multi-cooler housing where it goes through an end conditioning cooling loop having an after cooler therein and then flows through the discharge manifold 8 to the desired use or if the compressor is unloaded back to the suction inlet 65.

As is thought clear from FIG. 13, the cartridge 42 is slipped into assembled position and O-ring seals at 108 are provided to seal the various flow passages, ports or openings and annular chambers from each other to provide the desired cross-over flow patterns between the various stages of compression in the compressor and flow from the compressor 1 to the multi-cooler housing 7.

A transversely extending partition 107 in the casing divides one of the annular channels to delineate the passage 43d as is shown in FIGS. 27 and 28 of the drawings. This acts to reduce the volumetric capacity of passage 43d and prevents radiation heat build-up in the compressed fluid before it reaches the suction eye 53a.

BEARING MEMBERS

FIGS. 13 and 14 show that main line bearing 45 which supports one end of the rotor 24 is disposed in the portion of the bearing housing 74 outboard of an oil seal 108 adjacent to the bearing side oil seal 108.

The main line bearing 45 is associated with a thrust bearing generally designated 110. One side as at 111 of the main line bearing provides one of the fixed surfaces for the thrust bearing 110 and a fixed thrust bearing member 112 disposed in spaced relation to the side 111 provides a second fixed surface which is the normally loaded surface of the bearing. In the space between side 111 and the normally loaded member 112 is a thrust collar 113 which is mounted on and rotatable with the connecting portion 114 forming part of the rotor 44 outboard of the portion of the rotor 44 supported by the main line bearing 45.
The thrust bearing 110 operated by maintaining fluid pressure on either side of the thrust collar 113 so that the coating thrust faces on the part 111 of the main line bearing 48 and the fixed thrust bearing member 112 can absorb the thrust forces which occur along the longitudinal or axial line of the rotor 44. This is accomplished by feeding a suitable lubricant through inlet passages 115 and 116 which are connected to a source of lubricant under pressure and as indicated by FIG. 14 deliver the lubricant through outlet openings 117 and 118 which communicates respectively with the space 119 between the thrust collar 113 and the fixed thrust members 112 on the outboard side of the thrust collar 113 and the space 120 between the part 112 on the main line bearing on the opposite or inboard side of the thrust collar 113, as is shown in FIG. 14.

The collected lubricant is returned to the lubricating system through return passages 121 and 122 which communicates with the collecting passages 123 in communication with the oil sump provided in the multi-cooler housing as will be described below. The lubricant pump 124 or auxiliary lubricant pump 125 have their suction (not shown) in communication with the sump in the multi-cooler housing and will take the lubricant from the sump for use in the compressor. The pump delivers the lubricant to the lubricant cooler 126 and filter 127 and then it is transmitted through conduits means to rotating elements of the compressor requiring lubrication. Since this system apart from the multi-cooler is generally conventional, it is not more fully described.

**COMPONENT EPICYCLIC GEAR ASSEMBLY**

At the end remote from the main bearing 45, the rotor is supported by the component epicyclic gear 48. This is accomplished by means of the sun gear 47 which intermeshes and is held in position by the three respective double star gears 131, 132 and 133 and more particularly by the larger gear elements of the double star gears as at 131a, 132a and 133a as shown in the drawings at FIGS. 13, 22, 23, 24, 25 and 26.

Each double star gear of the component epicyclic gear train in accordance with the present invention consists of two pieces namely the above mentioned large star gears 131a, 132a and 133a which mesh with the sun gear 47 and the smaller star gears 131b, 132b and 133b which mesh with a ring gear 134 as is shown in FIGS. 13, 22, 23 and 26.

The advantageous results of the present invention are obtainable because of the manner in which these two elements of the double star gears 131, 132 and 133 respectively the larger star gears 131a, 132a and 133a and the smaller stag gears 131b, 132b and 133b are formed together and the unit assembled with respect to the sun gear 47 now to be described.

Thus, in accordance with known rules of mechanics for the design and assembly of gears trains the tooth number of the sun gear 47; the larger gear 131a, 132a and 133a; the smaller gears 131b, 132b and 133b and the ring gears 134 are selected.

One of the pair of star gears will then be assembled by shrink fitting a larger star gear and a smaller star gear to each other so that one tooth on each respective gear, i.e., one tooth on the large star gear and one tooth on the small star gear are centered on the same radial line. This is illustrated at FIG. 23 where the aligned teeth of star gear 131 are marked as indicated at 135a and 135b.

Since the number of teeth on each larger star gear is greater than the number of teeth on the smaller star gear the center lines of the marked teeth will as a general rule be the only aligned teeth of a given pair of larger and smaller gears for a given double star gear while the radial alignment of the other teeth of the pair will not be centered on the same radial line.

Once one pair of the larger and smaller gear of a given star gear are so formed it is necessary to repeat identical indexing as above described for each of the other double star gears of the component epicyclic gear train 48.

Once the respective double star gears 131, 132 and 133 are formed as above described they must be carefully assembled in accordance with certain known procedures for assembling the elements of an epicyclic gear train. However, the present epicyclic gear train differs from conventional gear trains in that there are double star gears in the train. Thus, when assembly is completed the larger star gears 131a, 132a and 133a will mesh with the teeth on the sun gear 47 while the smaller star gears 131b, 132b and 133b will mesh with the teeth 134a on the ring gear 134.

If the respective star gears have been carefully aligned to provide the desired alignment and identity of tooth arrangement and if they are then carefully assembled in accordance with the known assembly procedures, then the torque load will be divided equally between the double star gears 131, 132 and 133 when the driving force for rotating the rotor 44 is transmitted through the component epicyclic gear train 48.

It is known that epicyclic gear trains with three single star gears are limited to a ratio of approximately 1:11. However, such gear trains are desirable in contrast to the offset gearing of the prior art devices because they eliminate bearing loads. Helical gears always produce axial thrust loads for each gear and therefor require suitable axial bearings on each gear. The low pitch line velocity due to the small size of the sun gear in epicyclic gear trains permit the use of spur gear type teeth instead of the helical teeth. This eliminates the axial thrust which in turn eliminates the need for axial bearings and makes it cheaper to manufacture the epicyclic gear train.

These advantages are all inherent in the compound epicyclic gear train of the present invention in addition to the fact that three of the teeth of the sun gear share the load during the transmission of the torque acting thereon.

However, the provisions above described for formulating a double star gear design in which the larger gear which exceeds the diameter of the smaller gear engages the sun gear provides greater ratios than have been heretofore obtainable with the prior art epicyclic gear trains.

The compound epicyclic gear train 48 is disposed in the gear carrier 84 so that the double star gears 131, 132 and 133 are mounted on and rotatable about fixed spindles 140, 141 and 142 disposed in the gear carrier 84 connected to the second stage insert 55 of the cartridge.

The fixed spindles 140, 141 and 142 are spaced radially from and parallel to the axial line of the rotor 44 and sun gear 47 so that the larger star gear 131a, 132a and 133a mesh perfectly with the sun gear 47 when the
respective double star gears 131, 132 and 133 are in assembled position as above described.

The smaller star gears 131b, 132b and 133b in assembled position mesh with the Teeth 134a on the inner circumference of the floating low speed ring gear 134. Ring gear 134 is provided on its outer circumference with a corresponding set of teeth as at 134b which engage one of a set of gear teeth as at 143 spaced from a second set of gear teeth 144 on the inner circumference of a wide shell type coupling member 145.

The coupling member 145 is a floating member which has the second set of teeth at 144 in engagement with the teeth 146a on a hub 146 which is fixedly connected to the drive shaft 3.

Thus, whenever the driving motor 4 is in operation power is transmitted through the driving shaft 3 to the hub 146 and this power is transmitted through the coupling member 145, ring member 134 to the smaller star gears 131b, 132b and 133b and the larger star gears 131a, 132a and 133a.

Since the larger star gears 131a, 132a and 133a are in meshing engagement with the sun gear 47 they will rotate the sun gear and the rotor member 44 thereto.

The coupling member 145 is capable of taking a reasonable degree of misalignment between the shaft 3 and the rotor 44. However, those parts which require substantially close alignment namely the star gears with respect to the sun gear and rotor are all fixedly mounted in the gear carrier 84 and aligned with respect to the axial line of the rotor.

Further, as will be understood by those skilled in the art from the above description the ability to transmit power to the sun gear through the larger star gears in the manner described will permit gear ratios in excess of 1:11 which is the approximate limit for a simple star gear train of the known type in the prior art.

FIG. 22 indicates an alternate arrangement for higher capacity units and show a guide bearing housing generally designated 147 provided outboard of the sun gear 47. Where compressors of larger capacity are provided in accordance with the present invention the shaft extension 148 which has the sun gear 47 mounted thereon is further extended to receive a suitable bearing journal 149 which in the illustrated form of this device is an extension of the hub of the spur gear 47. Bearing journal 149 is then supported in a bearing member 149a. It will be understood that the compressor rotor and compound epicyclic gearing of the present invention can thus be made with or without the guide bearing as may be required.

OUTER CASING FOR COMPRESSOR

The associated outer casing which coacts with the cartridge assembly compound epicyclic gear train and drive means as above described is specially designed to provide the necessary channels or passages between the cartridge and multi-cooler housing. Further, it provides means for mounting the compressor so that the channels and passages can be aligned with the transport openings in the multi-cooler.

The outer casing in accordance with the present invention is shown in detail at Figs. 27, 28, 29, 30 and 31 as comprising a single unitary element with the cyindrical bore at 41 for receiving the cartridge assembly 42 as has been above described.

Compressor casing 40 is provided at one end with an inlet section as at 150 and at the other end with a gear section 151. Inlet section 150 is flanged as at 152 to provide means for connecting the inlet section 150 to the cone-inlet 19 and the first stage insert unit 54 by the flanged elements thereon as by any suitable threaded means 153. The gear section is provided with a closure means 154 through which the drive shaft 3 extends.

The gear section 151 and closure means 154 define a gear chamber 155 which houses the compound epicyclic gear assembly 48 and collects lubricant delivered to the epicyclic gear train which lubricant is passed by a return passage 156 disposed in a large horizontal connecting flange 157 at the lowermost portion of the outer casing 40. The horizontal connecting flange 157 extends substantially the full length of outer casing 40. This connecting flange 157 serves a dual purpose, first it provides means for connecting and supporting the compressor and its associated compound epicyclic gear assembly on a boss 158 on the multi-cooler housing as by the threaded member 159 and second it has the transport openings as at 160a, 160b, 160c, 160d and 160e which communicates and connect with the associated annular channels 43a, 43b, 43c, 43d and 43e.

Thus when the compressor 1 is as assembled position on the multi-cooler housing 7, air or gas being compressed in the compressor can be passed through the annular channels and the transport openings to the multi-cooler housing through the transport openings to the annular channels as has been above described.

It is thought clear from the Figs. 27, 28, 29, 30 and 31 that the transport opening 160a is associated with the annular channel 43a, 160b is associated with channel 43b, 160c is associated with channel 43c, 160d is associated with channel 43d and 160e is associated with annular channel 43e.

With reference to Figs. 27, 30 and 31 the annular channels 43a, 43b, 43c, and 43e and passage 43d are shown to enclose an increasing volume extending from the uppermost portion of the annular channel to the lowermost portion thereof in communication with the associated transport opening. Additionally, it will be noted that the annular channels 43a, 43b, 43c and 43e are bilaterally disposed with respect to the longitudinal or axial line of the compressor casing so that substantially equal volumes of air or gas under compression will flow on either side of the compressor to the associated transport opening for the particular annular channel. For example, this is clearly illustrated in FIG. 27 which shows the annular channel 43a and its associated transport opening 160a in the connecting flange 157. Passage 43d is also bilaterally disposed but does not open beyond the transverse projections 107.

Along the medial line of flange 157 a boss 161 is formed through which the collecting passage 123 extends. Collecting passage 123 communicates at one end with the lubricant return lines 121 and 122 communicating with the bearing housing 74 and also connects with the lubricant return line 156 which communicates with the chamber 155 formed in the gear section 151 of the outer casing 40 so that lubricant delivered to the compound epicyclic gearing 48 will be collected and discharged with that from the bearing housing 74 to a lubricant return port 160f which is formed in the connecting flange 157.
In assembling the compressor 1 so that it can coact with the multi-cooler housing in accordance with the present invention, the compressor casing 40 above is taken together with the driver, the compressor casing 40 first being attached to the boss 158 on the multi-cooler housing by threaded member 159 which extend through the connecting flange 157, and then the driver is connected to the multi-cooler housing and aligned with the casing 40.

The cartridge assembly 42 is then inserted into bore 41 and the flange 71 is clamped between the flange 19a of inlet cone 19 and flange 152 on the casing 40 by means of bolts 153. The remaining accessory equipment as above described can be added to complete the unit.

In this assembled position, the air or gas transport openings 160a, 160b, 160c, 160d and 160e and the lubricant return port 160f coincide and align with corresponding transport openings 180a, 180b, 180c, 180d, 180e and 180f in the boss 158 on the multi-cooler housing 7 now to be more fully described.

MULTI-COOLER HOUSING

Multi-cooler housing 7 shown in detail in FIGS. 32 to 42 of the drawings as a generally elongated rectilinear box-like structure which in cross-section is substantially square. It also includes a top 181, a bottom 182, sides 183 and 184, front end 185 and back end 186. While multi-coolers of various types are known in the prior art such as is shown in U.S. Pat. Nos. 3,476,485; 3,355,096 and the above mentioned U.S. Pat. No. 3,001,692, the design of the multi-cooler housing of the present invention is a more complex system of cavities, channels and inlet and discharge openings in communication therewith. It permits compressed air or gas to be passed through the multi-cooler housing a plurality of times.

The basic concept of the design adapted for this complex system of cavities, channels and flow openings into and out of the multi-cooler housing 7 is to provide passages, cavities, or channels which form cooling or conditioning loops one inside of the other. The longest and outermost cooling or conditioning loop receiving compressed air or gas at the lowest pressure and the smallest and innermost cooling or conditioning loop having and receiving the compressed air or gas at the highest pressure.

Thus, air or gas discharged from the first compression stage will pass through a low pressure cooling loop to the second compression stage inlet. The same air or gas will be discharged at a higher pressure from the second compression stage into an intermediate pressure cooling loop and passed through the intermediate pressure cooling loop to the third compression stage inlet.

The intermediate pressure loop will be disposed inside the low pressure loop. Finally, the same air or gas will be discharged at the highest system pressure from the third compression stage outlet into the high pressure cooling loop where it passes to the discharge outlet for the system. The high pressure loop once again lies within the intermediate pressure loop, all of which will appear clear from FIGS. 40 and 41 of the drawings.

Thus, the air and gas transport openings 180a, 180b, 180c, 180d and 180e in the boss 158 of the multi-cooler housing provide the flow passage inlets and outlets, for passing the air or gas being compressed in the compressor to and from the multi-cooler housing 7 to permit interstage cooling of such air or gas between each stage of compression and for the end conditioning of the compressed air or gas. This is a known expedient which improves the efficiency of the multi-stage compressor and permits adjustment of the temperature and/or specific humidity of the air or gas being delivered for use.

The relationship between the various cooling loops and the transport openings 180a, 180b, 180c, 180d and 180e formed in the boss 158 is shown in FIGS. 35, 36, 37, 40, 41 and 42 to include a plurality of convoluted partitions which extend transversely of the longitudinal line of the multi-cooler 7 are in fluid tight connection on each side of the respective partitions with the adjacent inner wall of the respective side walls 183 and 184 of multi-cooler 7. The partitions at one or both ends commence at the boss 158 and act to define the transport openings 180a, 180b, 180c, 180d and 180e and the lubricant transport opening 180f.

Referring to FIGS. 36, 40, 41 and 42, the first partition 190 of convoluted design is disposed to extend from the boss 158 on the top wall 181 to the bottom wall 182 and is connected at its edges to the side walls 183 and 184. It defines with the top wall, a connecting passage 191 which communicates with the lubricant transport opening 180f at one end and at the end remote therefrom with a cavity 192 which forms a lubricant sump as at 193. Lubricant entering transport opening 180f passes through the connecting passage 191 into the cavity 192 and is collected in the sump 193. The main pump 124 driven by driving means is connected to the sump 193 and draws lubricant therefrom. This lubricant is then pumped through the oil cooler 126 and filter 127 and flows by suitable conduits and passages to the bearings and epicyclic gear train as shown in the figures of the drawings. Lubricant systems of this type will be understood by those skilled in the art including the provision for an auxiliary pump 125 and accordingly will not be more fully described herein.

A second convoluted partition 200 is connected at its respective ends in the boss 158 to define the transport openings 180a and 180d and at the respective edges to the side walls 183 and 184. It is disposed relative to the top 181, bottom 182, end wall 186 and the first partition 190 to form the low pressure cooling loop generally designated 201. The low pressure loop 201 communicates at one end with the transport opening 180a and at the end remote therefrom with the transport opening 180b. Thus, air or gas compressed in the first stage of compression and discharged into the annular channel 43a will pass through the transport openings 160a and 180a into the low pressure cooling loop 201.

Disposed in the low pressure cooling loop is a heat exchange means generally designated 202 which consists of conventional tube bundles diagrammatically indicated in FIG. 32 at 203. The tube bundles are connected to a header 204. The header 204 is provided with an inlet pipe 205 for passing cooling water to heat exchanger means 202 and an outlet pipe 206 for returning cooling water from the heat exchange means 202.

The inlet pipe 205 in turn is connected to the common cooling water manifold 207 from the source of the cooling water, and the outlet pipe 206 is connected to
the common return conduit 208 for returning the heated cooling water to the course, as also shown in FIGS. 1, 4, 5 and 6 of the drawings.

Heat exchange means of the type above described are well known and easily purchaseable on the open market, will therefor be well understood by those skilled in the art and accordingly are not more fully described. Further, all the heat exchanger means in the various cooling loops will have a similar construction to that above described for heat exchange means 202. Accordingly, when heat exchange means is referred to in connection with the intermediate pressure cooling loop and high pressure cooling loop it is intended to refer to heat exchangers of this type.

In the multi-cooler housing 7 each of the respective cooling loops will be constructed and arranged to receive the respective heat exchanger means. Thus, in the low pressure cooling loop 201, a lower bracket member 210 connected respectively to front wall 185 the side walls 183 and 184 and the partition 200, a spaced distance from the bottom wall 182 and forms a centrally disposed flow opening 211. Similarly an upper bracket member 212 with a centrally disposed flow opening is formed a spaced distance from the upper wall 181 and the heat exchange means 202 can be mounted in the space determined between these brackets through the heat exchange mounting opening 214 and 215 in the sides 184 and 183 respectively of the multi-cooler housing 7. The openings 214 and 215 are provided with a mounting flange 216 and 217 about each of the openings. A corresponding mounting flange 218 and 219 is provided about the header 204 for connecting the heat exchange means 202 in assembled position, all of which is shown in FIG. 32.

In FIGS. 38, 39, 40 and 41 the low pressure cooling loop 201 defined by the partition 200 has an inlet section 201a in communication with the transport opening 180a. The inlet section 201a receives the heat exchange means 202 as above described, the loop 201 also has a constricted or narrow section as at 201b and an expansion section as at 201c.

Thus, compressed air or gas which first enters the low pressure cooling loop 201 through the communicating transport opening 180a flows down across the heat exchange means 202 in the inlet section 201a and will be cooled. It then turns approximately 90° to pass through the narrow or constricted section 201b and then it is turned again 90° to pass upwardly through the expansion section 201c and exits from the multi-cooler housing 7 through the transport opening 180b, for return to the second stage of compression through the transport opening 160b in connecting flange 157 and the annular channel 43b as has been above described.

The effects of this system of chambers and channels in the cooling loop 201 is to provide an inertial type moisture separator for the compressed air flowing therethrough. However, it will be understood that a wire-mesh type separator could be mounted in the cooling loop if required.

A third convoluted partition 219 extends from the boss 158 where the respective ends are disposed in space relation and define with the adjacent spaced ends of the second partition 200 and with each other, the transport openings 180d, 180c and 180e.

Partition 219 is disposed in spaced relation to the partition 200 and forms therewith an intermediate pressure cooling loop 220 which is disposed inwardly of and approximately concentric to the low pressure cooling loop 201.

The intermediate pressure cooling loop 220 also includes an inlet section as at 220a which defines a heat exchange space 221 with lower support brackets 222 and upper support brackets 223 for receiving a heat exchange means—not shown—which is mounted transversely through the side wall as indicated by the openings 224 and 225. Openings 224 and 225 are also provided with a composite mounting flange 226 and 227 which is common to the next adjacent heat exchange openings 228 and 229 in the high pressure cooling loop to be described below.

The intermediate pressure cooling loop 220 has a constricted or narrow section 220b and an expansion section 220c which has a separator space at 230 if it is desired to mount a wire mesh separator in the flow path as above described. The expansion section 220c communicates with and passes the compressed air or gas out of the intermediate pressure cooling loop through transport opening 180d for return to the third stage of compression through the associated transport opening 160d in connecting flange 157 and the annular channel 43d as has been above described.

Once again the effect of the system of chambers and channels which turn and expand the compressed air or gas as it is cooled during movement through the intermediate pressure cooling loop 220 also provides inertial separation for moisture in the moving air.

A fourth L-shaped partition 231 is connected across the third partition 219 and defines therewith high pressure cooling loop 232 which lies within and substantially concentric to the intermediate pressure cooling loop 220. The high pressure cooling loop 232 has an inlet section 232a which communicates with the transport opening 180e. Formed between the partition 231 and 239 to define a heat exchange space are the lower bracket means 233 and upper shoulder means 234 which have flow opening therethrough as at 235 in the lower bracket means and 236 in the upper shoulder means so that a heat exchange means—not shown—can be mounted therein through the openings 228 and 229 in the sides 183 and 184 respectively of the multi-cooler housing 7.

The inlet section 232a communicates with the narrow or constricted section 232b and the expansion section 232c which delivers the compressed air or gas through the discharge passage 237 in communication with discharge outlet or conduit 8 for the system which is connected in the top 181 at the boss 188 on the multi-cooler housing 7.

Air or gas compressed in the third stage of compression and discharged into the annular channel 43c will pass through the transport openings 160e and 180e into the high pressure cooling loop 232. In the high pressure cooling loop 232, it will be conditioned as it passes over the end conditioning heat exchange means—not shown—in the inlet section 232a and then it is passed through the narrow section 232b, the expansion section 232c and exit from the high pressure cooling loop 232 through the discharge outlet or pipe 8 to use. The check valve 9 on the discharge outlet or pipe 8 will close whenever the pressure downstream of check valve 9 exceeds the pressure upstream of the valve. Thus, generally when the blow off or by-pass line 10 is opened to by-pass compressed air or gas back to the suction inlet the check valve 9 will close.
In the above description, a multi-cooler housing of a particular construction and design has been disclosed for operative coaction with a multi-stage in line centrifugal compressor driven through a compound epicyclic gear train having a plurality of double star gears designed and arranged to distribute the driving load equally among them.

This design permits the casing 40 and the multi-cooler housing 7 and other parts to be made of cast iron which helps to silence or reduce noise transmission between the elements and in and by the system.

In particular, in the multi-cooler housing 7 the transverse heat exchange receiving openings are shown as disposed perpendicular to the longitudinal line of the housing so that in the casting of this intricate and complex combination of channels and cavities the core boxes are easily removable to provide the desired cores in the casting.

In addition to serving as a base or support for the compressor, its driving means and the accessory equipment the multi-cooler housing 7 as above described provides other advantages.

First, it provides an ideal arrangement of pressurized passages and cavities to form the cooling loops in that compressed air at its lowest pressure is in the outermost cooling loop and the innermost and shortest cooling loop is exposed to compressed air at its highest system pressure. The advantage of this arrangement is that the partitions which separate the respective loop can be relatively thin in that they are never subjected to the pressure acting in the cooling loops but only the difference in pressure between the pressures in the respective cooling loops on opposite sides of any given partition.

Second, the distribution of the compressed air or gas as it approaches the face of each heat exchange means in a given cooling loop is substantial uniform access the entire face of the heat exchange means and thus the arrangement is able to meet the required conditions for proper interstage cooling and end conditioning of the compressed air or gas.

Third, the design is sufficiently flexible to permit the inclusion of other components for example moisture separators and it provides a section which is used as an oil sump for the entire system.

It will be appreciated in a complex unit as has been described in its preferred form that a wide variety of changes may be made within the ability of one skilled in the art without departing from the scope of this invention. For example, some of the construction of the units described may be reversed, certain features may be used independently of others, and equivalent components may be substituted for those described all within the invention as defined by the scope of the following claims.

What is claimed is:

1. In a multi-stage centrifugal compressor and multi-cooler assembly, a multi-stage compressor having a cartridge assembly with a plurality of cooperating compression stages and at least one of said compression stages forming a suction inlet, an axially extending rotor in said cartridge assembly, and impeller means in each of said compression stages mounted on and rotatable with said rotor, c. means for rotating said rotor including, a main line and thrust bearing at one end of the rotor and a compound epicyclic gear train having, a sun gear connected to said rotor remote from the main line and thrust bearing, a gear train having spaced double star gears carried by said cartridge for supporting said sun gear and to distribute the torque equally among the double star gears, a driving means, and means coupling said driving means to said compound epicyclic gear train,

d. means on said compressor forming a plurality of channels for passing air or gas to be compressed between said coacting compression stages.

e. a multi-cooler housing,

f. said plurality of channels operatively connected to coacting passages on said compressor and in said multi-cooler housing respectively to cool compressed air flowing between said compression stages and to end cooling the compressed air from the last of said compression stages,

g. an outlet on said multi-cooler housing for said compressed air or gas,

h. said compressor and means for rotating the compressor disposed to be mounted on the multi-cooler housing,

i. and means to align the coacting passages on said compressor and said multi-cooler housing when said compressor is in assembled position on said multi-cooler housing.

2. In a multi-stage centrifugal compressor and multi-cooler assembly as claimed in claim 1 wherein the respective double star gears include:

a. a large star gear and a small star gear on each respective double star gear in the compound epicyclic gear train,

b. said large star and said small star gear formed and indexed to each other and assembled with respect to the sun gear to distribute the load equally amongst the spaced double star gears.

3. In a multi-stage centrifugal compressor and multi-cooler assembly as claimed in claim 1 includes, a guide bearing operatively associated with said rotor for providing additional support therefor.

4. In a multi-stage centrifugal compressor and multi-cooler assembly as claimed in claim 1 including an inlet, filter and noise suppressor means having an inlet for air or gas to be compressed, and an outlet thereon in communication with the suction inlet.

5. In a multi-stage centrifugal compressor including:

a. casing means having a bore extending there-through along the longitudinal line,
b. a cartridge assembly mounted in said bore with a plurality of cooperating compression stages,
c. impeller means for each of said compression stages,
d. rotor means extending through said cartridge and having said impeller means fixedly mounted and rotatable with the rotor,
e. bearing means supporting said rotor at one end, f. a compound epicyclic gear train for driving said rotor connected to the end of the rotor remote from the bearing including, a sun gear, a gear train including spaced double star gears carried by said cartridge operatively associated with the sun gear for supporting and rotating said sun gear and rotor, and
A transmission means to be connected to the shaft of a driving motor and to the driven shaft of a centrifugal compressor and the like rotating device including,

a. a sun gear to be connected to the driven shaft,
b. a plurality of double star gears in driving connection with the sun gear,
c. each of the double star gears including a large star gear disposed in said transmission means for engagement with the sun gear and a small star gear fixedly connected to said large sun gear so that at least one tooth of the large star gear and one tooth on the small star gear are in radial alignment,
d. coupling means to connect said transmission means to the shaft of the driving motor,
e. and a ring gear disposed for operative engagement with the coupling means and with the small gear of each respective double star gear to transmit the driving force through said spaced double star gears to the sun gear.

7. In a transmission means as claimed in claim 6, including,
a. a guide bearing means operatively supporting said driven shaft outboard of the sun gear,

8. In the transmission means as claimed in claim 6, wherein the teeth of the large gear and the small star gear of the respective double star gear are assembled and disposed for engagement with the sun gear to distribute the load equally amongst the spaced double star gears.

9. In the transmission means as claimed in claim 8, including,
a. fixed gear support means,
b. the driven shaft of the rotating device extends into the gear support means,
c. the sun gear is disposed on the end of the driven shaft in the gear support,
d. a plurality of fixed spindles connected in the gear support means parallel to and in spaced radial alignment to the axial line of the sun gear,
e. and at least one double star gear rotatably mounted on each of said spindles.

10. In a transmission means as claimed in claim 9, including,
a. guide bearing means connected in said gear support means and disposed to support the driven shaft.

11. In combination,
a. a compressor having a mounting flange and means forming a plurality of compression stages in said compressor,
b. a box-like member forming a heat exchange housing having a plurality of inlets and outlets,
c. said mounting flange having a plurality of transport openings for receiving compressed air or gas from at least one of the compression stages in the compressor and a plurality of transport openings for returning treated compressed air or gas to at least one other compression stage in the compressor,
d. said mounting flange for mounting the compressor on the box-like member forming the heat exchange housing to bring the plurality of receiving and returning transport openings into alignment with the inlets and outlets in the heat exchange housing to enable the compressor to pass compressed air or gas to the heat exchange housing for intercooling and to receive the treated compressed air or gas from the heat exchange housing,
e. said box-like member having partition means forming a plurality of heat exchange loops and at least one heat exchange means for each of said heat exchange loops,
f. each of said plurality of heat exchange loops communicating with one of said inlets at one end and one of the outlets at the opposite end, and
g. said partition means disposed so that the plurality of heat exchange loops are substantially one within the other.

12. In a compressor and heat exchange housing assembly as claimed in claim 11, wherein the plurality of heat exchange loops are disposed in the box-like member forming the heat exchange housing so that compressed air or gas at the lowest pressure flows through the outer of the plurality of heat exchange loops and the compressed air or gas at the highest pressure flows through the innermost of said heat exchange loops.

13. In a compressor and heat exchange housing assembly as claimed in claim 11, wherein,
a. at least one of the outlets constituting a discharge outlet for the compressor and heat exchange housing assembly,
b. and the discharge outlet is in communication with the innermost of said heat exchange loops.

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