June 14, 1960 A. LORENZ 2,940,661

VACUUM PUMPS

Filed Jan. 14, 1957 5 Sheets-Sheet 1

FIG. 1.

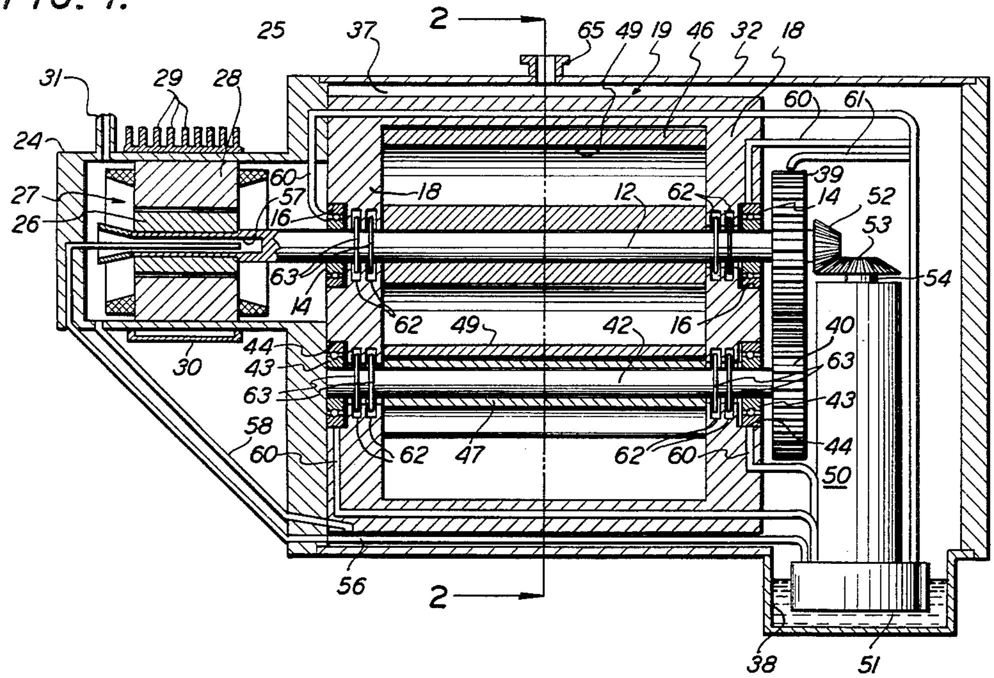

FIG. 2.

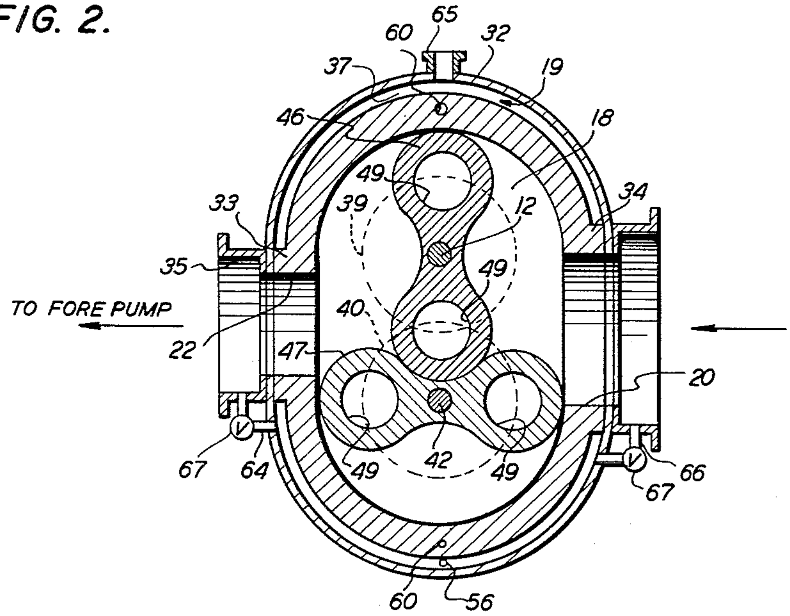

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FIG. 3.

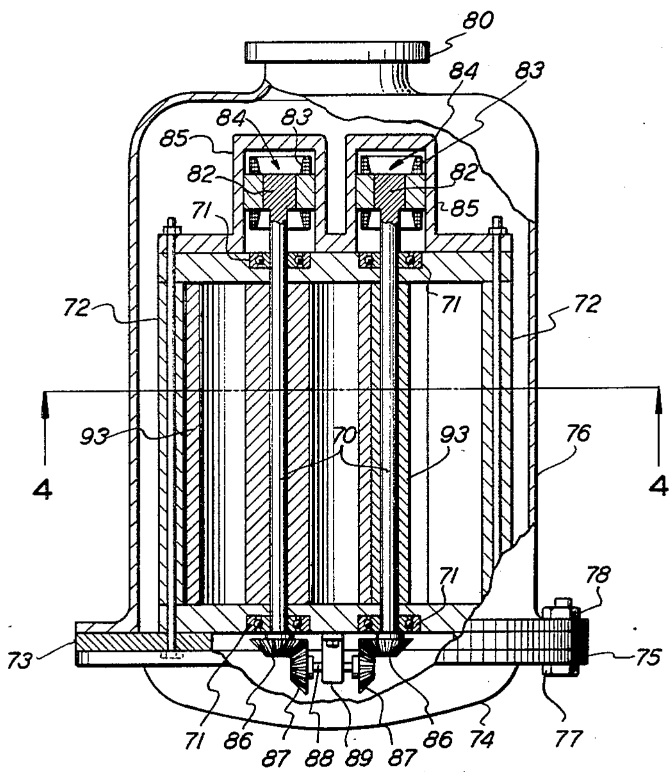
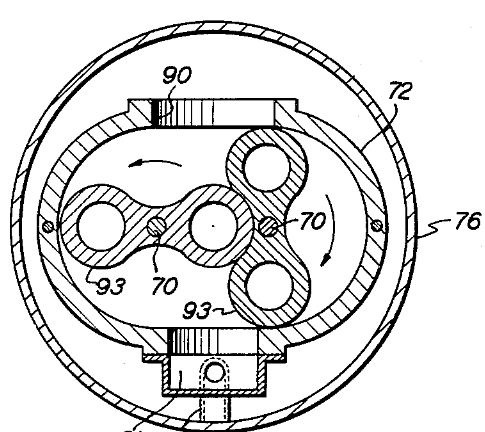


FIG. 4.



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VACUUM PUMPS

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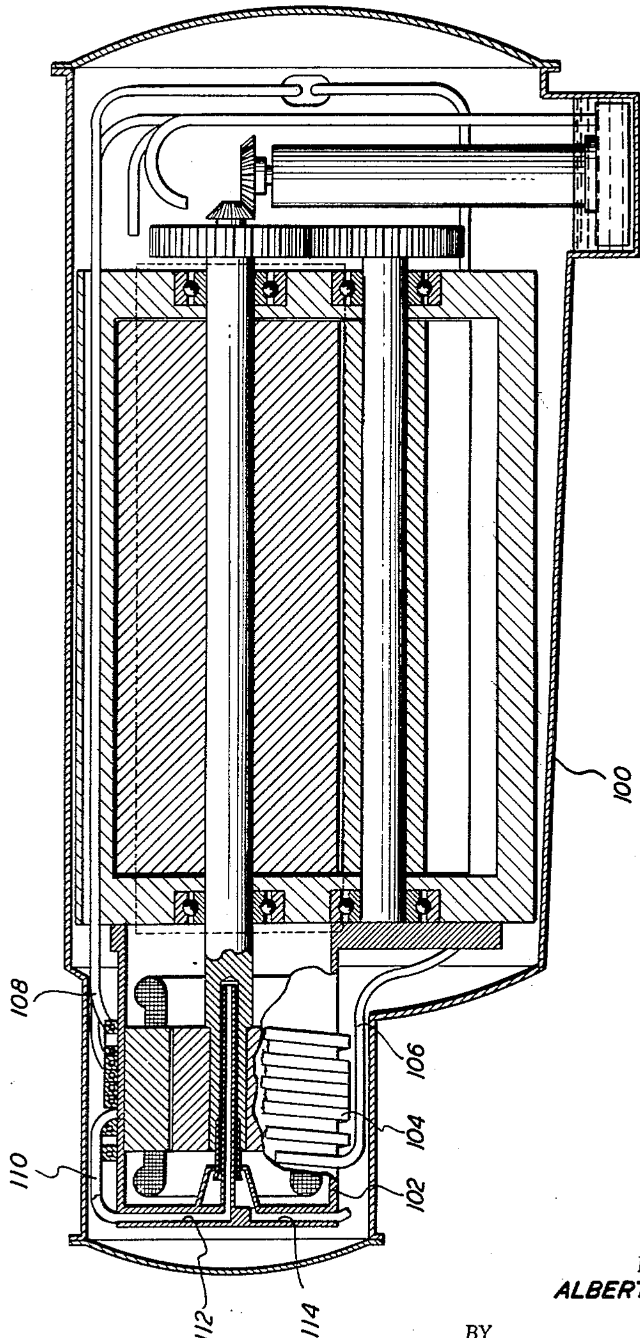

FIG. 5.

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FIG. 6.

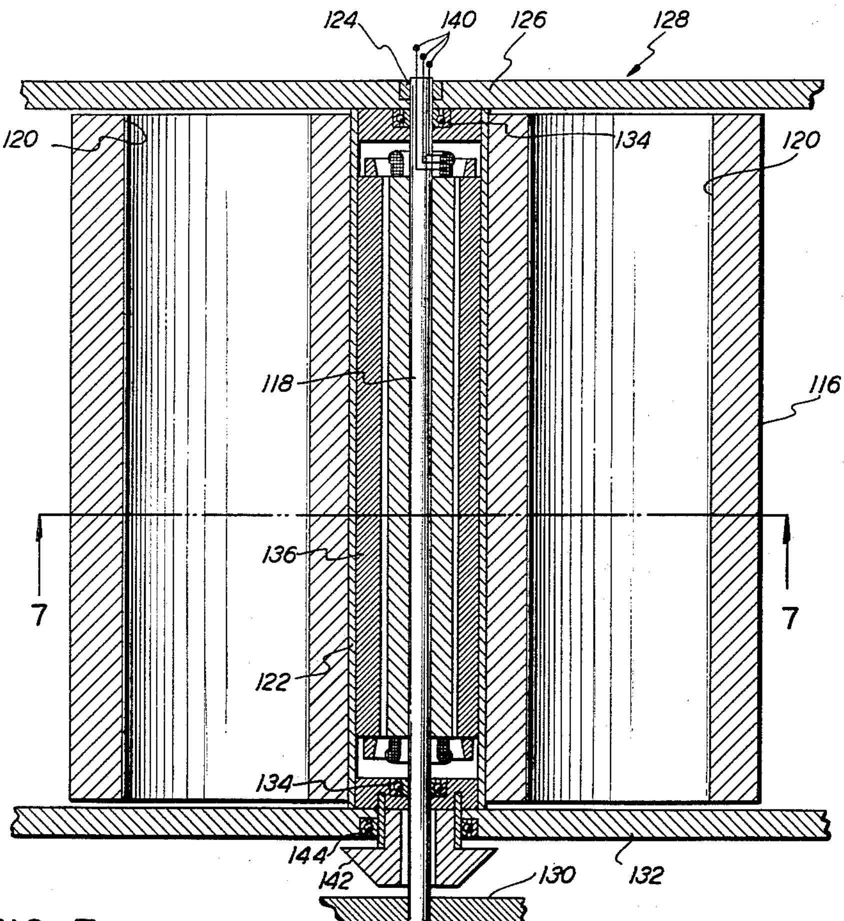
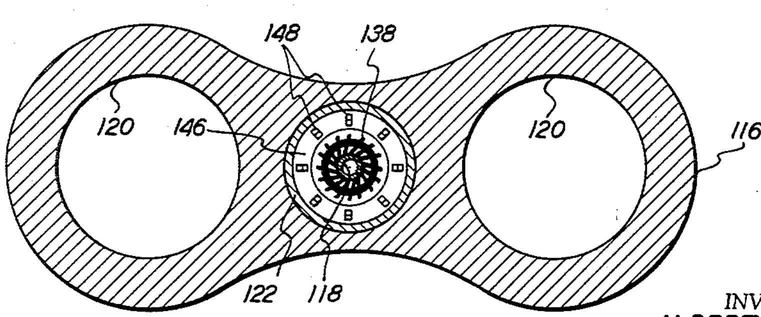


FIG. 7.



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VACUUM PUMPS

Filed Jan. 14, 1957 5 Sheets-Sheet 5

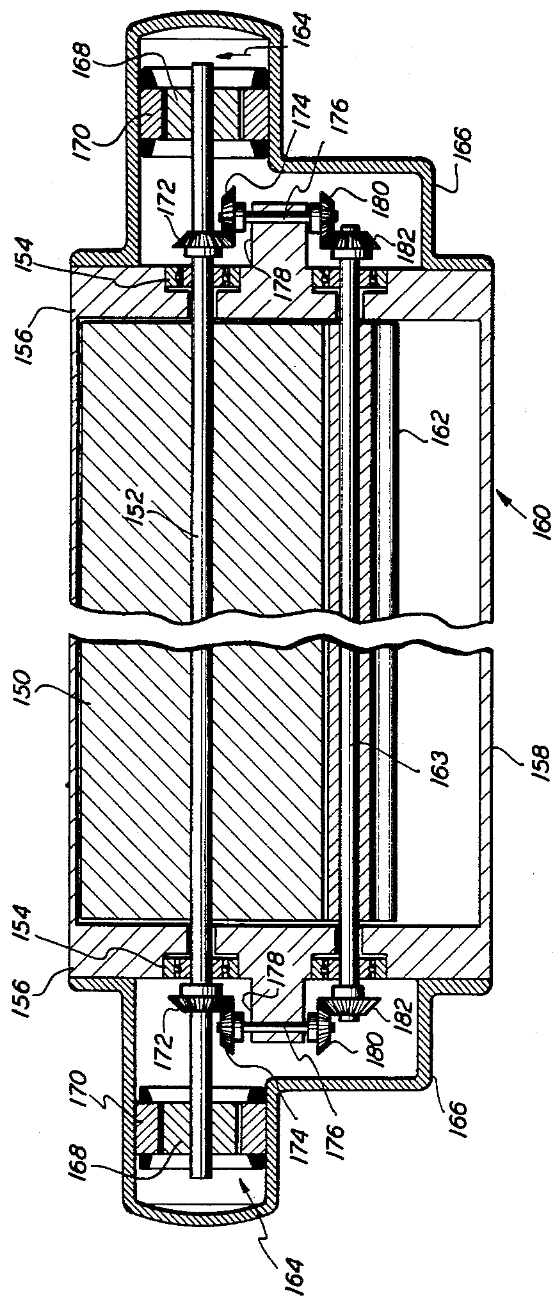

FIG. 8.

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United States Patent Office

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VACUUM PUMPS

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Filed Jan. 14, 1957, Ser. No. 633,896

2 Claims. (Cl. 230—139)

This invention relates to high vacuum pumps of the Roots type, and is a continuation-in-part of my co-pending application Serial No. 490,316, filed February 24, 1955, now abandoned. More particularly, this invention provides an improved drive for operating a Roots pump at high rotational speeds.

Roots pumps (also known as Connersville blowers) have been in use for many years, and are described in technical literature such as "Industrial Chemistry," by E. R. Riegel, Reinhold Publishing Corporation, pp. 696–7. In the typical Roots pump a pair of parallel and laterally spaced rotatable shafts are journalled through shaft openings in a casing which has an inlet and an outlet. Separate impellers mounted on each shaft mesh as the shafts are rotated and sweep fluid from the inlet to the outlet. Such pumps have been used in the past principally for moving relatively large volumes of liquid or gas under atmospheric or higher pressures and at moderate rotational speeds, say several hundred revolutions per minute.

This invention provides Roots type vacuum pumps for operation at rotational speeds much higher than has been the practice with conventional Roots type pumps, and thereby provides mechanical vacuum pumps which can handle large volumes of gas at pressures from about 50 mm. Hg to less than 10^{-4} mm. Hg. This vacuum range has been handled in the past by combinations of prior art mechanical vacuum pumps with vapor-operated ejector or diffusion pumps. The prior art mechanical pumps are efficient in the range from atmospheric down to a few mm. Hg, and the vapor-operated pumps are required to extend the vacuum into the range from about 1 mm. Hg to less than 10^{-4} mm. Hg.

The vacuum pumps of this invention operate efficiently in the range beginning where the efficiency of previous mechanical pumps drop off, i.e., a few mm. Hg, and continue to operate efficiently well into the vacuum range now handled effectively only by vapor-operated pumps. Moreover, the pumps of this invention operate without using a pumping vapor, and thereby avoid the difficulty of vapor back-diffusion which is always present in systems using vapor-operated pumps.

Thus, by using a suitable "backing" or fore-vacuum pump, in combination with one or more pumps of this invention, "dry" mechanical pumping systems are provided which handle large volumes of gas from atmospheric pressure to less than 10^{-4} mm. Hg. Such systems are particularly suitable for various industrial vacuum plants, such as vacuum drying, metallurgy, and coating.

In the past, Roots pumps were constructed with the smallest possible clearances between their moving parts to increase the efficiency of the pumps, the thought being that excessive clearances would permit backflow of the gas being pumped. As a consequence of the close tolerances, the prior art Roots pumps could be operated only at relatively low rotational speeds, which made them unsuitable for high vacuum operation. The high vacuum pumps of this invention can operate efficiently with

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relatively large clearances, say .1 mm. or greater, and thus can be operated at relatively high rotational speeds without the danger of jamming. For example, in the preferred embodiment of the invention, the pumps are adapted to be operated at several thousand revolutions per minute. However, even with the relatively large clearances with the pumps of this invention, such high rotational speeds present the problem of vibration or oscillation of the pump shafts and impellers, but this difficulty is avoided in accordance with this invention by providing an improved pump drive for the high speed, high vacuum Roots pumps.

Briefly, the invention contemplates a mechanical vacuum pump of the Roots type for operation at high speeds and at absolute pressures below 50 mm. Hg. The pump includes a pump casing having an inlet and an outlet. A pair of rotatable shafts are disposed within the casing, and a separate and balanced Roots type impeller is mounted on each shaft. The impellers are adapted to mesh when the shafts are rotated and drive gas from the casing inlet toward the outlet. An electric motor armature is mounted directly on one of the shafts, and an electric motor stator is mounted adjacent the armature. Thus, at least one of the shafts is driven by an electric motor having its armature rigidly close-coupled to the impeller on the shaft. The symmetrical arrangement of the armature on the shaft permits a uniform and balanced torque to be applied to the shaft, thereby permitting the shaft to be turned at a high rate of speed without causing it to vibrate or oscillate, and without putting an excessive strain on the casing and shaft, which would make alignment and vacuum tightness more difficult to achieve and maintain.

Preferably, the armature is surrounded by a motor housing which is either rigidly attached to, or is an integral unit with, the pump casing, and the stator is rigidly attached to the motor housing interior. Also, the motor housing is adapted to be evacuated, so that there is little or no pressure drop across the opening in the casing through which the driven shaft passes. With such an arrangement, the motor is not cooled in the usual way by convection, and therefore an internal cooling system is provided for it.

The high operational speed of the pump of this invention requires accurate synchronization of the two impellers, and in one form of the invention, they are synchronized by a pair of spur gears mounted on adjacent ends of the shafts. However, for large pumps, in which the distance between the two shafts is relatively great, each spur gear has a relatively large diameter and therefore a large rotational inertia. Preferably, the impellers are synchronized by a train of small bevel gears which can accommodate large pumps without a corresponding increase in rotational inertia. This permits the pumps to be operated efficiently and at high speeds with relatively small and inexpensive motors.

For the large pumps of this invention, i.e., those which have relatively long shafts, the possibility of oscillations and vibrations at high rotational speeds is increased. For such pumps, either each shaft is driven by a separate motor and the shafts are synchronized by relatively lightweight bevel gear trains, or one or both of the shafts are driven by a separate motor at each shaft end, using bevel gear trains for synchronization.

These and other aspects of the invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a vertical section of one embodiment of this invention in which a single motor drives the pump;

Fig. 2 is a view taken on line **2—2** of Fig. 1;

Fig. 3 is an elevation partially broken away and partially in section of a pump of this invention with vertical shafts and using a separate motor for each shaft;

Fig. 4 is a view taken on line 4—4 of Fig. 3;

Fig. 5 is a view similar to Fig. 1 of a pump in which the stator motor housing is enclosed by an additional outer housing, and heat is removed from the stator by an external cooling coil on the motor housing;

Fig. 6 is a longitudinal sectional view of a motor impeller mounted on a hollow shaft in which there is disposed an electric motor for driving the impeller;

Fig. 7 is a sectional view taken on line 7—7 of Fig. 6; and

Fig. 8 is a longitudinal sectional elevation of a Roots pump in which a separate motor is provided at each end of one of the shafts and separate synchronizing and coupling means are provided at each end of the shafts.

Referring to Figs. 1 and 2, a horizontal drive shaft **12** is journalled at opposite ends in separate roller bearings **14** mounted in respective openings **16** in end walls **18** of a pump casing **19** having an inlet **20** and an outlet **22**, the inlets and outlets being at diametrically opposed points in the central portion of the pump casing. The pump casing is of oval cross section, and the inlet is somewhat larger than the outlet.

The left end (as viewed in Fig. 1) of the drive shaft extends outwardly from the pump casing and is surrounded by a first vacuum tight housing **24** secured by a flange **25** to the left end wall of the pump casing. A rotor **26** of an electric motor **27** is attached to the left end of the pump drive shaft and is coaxially disposed within a stator **28** of the motor. The motor is supplied power through electric leads (not shown) sealed through the wall of the first housing. Cooling fins **29** and a cooling jacket **30**, which may be supplied cooling water by suitable conduits (not shown), surround the first housing. The first housing is adapted to be evacuated through a conduit **31** which leads to a suitable vacuum system (not shown).

A second vacuum tight housing **32** is disposed over the right hand end of the pump casing. The second housing is spaced from the right hand end of the pump casing and from the intermediate portion of the pump casing and is sealed at its left hand end to the outermost portion of the first housing flange which projects outwardly of the left hand end of the pump casing. The housing is also sealed to an outwardly extending boss **33**, which surrounds the pump casing outlet, and to an outwardly extending boss **34**, which surrounds the casing inlet. The housing has an outlet **35** and an inlet **36** which are collinear with the casing outlet and inlet, respectively. Thus, there is a space **37** between the intermediate portion of the pump casing and the second housing, and between the right hand ends of the pump casing and second housing. A sump **38** is in the bottom of the right hand end of the second housing. A drive gear **39** is connected near the right hand end of the pump drive shaft which extends beyond the end of the pump casing. Gear **39** meshes with a driven gear **40** which is mounted on the right hand end of a second shaft **42** journalled at opposite ends in bearings **43** located in openings **44** of the pump casing end walls.

First and second Roots type impellers **46**, **47** are, respectively, mounted on the first and second pump shafts. Each impeller has a pair of longitudinal bores **49** to reduce the mass of the impellers, and thereby facilitate the operation of the pump at high rotational speeds.

A vertical lubricating pump **50** has its lower end immersed in a pool of lubricant **51** in the sump. The pump is driven by a first bevel gear **52** located on the extreme right hand end of the shaft **12** and meshing with a horizontal bevel gear **53** attached to the upper end of a vertical lubricating pump drive shaft **54**. The lubricant both lubricates and cools the vacuum pump, and is supplied through a conduit **56** to the interior of a bore **57** in the left hand end of drive shaft **12**. The fluid flows out conduit **56**, and back out the left hand end of bore **57** where it then drains through a conduit **58** to return to the sump. Each of the four shaft bearings are supplied lubricant through conduits **60**, and gears **39** and **40** are supplied lubricant through conduit **61**.

Preferably, the lubricating oil has a low vapor pressure to avoid adverse effects on the ultimate vacuum produced by the pump. Various organic oils used in condensation vacuum pumps, for example, "Apiezon" oil, are suitable.

Each shaft opening in the casing end walls includes a pair of annular grooves **62** located between the casing interior and the adjacent roller bearing. Each groove receives the outer periphery of a respective disk or baffle **63** attached to the shafts. Thus, the grooves and baffles form labyrinth seals to impede the diffusion of gas between the pump casing interior and the spaces enclosed between housings.

The space between the pump casing and the second housing may be evacuated by providing a conduit **64** (see Fig. 2) which connects the space with the housing outlet, which in turn is connected to a fore pump (not shown) that maintains the pump outlet at sub-atmospheric pressure. The space between the pump casing and the second housing may also be kept under sub-atmospheric pressure through a conduit **65** which is adapted to be connected to a suitable vacuum pump (not shown), or the space may be connected to the inlet side of the pump through a conduit **66**.

Both conduits **65** and **66** each have a valve **67** to permit their optional operation.

As can be appreciated from the foregoing description, the pump of Figs. 1 and 2 can be operated at extremely high rotational speeds due to the absence of any sliding or friction seals around the shafts. The spaces within the two housings are evacuated to sufficiently low pressures, so that gas within them flows by diffusion rather than by pressure differential. Thus, there is little flow of gas through the shaft openings, and the flow of gas is further reduced by the presence of the labyrinth seal arrangement.

In the pump of Figs. 3 and 4, a pair of vertical and laterally spaced shafts **70** are journalled at their respective upper and lower ends on roller bearings **71** supported in the upper and lower end walls of upright pump casing **72**, the lower end of which rests on an inwardly extending annular flange **73** of a base **74** which has an outwardly extending flange **75** and an upwardly opening concave central portion. A bell jar type housing **76** is disposed over the upper portion of the pump casing and is secured by bolts **77** and nuts **78** to flange **75** of the base. The housing has an inlet **80** at its upper end and an outlet **81** in an intermediate portion. The upper ends of the shafts project above the pump casing and are each provided with a rotor **82** formed integrally on their upper ends. Each rotor is coaxially disposed within a stator **83** to form an electric motor **84** which is supplied power through suitable leads (not shown) sealed through the walls of a motor housing **85** disposed over each of the motors and sealed to the upper end of the pump casing. A separate bevel gear **86** is attached to the lower end of each shaft beneath the casing, and engages respective synchronizing gears **87** located at opposite ends of a rotatable horizontal synchronizing shaft **88**, supported in a bearing **89** attached to the bottom of the pump casing.

The pump casing has an inlet **90** which opens into the space between the housing and casing, and it has an outlet **91** which is sealed from the space between the housing and pump casing and connected to the housing outlet by a conduit **92**. A separate Roots type impeller **93** is mounted on each of the shafts.

Thus, with the pump of Figs. 3 and 4, the shafts are driven by separate motors at a uniform speed, which is insured by the synchronizing gears. The pumped gas enters the inlet at the upper end of the housing and passes into the pump through the pump casing inlet. The impellers move the gas to the pump outlet where it is discharged from the housing outlet through conduit 92. As with the pump of Figs. 1 and 2, the shafts rotate freely in the openings in the casing walls through which they pass.

The pump shown in Fig. 5 is similar to the pump shown in Figs. 1 and 2, except that the pump of Fig. 5 has an outer housing 100 which completely surrounds the pump casing and a motor housing 102 rigidly attached to the left hand end of the pump casing. All elements of the pump of Fig. 5 which are not described in detail and which have no reference numbers are identical with corresponding elements of the pump shown in Figs. 1 and 2.

A cooling coil 104 is soldered to the exterior of the cylindrical motor housing and cools the stator attached to the motor housing interior by the circulation of fluid from the lubricant pump, which supplies cooling fluid through conduit 106. The cooling fluid returns to the sump from the cooling coil through conduit 108. Conduit 110 supplies cooling fluid to the bore in the left hand end of the upper shaft through a conduit 112 in the left hand end of the motor housing. Fluid flows out of the bore and returns to the pump sump through conduit 114 in the lower portion of the left hand end of the motor housing and through the space between the pump casing and the surrounding housing 100.

In Figs. 6 and 7, a Roots type impeller 116 is mounted on a hollow and vertical (as viewed in Fig. 6) rotatable shaft 122. The impeller has a pair of longitudinal bores 120 to reduce the impeller mass.

A stationary hollow shaft 118 extends coaxially through the rotatable shaft and is supported at its upper end (as viewed in Fig. 6) by a support 124 in an end wall 126 of a pump casing 128. The other end of the shaft is in a support 130 which is spaced from the other end casing wall 132.

The rotatable shaft is journalled at each end on the stationary shaft by bearings 134 which are located just inside each adjacent end wall of the pump casing.

An annular rotor 136 is rigidly attached to the inside of the rotatable shaft and is coaxially disposed around an annular stator 138 which is attached to the stationary shaft and which is supplied three phase alternating current through leads 140 sealed through the upper portion of the hollow stationary shaft.

A synchronizing bevel gear 142 is attached to bearing 134 at the lower end of the rotatable shaft and is journalled on a bearing 144 in the pump casing end wall 132.

As shown in Fig. 7, the rotor or armature has sheet laminations 146 and electromagnetic eddy current ribs 148. The sheet laminations of the rotors of the various electric motors shown in the accompanying drawings are similar to conventional laminations, except that they are not impregnated with materials which liberate gas.

The structure shown in Figs. 6 and 7 has the advantage that the pump requires less space and operates quietly and with a minimum amount of vibration or oscillation due to the symmetrical construction of the motor. No uneven stresses are exerted on the pump housing or rotatabe shaft, thus assuring the vacuum tightness of the housing and smooth shaft operation. Such an arrangement is particularly suited for large pumps with large pumping capacity and power requirements.

The impeller of Figs. 6 and 7 may be coupled through bevel gear 142 to drive another impeller, if the other impeller does not have any drive of its own, or the bevel gear may be used merely as a synchronizing gear to synchronize the rotation of the impeller shown in Figs. 6 and 7 with a second similarly constructed impeller.

Referring to Fig. 8, a Roots type upper impeller 150 is mounted on an upper rotatable and horizontal shaft 152 journalled at each end in bearings 154 supported in end walls 156 of a casing 158 of a Roots type pump 160. A Roots type lower impeller 162 is mounted on a rotatable shaft 163 supported in the end walls as described for the upper shaft. Each of the shafts project outwardly from the end walls.

A separate driving motor 164 is provided for each end of the upper shaft, and each motor is enclosed in a separate respective end housing 166. An armature 168 of each motor is rigidly attached to a respective end of the upper shaft, and is coaxially disposed within its respective annular stator 170, which is rigidly attached to the interior of its respective end housing.

A separate upper synchronizing bevel gear 17 is mounted on the upper shaft just outboard of the shaft bearings in each end wall. Each upper synchronizing bearing engages a separate second bevel gear 174 mounted on the upper end of a vertical rotatable shaft 176 journalled in an outwardly extending projection 178 on each respective end wall of the pump casing. A separate third bevel gear 180 on the lower end of each vertical shaft 176 meshes with a respective lower synchronizing bevel gear at each end of the lower shaft.

Thus, with the arrangement of Fig. 8, the relatively long upper shaft is driven by a separate motor at each end, and the correspondingly long lower shaft is coupled and synchronized with the upper shaft through synchronizing gears at each end of the shafts. This arrangement reduces vibration and oscillation of shafts and impellers of relatively large pumps when operated at high rotational speeds.

With the improved driving means of this invention, Roots type pumps can be driven at high rotational speeds to permit their operation as mechanical high vacuum pumps, which operate without using a pumping vapor, such as is required in diffusion and ejector type pumps.

I claim:

1. A mechanical vacuum pump of the Roots-type for operation at absolute pressure below 50 mm. Hg, the pump comprising a pump casing having an inlet and an outlet, a pair of rotatable shafts disposed within the casing, one of the rotatable shafts being hollow, a separate and balanced Root-type impeller mounted on each shaft, the impellers being adapted to mesh when the shafts are rotated to drive gas from the casing inlet toward the outlet, an annular electric motor armature mounted to the inner surface of the hollow shaft, a stationary shaft extending through the hollow shaft and disposed concentrically therewith, one end of the stationary shaft being secured to the casing, and an electric motor stator mounted on the stationary shaft and disposed within the annular armature.

2. A mechanical vacuum pump of the Roots-type for operation at absolute pressure below 50 mm. Hg, the pump comprising a pump casing having an inlet and an outlet, a pair of rotatable shafts disposed within the casing, one of the rotatable shafts being hollow, a separate and balanced Roots-type impeller mounted on each rotatable shaft, the impellers being adapted to mesh when the shafts are rotated to drive gas from the casing inlet toward the outlet, an annular electric motor armature mounted to the inner surface of the hollow shaft, a stationary shaft disposed concentrically within the hollow shaft, each end of the stationary shaft being disposed outside of the hollow shaft, one end of the stationary shaft being secured to the casing, an electric motor stator mounted on the stationary shaft and disposed within the armature and a gear train including a plurality of gears connected to the rotatable shafts for synchronizing the rotation of the impellers, one of the gears being secured to the hollow shaft adjacent the other end of the stationary shaft and having an axial opening therein through which the stationary shaft extends.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,940,661 June 14, 1960

Albert Lorenz

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 28, for "65" read -- 64 --; column 5, line 58, for "rotatabe" read -- rotatable --.

Signed and sealed this 15th day of November 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents