

[54] **MULTI-STAGE VACUUM PUMP**

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[58] **Field of Search** 417/2, 69, 46, 243, 205;
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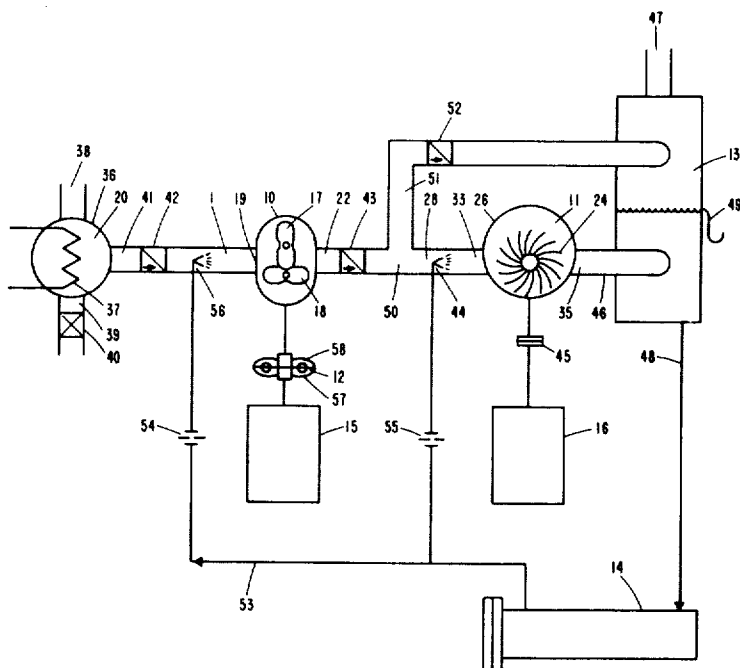
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ABSTRACT

A multi-stage vacuum pumping system utilizing a first stage positive displacement pump and a second stage liquid ring pump, and wherein a pressure differential below a predetermined value is maintained across the first stage pump due to the provision of a slip producing constant torque coupling means.

12 Claims, 4 Drawing Figures



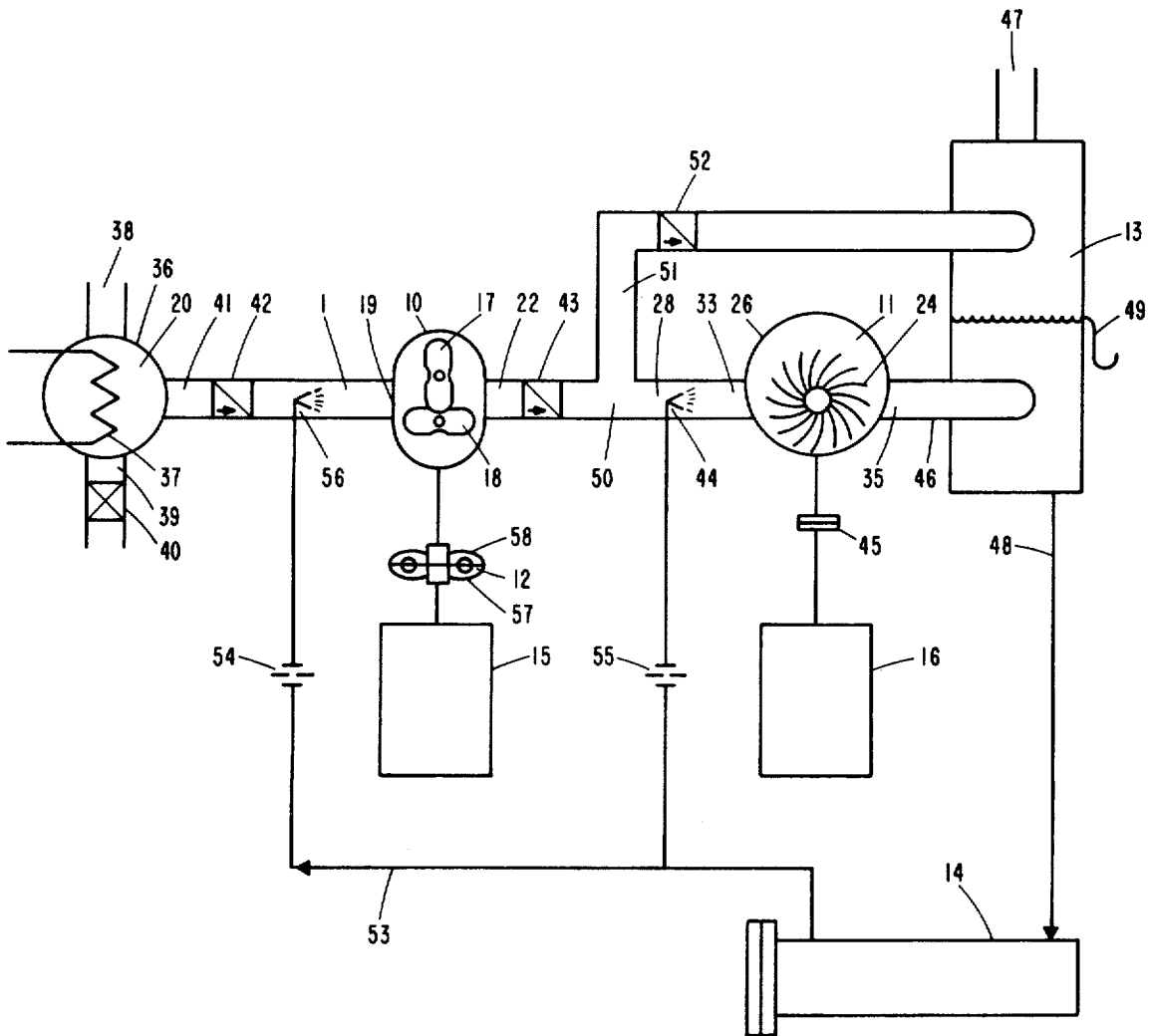
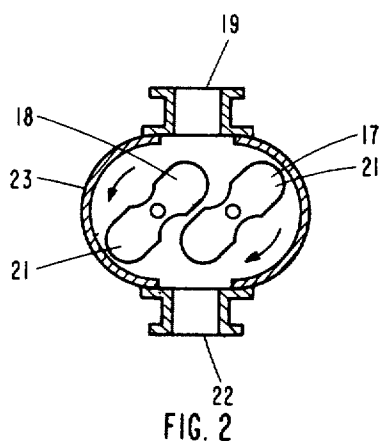
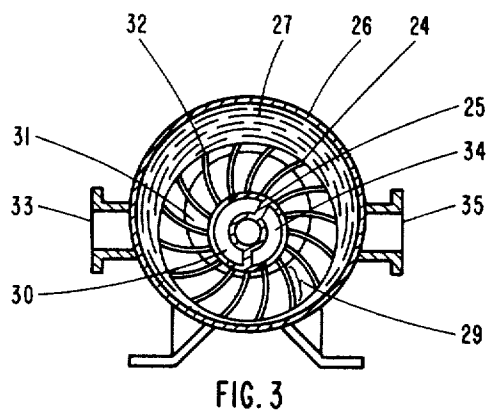
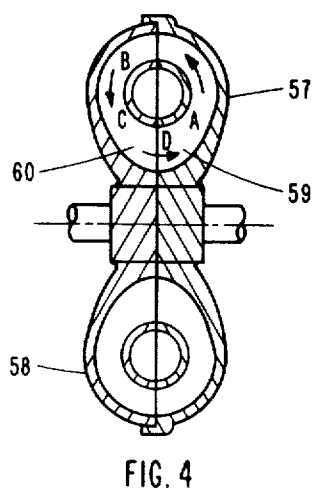


FIG. 1



MULTI-STAGE VACUUM PUMP

BACKGROUND OF THE INVENTION

Liquid ring vacuum pumps are ideally suited for wet vacuum applications where the sealing fluid acts as a coolant, absorbing the heat of compression, and condensing vapors accompanying the gas being pumped. Because of this desirable isothermal compression liquid ring pumps are widely used on wet vacuum applications and are capable of compression ratios of up to 10 to 1 in single stage. This type of pump can be designed for a rising, falling, or steady power curve as related to pressure differential or compression ratio.

On wet high vacuum applications the combination of rotary positive displacement and liquid ring vacuum pumps provides a highly efficient vacuum producing system. For that reason this combination has many advantages when applied to steam turbine condensers, vacuum dryers, vacuum cookers, vacuum strippers for chemical processes, sterilizers, autoclaves, and rotary vacuum filters. Extremely high efficiency is attained because the pump combination efficiently extracts noncondensable gases by mechanical displacement and at the same time, through isothermal compression, removes the vapor in saturation by condensation.

The power required by the first stage rotary positive displacement vacuum pump is a direct function of the pressure differential across the pump. It is necessary, therefore, to provide some means of limiting the pressure differential so as to obviate oversizing the driving motor. Because of the great difference in displacement of the first stage pump and the second stage liquid ring pump the advantage in the staged arrangement applies primarily to the design high vacuum condition where the compression ratio of the first stage balances the volumetric displacement of the second stage. To prevent overloading the motor driver while pulling up to the operating vacuum several methods have been employed.

By throttling the pump suction it is possible to reduce the flow of gas through the pump so that the design compression ratios are achieved and the pumps can be started without overloading the driving motor or motors. This has the great disadvantage of reducing the effective capacity of the pump during pull up and the time required to pull up to design operating conditions is greatly increased.

A commonly used method is to start the second stage vacuum pump first and pull up the system to high vacuum, at which time the first stage pump is started either manually or automatically by action of a pressure switch. This method has the disadvantage of long pull up time because the very small displacement second stage pump is used for evacuation. It has the further disadvantage of requiring manual action by an operator or the addition of a pressure switch and attendant controls.

Another method that can be used is the use of a bypass valve to regulate the pressure differential across the first stage rotary positive displacement vacuum pump. This method permits simultaneous starting of both pump stages, but has the disadvantage of requiring a sensitive control valve and bypass piping. It is not practical when not employing fluid injection in the system for cooling, because when pumping dry gases the temperature build-up is excessive.

SUMMARY OF THE INVENTION

This invention is directed to the combination of a rotary positive displacement vacuum booster pump as the first stage of a vacuum pumping system and a liquid ring vacuum pump second stage. The invention includes a constant torque coupling to drive the positive displacement pump so that the speed of the first stage is automatically adjusted so that its power requirements are not in excess of the power output of the driving motor and its displacement is matched to the requirements of the second stage pump.

The system provides high volumetric efficiency over a wide vacuum range, is self-regulating and the rotary components are not in metal-to-metal contact and require no internal lubrication.

The motor driving the first stage pump operates continuously at full speed and constant torque throughout the pull up or hogging period. When the design operating, or holding vacuum has been attained the load on the motor is reduced automatically to a level substantially below the full load, and the constant torque coupling is thereby transmitting less than its design torque loading. It thereby reverts to non-slip operation whereby the coupling input and output speeds are matched.

The first and second stages of the vacuum pumping system are automatically stabilized to insure efficient operation over a full vacuum range. The first stage displacement is always in equilibrium with the second stage due to the action of the constant torque coupling.

Also the first stage is always properly matched to the compression ratio dictated by the second stage pump capacity since the capacity of a positive displacement pump is directly proportional to the pump speed and thus by slowing the rotational speed of the pump the displacement is reduced accordingly.

An additional function of the constant torque coupling is to provide a means of protecting the first stage positive displacement pump from breakage should a slug of liquid enter the pump suction. Such liquid, being relatively incompressible would impose a heavy shock load on the rotors and driving shaft of the positive displacement first stage pump. The excessive torque loading on the shaft is dissipated by the slip induced on the constant torque drive coupling.

The coupling can be of the hydraulic type or otherwise and can be of the spring loaded friction shoe type.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic showing of a multistage vacuum pumping system according to this invention;

FIG. 2 is a side sectional view of the first stage positive displacement pump shown in FIG. 1;

FIG. 3 is a side sectional view of the liquid ring vacuum pump shown in FIG. 1; and

FIG. 4 is a side sectional view of the constant torque hydraulic coupling shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The main components of the system are the first stage positive displacement pump 10, the second stage liquid ring pump 11, constant torque coupling 12, separator tank 13, heat exchanger 14 and constant speed driving motors 15 and 16. Alternately the pumps 10 and 11 can be driven by a single motor if desired.

Pump 10 in the first stage is a rotary positive displacement vacuum booster pump of the lobed Roots type. It consists of two counter-rotating rotors 17 and 18 matched to rotate together to trap and displace a fixed volume of a saturated gas-vapor mixture entering the pump at inlet 19. The gas-vapor mixture is illustrated as being pumped from a condenser 20.

The first stage rotary positive displacement pump 10 is shown in greater detail in FIG. 2 where the rotors 17 and 18 are shown capable of counter-rotation without metal-to-metal contact. The gas-vapor mixture is trapped by intermeshing lobes 21 of the rotors and displaced from the low pressure zone at inlet 19 to the high pressure zone at outlet 22. The clearances between the lobes 21 and the casing 23 may be sealed by injecting water and thereby eliminating slip and improving pump volumetric efficiency. The pump 10 is driven by the constant speed motor 15 through the constant torque coupling 12. The constant torque coupling 12 is shown in detail in FIG. 4 and will be described in greater detail below.

The second stage liquid ring vacuum pump 11 as shown in detail in FIG. 3 has one rotating part, a bladed rotor 24 which rotates freely and without metal-to-metal contact around a stationary port cylinder 25. The rotor 24 and port cylinder 25 are concentric but the casing 26 has an eccentric lobe 27 formed therein. Sufficient sealing water is supplied through interstage cooler 28 to form a liquid ring 29 inside the casing 26 conforming to the eccentric contour of casing 26. The port cylinder 25 is provided with an inlet port 30 located such that it corresponds to the position at which the liquid ring 29 is receding away from port cylinder 25 thereby defining chamber 31 between rotor vanes or blades 32 in which gas-vapor entering inlet 33 is trapped. As rotation continues the chamber volume is reduced by compression caused by the liquid ring 29 as it is being forced by the casing 26 contour radially inward toward the port cylinder 25. At the end of the compression stroke the gas-vapor mixture is compressed by liquid ring 29 and forced into the discharge port 34 of the port cylinder 25. The gas-vapor mixture and some of the sealing water is then discharged from pump outlet 35 to the separator tank 13.

During compression the gas-vapor mixture is in intimate contact with the liquid ring 29 which absorbs the heat of compression. Furthermore, since compression is nearly isothermal the liquid ring pump 11 acts as a condenser since compression occurs under nearly constant temperature.

As shown in FIG. 1 the condenser 20 at the input of the system has a shell 36, condenser tubes 37, condenser steam inlet 38, condenser drain 39, drain control valve 40, and condenser air take-off conduit 41. A check valve 42 is provided to prevent back flow of gases upon interruption of the vacuum producing system.

Alternately the pumping system permits handling dry gases or gases accompanied by liquid from other vacuum processes such as evaporators, sterilizers, cookers, distillation columns and so forth.

As the gas-vapor mixture enters pump 10 at inlet 19 it is displaced and compressed and discharged from outlet 22 through check valve 43. During compression in pump 10 there is an increase of heat so that the temperature of the gas-vapor mixture is higher at discharge 22 than at inlet 19. The gas-vapor then passes through

the inter-stage cooler 28, which in the preferred embodiment is in the form of a spray nozzle 44. The inter-stage cooler reduces the temperature of the gas-vapor mixture causing condensation to occur and reducing the volume of gas-vapor mixture.

The gas-vapor mixture enters liquid ring pump 11 at pump inlet 33. The liquid ring pump is driven through coupling 45 at a constant speed by motor 16. The discharge of pump 11 is gas-vapor mixture and sealing water which discharges at outlet 35 through conduit 46 to the separator tank 13 where the gas and water are separated, the gas being discharged to atmosphere from separator vent 47 and water drained through water conduit 48. A level control overflow connection 49 is provided to maintain a constant level of water in separator tank 13 and allow drain off of the excess liquid of condensation.

During initial start up of the vacuum system the greater displacement of the first stage booster pump 10 could be such that a positive pressure is built up in the pump interstage conduit 50. To prevent interstage pressure build-up and to improve the hogging or pull-up characteristics of the system conduit 51 is provided to bypass excess capacity around second stage pump 11 direct to separator tank 13. The bypass conduit 51 is provided with check valve 52 which prevents back flow of air or gas when subatmospheric pressure is attained at pump interstage 50.

The sealing water separated in tank 13 is routed through heat exchanger 14 where heat of compression and condensation are removed from the recirculated sealing water. The sealing water is transported by means of a pressure differential or pump not shown through conduit 53 and flow control orifices or valves 54 and 55 to spray nozzles 44 and 56. The water sprayed from nozzle 56 enters first stage pump inlet 19 and serves the function of cooling the gas during compression and sealing the pump clearances thus optimizing pumping efficiency.

The coupling 12 which is shown in detail in FIG. 4 is arranged with the driving impeller 57 and driven impeller 58 in hydraulic contact such that upon increasing torque the two coupling pairs will slip so that the rotational speed of the driven member is determined by the torque being transmitted.

While a friction type coupling could be used as well, the hydraulic type is preferred and is described for illustrative purposes. Both driving impeller 57 and driven impeller 58 have radial guide vanes 59 and 60 to transmit hydraulic energy from driving impeller 57 to the driven or runner impeller 58. When impeller 57 is rotated liquid in radial guide vane 59 is given rotational velocity. Centrifugal forces sling the liquid outward, and at the point B the liquid is forced across the gap into the runner guide vane 60. As it does so it imparts torque to the runner 58. If the load on driven runner 58 is greater than the energy imparted to it from driver 57 the runner 58 will slow down, the difference in rotational speed representing the coupling slip. This drive means is ideally suited for constant torque input to the rotary positive displacement pump 10 in the combination described in the invention because as the pump 10 slows down the power it requires is reduced in direct proportion to the pressure differential across the pump 10. Since transmitted torque is constant the pump 10 is caused to speed up to load the coupling or slow down to unload the coupling as may be dictated

by the pressure and displacement requirements of the system. This action is fully automatic and requires no auxiliary control means.

Thus, the constant torque coupling 12 permits obtaining the maximum displacement from a given power input. This advantage is illustrated by the superior hogging capability of the system as compared to the other methods used to provide automatic operation over the entire vacuum range from start up to the holding vacuum. When holding vacuum has been achieved the first stage pump 10 power requirements are lower than the available output of the motor 15 and coupling 12 and therefore the slip is reduced to one percent or less.

The use of a constant torque coupling for control also permits pumping dry gas without liquid injection for cooling since there is no recirculation of gas through the rotary positive displacement pump and hence no danger of excessive heat build-up.

I claim:

1. A multi-stage vacuum pumping system, including in combination a first stage positive displacement pump, a second stage liquid ring pump, means providing direct fluid communication between the outlet of the first stage pump and the inlet of the second stage pump, first and second constant speed driving means for said first and second stage pumps respectively, constant torque coupling means coupling said first driving means to said first stage pump, direct non-slipping coupling means coupling said second driving means to said second stage liquid ring pump, said constant torque coupling means having means to provide slip whereby the speed of said first stage pump is reduced when the established torque loading of said first coupling is attained thereby maintaining a pressure differential across said first stage pump below a predetermined value.

2. A vacuum pumping system in accordance with claim 1 including auxiliary cooling means at the output of said first stage pump to reduce temperature of vapor-gas mixture being pumped through the system.

3. A vacuum pumping system in accordance with claim 1 including interstage cooling means disposed between the first stage positive displacement pump and the second stage liquid ring pump to provide additional cooling liquid at the inlet to the second stage liquid ring pump.

4. A vacuum pumping system in accordance with claim 1 including a separator tank for receiving the discharged condensate-gas-liquid seal mixture from the outlet of the second stage liquid ring pump with a gas vent disposed in the upper portion of said separator tank for discharging gases from the system.

5. A vacuum pumping system in accordance with claim 1 including a liquid recirculation loop interconnecting the outlet of the second stage liquid ring pump with the inlet thereof to provide sufficient liquid to the second stage liquid ring pump for uninterrupted operation of the vacuum pumping system.

6. A vacuum pumping system in accordance with claim 5 including heat exchanger means disposed in said liquid recirculation loop for regulating the temper-

ature of the liquid recirculated to the second stage liquid ring pump.

7. A vacuum pumping system in accordance with claim 4 including vapor-gas by-pass conduit means with non-return flow valve connecting the first stage pump discharge to atmosphere whereby pressure is relieved at the interstage between first and second stage pumps during start-up of the system and periods of operation when capacity of second stage pump is temporarily exceeded.

8. A vacuum pumping system in accordance with claim 2 in which the auxiliary cooling means includes a liquid spray injected into the fluid stream downstream from the positive displacement pump and upstream from the liquid ring pump.

9. A multi-stage vacuum pumping system for pumping a saturated vapor-gas-liquid mixture including in combination a first stage positive displacement pump, a second stage liquid ring pump, means providing direct fluid communication from the outlet of the first stage positive displacement pump to the inlet of the second stage liquid ring pump, a second stage liquid recirculation loop interconnecting the outlet of said second stage liquid ring pump with the inlet thereof to provide sufficient liquid to said second stage liquid ring pump for uninterrupted operation of the vacuum pumping system, first stage constant torque driving means for controlling rotative speed of the first stage pump so as to limit pressure differential across the first stage pump, direct non-slipping driving means for said second stage pump, a first stage liquid recirculation loop connected to said second stage liquid recirculation loop and to the inlet to said first stage pump, each of said first and second stage liquid recirculation loops including valve means for controlling flow there-through whereby the quantity of recirculated cooling liquid is regulated to maintain the optimum thermodynamic conditions in the vacuum pumping system.

10. A vacuum pumping system in accordance with claim 9 including a vapor-gas by-pass means with non-return flow valve connecting first stage pump discharge to atmosphere whereby pressure is relieved at the interstage between said first and second stage pumps during start-up of the system and periods of operation when capacity of said second stage pump is temporarily exceeded.

11. A vacuum pumping system in accordance with claim 9 including a separator tank disposed in communication with the outlet of said liquid ring pump said separator tank separating gases from liquids discharged from said liquid ring pump.

12. A vacuum pumping system in accordance with claim 11 including an auxiliary by-pass conduit means connected to the outlet of the positive displacement pump and pressure responsive valve means in said conduit providing an auxiliary flow path by-passing liquid ring pump when the quantity of fluid pumped through the positive displacement pump exceeds the capacity of the liquid ring pump.

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