MERCURY-VAPOR VACUUM PUMP

William G. Clarkson, Port Nelson, Ontario, and Charles F. Currey, Stoney Creek, Ontario, Canada, assignors to Canadian Westinghouse Company, Limited, Hamilton, Ontario, Canada

Application September 24, 1956, Serial No. 611,443

4 Claims. (Cl. 230—101)

Our invention relates to an improved form of vacuum pump, and in particular to an improvement in the construction of multistage high-vacuum mercury-vapor pumps.

When it is desired to produce vacuums in the neighborhood of a fraction of a micron pressure, that is, a pressure equal to a fraction of .001 millimeter of mercury pressure-head, it is usual to make use of diffusion pumps. Such pumps cannot operate against atmospheric pressure but become quite effective against back pressures of about 500 microns. For this reason, backing pumps are used, to reduce the back pressure on the diffusion pump. Ordinary rotary-vane pumps are capable of producing vacuums of 250 microns but are not very effective below 1000 microns. It is known to be advisable, therefore, that some intermediate pump be arranged between the diffusion pump and the rotary pump. A very effective intermediate pump for such operation is an ejection type of pump. One or more stages which operate on the ejection principle can conveniently be combined with a diffusion stage, in a single unit, all stages using the same source of vapor.

Pumps of this type, including a diffusion stage and one or more ejection stages in a common casing and using a common mercury boiler, have been used in the past and are very effective in rapidly reducing the pressure within the vessel, for example pumped mercury-arc rectifiers or other vacuum-electrical devices.

One problem with such pumps is their lack of effectiveness when contaminated. Contamination may arise when the pump evacuates relatively large quantities of air, which combine with the mercury, forming solid compounds which plug up various apertures within the pump. At certain intervals, therefore, such pumps must be cleaned, to remove these solids or any other contaminating material which may have accumulated, and which may have deleteriously affected the operation. To this end, such pumps are normally made disassemblable, the various parts being removable and, where necessary, sealed together by either metal-to-metal seals or compressible gaskets.

This type of construction has numerous disadvantages; for example, the gaskets deteriorate with age, heat or servicing, and produce leakage. The gaskets may also contain volatiles which may be released, contaminating the pump. The parts which are to be sealed together with gaskets, and the gaskets themselves, must be quite accurate, if the gaskets are to be effective, and such accuracy may result in increased costs. Precision metal-to-metal seals are difficult to obtain and expensive to manufacture, and their disassembly and assembly must be accomplished under controlled conditions by trained personnel to prevent further contamination of the pump parts. Any leakage, whether from the outside or from stage to stage, reduces efficiency.

It is an object of our invention, therefore, to provide a multistage vacuum-pump which does not require internal disassemblable seals.

It is a further object of our invention to provide a multistage vacuum-pump of unitary construction.

It is a still further object of our invention to provide a multistage vacuum-pump which is less prone to clogging due to contamination.

It is a further object of our invention to provide a multistage vacuum-pump of more economical design and improved efficiency.

It is a further object of our invention to provide a multistage vacuum-pump which will not require repair after exposure to abnormally high temperatures.

These and other objects are achieved by eliminating all disassemblable internal seals, by eliminating, wherever possible, restricted mercury-passages, by welding the various stages of the pump into a unitary assembly, and by aligning the various orifices and certain apertures so that they may be cleaned from outside the pump. The efficiency of the pump is improved by the particular arrangement of its parts, and by a reduction in heat and pressure leakages.

A clearer understanding of our invention may be had from the following description of one specific example, together with the accompanying drawing in which the single figure illustrates a three-stage mercury-vapor pump according to our invention.

At the bottom of the illustrated pump, there is a mercury boiler 1 which is adapted to be heated by some external source (not shown), usually an electrical resistance-heater. Leading axially up from the top of the boiler, through the center of the pump, there is a mercury-vapor supply-line in the form of a vertical tube 2 which distributes mercury vapor to the various stages. At the extreme upper end of the tube 2, there is a diffusion nozzle 3 which is an essential portion of the first or diffusion stage of the pump. This diffusion stage includes also a top cylindrical outer casing 4 which is surrounded by a cooling coil 5, and a flange 6 which is welded to the top of the casing 4 for connecting the pump to a vacuum system, that is, to the device to be evacuated (not shown). The nozzle 3 has a depending flared skirt-portion 7 which determines the angle of a downwardly directed conical blast of mercury vapor, which flows out of the top end of the tube 2, through lateral orifices 8, into an annular space which is provided between the outside surface of a truncated conical member 9 and the inside surface of the skirt 7. The conical member 9 is supported on the tube 2, just below the top thereof, so as to form a frustoconical expansion on said tube. The radial spacing between the skirt-portion 7 and the conical member 9 is determined by a spacer-means 9' of suitable thickness, disposed axially between the top of tube 2 and the internal bore of skirt-portion 7.

The second stage is an ejection stage. It includes a partition 10 which has an orifice 11, and an ejection nozzle 12 which is supported above the partition 10 in a position to face into the entrance of the orifice 11. This nozzle 12 is surrounded by the topmost casing 4. The partition 10 serves to permanently join said top casing 4 to an intermediate cylindrical outer casing 14 which surrounds the high-pressure side of the second stage. The intermediate casing 14 is also cooled by the coil 5. The nozzle 12 is carried by a vapor box 15 which is connected between two separate sections of the tube 2 and which provides an open channel from the tube 2 to the nozzle 12.

The third stage is essentially the same as the second, differing only in its dimensions, to allow for different operating pressures. It includes a partition 18, an orifice 19 and a nozzle 20. The nozzle 20 is surrounded by the intermediate casing 14, and the partition 18.
serves to permanently join the intermediate casing 14 to a lower cylindrical outer casing 24 which surrounds the high-pressure side of the third stage, and which is also cooled by the coil 5. The nozzle 20 is carried by a vapor box 21. The lowermost outer casing 24, which surrounds the high-pressure side of the third stage, is provided with an outlet-pipe 25 which is adapted to be connected to a mechanical vacuum-pump (not shown).

The lower end of the tube 2 is in communication with the top of the mercury boiler 1, through a partition 26 which permanently joins the bottom of the lower casing 24 to the top of the boiler 1. The partition 26 is provided with a connecting mercury-return line 27 which is a double-walled tube.

The operation of the pump may be described as follows: The mercury in the boiler 1 is heated to a sufficiently high temperature to cause it to boil, and a blast of mercury vapor is conducted up through the tube 2 to the nozzle 3. The vapor flows out from the orifices 8, and through the annular space between the conical member 9 and the skirt 7, in a conical sheet which flows downwardly and outwardly toward the casing 4, where it is cooled and condensed, running down the wall of the casing 4, and collecting at the partition 10. The gas thus exhausted by the cone of mercury vapor and held between it and partition 10. Diffusion pumps of this type are capable of producing pressures less than ½ micron, against a head of about 500 microns. It is important for efficiency that the cone of vapor be as complete as possible, and it will be noted that, in our design, no obstructions occur in the path of the mercury vapor forming the cone. The cone covers the complete 360° at the diffusion end of the pump.

The second stage is an ejection stage operating on the venturi principle. A blast of mercury vapor is conducted from the tube 2, into the vapor box 15, and out through the nozzle 12, which directs a stream of vapor into the orifice 11. The orifice 11 is of such contour as to increase the mercury-vapor pressure and decrease its pressure, causing the gas-molecules from the low-pressure side to be entrained and carried through into the high-pressure side of this stage. Here the mercury vapor condenses on the cooled walls of the casing 14, and accumulates at the partition 18. A lateral plug 30 is provided in the vapor box 15, primarily for convenience of construction. A plugged aperture 31 is provided in the top of the vapor box 15, in alignment with the orifice 11, this plug 31 being removable for cleaning purposes. A short tube 32, which surrounds the axially disposed tube 2, extends upwardly from the partition 10 to the vapor box 15, to prevent mercury which accumulates at this partition from being vaporized by the heat of the mercury vapor flowing through the tube 2, and also to isolate the tube 2 from the side walls 4 which are cooled. The condensed mercury flows through the orifice 11, as it accumulates from the operation of the first stage. The second stage is capable of producing pressures as low as 100 microns, against a head of about 15 millimeters.

The third stage is similar to the second stage, differing only in the design of the orifice 19 and the nozzle 20, so that it is capable of producing pressures as low as 2 millimeters, against a head of about 25 millimeters.

The mercury from all three stages is condensed, and accumulates at the partition 26, whence it runs back into the boiler 1 through the mercury-return line 27. The condenser-walled tube to prevent the returning mercury from being vaporized by the boiling mercury which surrounds said tube. The lower end of this return-tube 27 dips into the mercury in the boiler 1, and prevents the vaporized mercury from flowing up and out through this return-line 27. No other precaution is necessary to prevent ebullition of mercury in the return-line 27. Previous designs have made use of cooling-rods, and restrictions in the return-line, but it has been found that, with pumps of our design, cooling-rods only reduce the efficiency, and restrictions in the return-line only lead to failure due to obstruction by accumulation of mercury.

The gases compressed by the various stages accumulate within the lowermost casing 24, whence they are removed by a fore pump (not shown), which is generally of a mechanical type, capable of producing pressures in the neighborhood of 20 millimeters or less, at high volume against atmospheric pressure.

Multistage pumps of the nature herein described have heretofore usually included a separate mercury-return for each stage, each with its accompanying trap. It has been found, however, that no deleterious effect arises from the flow of condensed mercury through the ejection-stage orifices, and hence we have omitted the separate mercury-returns.

In operation, excessive quantities of air, entering through the intake 6, lead to the formation of solid matter, which tends to accumulate in the jets and to prevent their operation. It is necessary, therefore, that the jets be cleaned at intervals. To this end, our diffusion plug 3 is made so that it can be removed by unscrewing it from the top end of the tube 2. The nozzle 3 may then be separately cleaned, and tube 2 and its lateral orifices 8 may be cleaned by brushing. The presence of the spacer 9 permits accurate adjustments of the nozzle, by selection of the spacer-thickness. By removing the plug 31, the orifice 11 and the nozzle 12 may be cleaned with a suitable brush (not shown). The base or bottom of our mercury boiler 1 is provided with a plugged aperture 33, which is aligned with the return-line 27, and when the plug 33 is removed, the mercury and any dirt at the bottom of the boiler may be removed, and a suitable brush (not shown) may be inserted to clean the mercury-return line 27, the orifice 19, and the nozzle 20, all of which are carefully aligned with the mercury-return line 27 to permit this operation.

The removal and replacement of the various parts will not change the operation of our pump, because it has no seals which could be damaged, and no spacings which could be changed, as was the case in former pumps in which organic seals were used. Our various stages, it will be noted, are rigidly aligned and assembled, by welding, thus eliminating the problem of leaks at the partitions, which previously existed. At the same time, our rigid stage-partitions 10 and 18 also support the central tube 2, and the short spaced tubes 32 between the partitions and the central tube reduces the heat-loss from the central tube to the water-cooled walls 4 and 14.

While we have shown and described our pump as having a specific construction, numerous variations can be made, depending upon any specific application. The diameters and angles of the various nozzles and orifices are dependent on the pressures encountered, but the principles of such design are well known in the art.

We claim as our invention:
1. A multistage high-vacuum mercury-vapor pump comprising a casing, a mercury boiler connected to said casing, a mercury-vapor supply-line from said mercury boiler, extending through said casing, a diffusion stage comprising a conical-jet-forming nozzle at the end of said vapor supply-line remote from said boiler and means operatively associated with the casing for cooling the casing below the boiling point of mercury in the vicinity of said jet, at least one ejection stage comprising a partition across said casing between said diffusion stage and said mercury boiler, said partition being permanently mounted within said casing, an orifice in said partition, an ejection nozzle and means connected to said nozzle for supplying said ejection nozzle with mercury vapor from said supply-line, said ejection nozzle being on the same side of said parti-
tion as said diffusion stage and being capable of directing a jet of mercury vapor through said orifice, a mercury return-line from said casing to said boiler, return-line being aligned with said orifice, a normally closed aperture in the base of said boiler, aligned with said mercury return-line, said aperture, return-line, orifice, and ejection nozzle being essentially in axial alignment with each other to permit cleaning of said return-line, orifice and ejection nozzle through said aperture.

2. A multistage high-vacuum mercury-vapor pump comprising a casing, a mercury boiler permanently sealed to said casing, a mercury-vapor-supply-line from said mercury boiler, extending through said casing, a diffusion stage comprising a conical-jet-forming nozzle consisting of a frusto-conical expansion on the end of said vapor-supply line and a surrounding conical skirt, a spacer-means of suitable thickness, disposed axially between said expansion and said skirt for controlling the radial spacing between said expansion and said skirt, at least one ejection stage comprising a permanently assembled partition, between said diffusion stage and said mercury boiler, said partition having only one orifice therein, an ejection nozzle, and means connecting to said ejection nozzle and supply-line for supplying said ejection nozzle with mercury vapor from said supply-line, said ejection nozzle being associated with said orifice so as to form an ejection stage, a mercury return-line from the casing to said mercury boiler, and a normally closed aperture in one end of the said boiler, said aperture being aligned with said mercury return-line and said ejection stage to permit cleaning of said return line and said ejection stage from exteriorly of said boiler.

3. A multistage high-vacuum mercury-vapor pump comprising a casing, a mercury boiler permanently sealed to said casing, a mercury-vapor-supply-line from said mercury boiler to the intake end of said casing, a diffusion stage comprising a conical-jet-forming nozzle consisting of a frusto-conical member at the end of said supply-line, with its smaller end toward the intake end of the casing, one or more ports from the end of said supply-line to said smaller end of the frusto-conical member, a conical skirt-member surrounding said frusto-conical member to provide a conical between said skirt and said frusto-conical member, means between said frusto-conical member and said conical skirt member for determining the relative axial positions of said frusto-conical member and said conical skirt member whereby to control the radial spacing therebetween, at least one ejection stage comprising a partition permanently sealed within said casing, a single orifice in said partition, an ejection nozzle, and means connecting between said supply-line and said ejection nozzle for supplying mercury vapor from said supply-line for producing a jet of mercury vapor through said orifice, means operatively associated with said casing for cooling said casing below the boiling point of mercury, a mercury return-line from said casing to said boiler, said return line being coaxial with said orifice, and a normally closed aperture in the outer wall of the boiler, essentially coaxial with said mercury return-line to permit cleaning of said mercury return line and said orifice from exteriorly of the boiler.

4. A three-stage vapor-pump comprising a permanently enclosed boiler, an upwardly extending, open topped, vapor-condensing casing having its lower end permanently secured to the top of the boiler, a pump-intake flange permanently secured to the top of said casing, the top of said boiler, inside of the lower end of said casing, having a centrally disposed vapor-outlet opening and a condensate-return opening, a centrally disposed, upwardly extending vapor-supply pipe permanently secured to the top of said boiler in communication with said vapor-outlet opening, the top end of said vapor-supply pipe terminating near the top of said casing, a diffusion stage comprising a conical-jet-forming diffusion-stage nozzle removably secured over the top end of said vapor-supply pipe, means connecting between said vapor-supply pipe and said diffusion stage nozzle for supplying vapor from said supply pipe to said diffusion-stage nozzle so as to cause vapor to flow downwardly and outwardly from said diffusion-stage nozzle in a conical sheet, a first ejection stage comprising a first partition permanently disposed within said casing at a point below said diffusion-stage nozzle, said partition having an ejection-stage orifice therefrom, a vapor-box permanently disposed above said partition, an ejection-stage nozzle carried by said vapor-box in a position adapted to blow a jet of vapor downwardly through said ejection-stage orifice, means connected to said vapor-supply line for supplying vapor to said vapor-box and thence to said ejection-stage nozzle, the top of said vapor-box having an ejector-cleaning opening in alignment with said ejection-stage nozzle and a plug therefor which is removable from the top for cleaning purposes, a second ejection stage comprising a second partition permanently disposed within said casing at a point below said first partition, said second partition having a second-ejection-stage orifice therefrom, a second-ejection-stage vapor-box permanently secured to the supply-line at a point above said second partition, a second-ejection-stage nozzle carried by said second-ejection-stage vapor-box, means to said second-ejection-stage vapor-box in a position adapted to blow a jet of vapor downwardly through said second-ejection-stage orifice, means connected to said vapor supply pipe for supplying vapor to said second-ejection-stage vapor-box and thence to said second-ejection-stage nozzle, said second-ejection-stage orifice and nozzle being, in alignment with the condensate-return opening in the top of the boiler, a pump-discharge outlet permanently secured to the casing below said second partition, and a downwardly extending condensate-return pipe permanently secured to the top of the boiler in communication with said condensate-return opening and in alignment with said second-ejection-stage orifice and nozzle, the bottom of said boiler having a bottom cleaning-opening therefrom in alignment with said condensate-return pipe, and a plug for said bottom opening, which is removable from the bottom of said boiler to permit cleaning of said condensate-return pipe and said second-ejection-stage orifice.

References Cited in the file of this patent

UNITED STATES PATENTS

1,490,918 Gagge 22,1924
2,386,298 Downing 9,1945
2,386,299 Downing 9,1945
2,505,953 Flosdor 2, May 1950
2,585,139 Lawrence 12, 1952

FOREIGN PATENTS

117,803 Switzerland 1, Dec. 1926