Our invention relates to vacuum pumping systems, and it has particular relation to such systems utilizing two pumps in series, with an interstage reservoir in between, into which the high-vacuum pump exhausts, with automatic means for starting and stopping the fore-vacuum pump in response to the degree of vacuum in the interstage reservoir.

The object of our invention is to provide an improved mechanism and system for carrying into effect the object just stated.

Our invention will best be understood by reference to the accompanying drawing, the single figure of which is a diagrammatic view of circuits and apparatus embodying our invention, in a preferred form, some of the parts being shown in section, others in elevation and still others by means of diagrammatic representation.

Our invention is particularly adapted for evacuating, or maintaining a high degree of evacuation in, a metal-tank rectifier, which is indicated on the drawing at 1, the rectifier being shown, however, on a somewhat reduced scale, in proportion to the other apparatus, for convenience in illustration.

Connected to the rectifier tank is a high-vacuum pump 2, which may be a mercury-vapor pump of well-known design, connected to the tank through the interconnection of a vacuum valve 3 which may be automatically controlled by any suitable mechanism 4, such as that which is shown and described in the application of E. B. Shand, Ser. No. 210,299, filed Aug. 3, 1927.

The high-vacuum pump 2 discharges into an interstage reservoir 5 which is, in turn, exhausted by means of a fore-vacuum pump 6, illustrated as being of the rotary type, driven by an electric motor 6*. In the connections' between the interstage reservoir and the fore-vacuum pump, is provided another vacuum valve 7 to be operated by a motor mechanism 8 which may be the same as that already referred to.

In particular, the valve-operating mechanism 8 comprises a cam segment 9 bearing on the top of the valve stem 10 and biased toward a valve-closing position by means of a spring 11. The cam segment 9 is moved to its valve-opening position by means of an electric motor 12 which is geared to a worm shaft 13 carrying a worm 14 which meshes with a worm gear segment 15 mounted on the same shaft as the cam segment 9. The worm shaft 13 is movable to a position in which the worm is either in or out of engagement with the worm-gear segment 15 by means of a solenoid 16. Any suitable stopping mechanism, such as that indicated at 17, may be utilized to stop the motor 12 when the valve has reached its full-open position.

The operation of the valve-operating mechanism just mentioned, as well as the starting and stopping of the pump motor 6*, may be controlled by means of a manometer 20 which is connected to the interstage reservoir 5 and is thus responsive to the fore-vacuum existing therein. The manometer may conveniently comprise a glass vessel 21 having a U-shaped tube 22, connected to its bottom portion and terminating in an arm 23 extending upwardly alongside the vessel 21. In the upwardly-extending arm 23, we provide at least one, and preferably two, contact wires 24 and 25, and a lower portion of the U-tube is provided with an additional contact member 26. The manometer is partially filled with mercury 27.

In operation, the mercury-vapor pump is capable of pumping from a vacuum of the order of about a micron of mercury, more or less, to a fore-vacuum which may vary in pressure up to about 5 or 10 millimeters of mercury, the figures just stated being given for illustrative purposes only. The rotary pump 6 is capable of pumping from a pressure of a small fraction of a millimeter of mercury, exhausting against atmospheric pressure.

The accurate measurement of the extremely high vacua utilized in the rectifier tank 1 or, in general, in the vessel to be exhausted, is extremely difficult, particularly when
an attempt is made to utilize automatic apparatus. On the other hand, the measurement of pressures of the order of millimeters may be very accurately and simply accomplished by means of a manometer, such as that which is hereinabove described, and such apparatus readily lends itself to embodiment in automatic equipment.

In operation, the manometer makes a contact between the upper electrode 24 and the mercury column, when a predetermined maximum fore-vacuum pressure of 5 or 6 millimeters is present. The contact of the mercury with the upper contact electrode 24 is utilized to energize the solenoid 28 of a relay 29 for closing a switch 30 which starts the pump motor 6 by means of a dash-pot 36 connected thereto in such manner as to cause the rotary pump to continue to operate for any predetermined length of time after the deenergization of the relay 29.

When the main relay contacts 30 finally open, the pump motor 6 and the gear-shift magnet 16 of the valve mechanism are simultaneously deenergized. It will be understood that the valve-operating motor 12 was deenergized, by means of the stop mechanism 17 of the valve, as soon as the valve reached its full-open position. It takes the rotary pump 6 a few seconds to slow down to a speed at which, the pump is ineffective, but the gear-shift magnet 16 operates instantly to release the worm shaft from its operative position, so that it drops down out of engagement with the worm-gear segment 15, thereby permitting the valve-closing spring 11 to snap the valve instantaneously to its closed position. It will be understood that the dash-pot 32, if used at all, will be arranged to permit a substantially unopposed downward movement of the worm shaft 13, but to oppose the upward movement thereof, as indicated in the drawing.

By utilizing an interstage reservoir of sufficient capacity to enable the mercury pump to discharge into it for a considerable length of time without having the fore-vacuum pressure therein rise to a pressure against which the mercury pump cannot operate, and by providing a vacuum-responsive device, such as the manometer 20, which responds to mercury columns which are not microscopic in their dimensions, as in the case of the mercury columns corresponding to the vacuum in the rectifier tank 1, we have been able to provide an extremely simple and reliable automatic pumping system, as above described.

We find it highly desirable to operate the mercury pump continuously, in order to preserve as high vacuum as possible in the rectifier tank 1, and also in order to be instantly available, in case of sudden gassing or evolution of gases or sudden loads on the rectifier. Heretofore, in devices utilizing an automatic response to the vacuum conditions in the rectifier to start both of the pumps, there has been a time delay of the order of three-quarters of an hour before the mercury pump could be heated to an operative temperature, during which time it has been necessary to keep the valve 3, for example, closed.

We have found that mercury pumps, as
now manufactured, are extremely reliable, provided that the fore-vacuum pressure is not permitted to become excessive, and that a very great advantage in the operation of the rectifier is obtained by our system in which the mercury-vapor pump is designed to operate continuously. On the other hand, an intermittent operation of the rotary pump, for only a small fraction of the entire time, depending upon the amount of pumping which is necessary to maintain the vacuum in the tank, is quite sufficient, and the provision of the interstage reservoir, with the automatic pressure-responsive device thereon, makes such intermittent operation of the rotary pump feasible.

While we have described our invention in a preferred embodiment and explained its advantages and operation with respect to such preferred embodiment, we wish it to be distinctly understood that our description and explanation are largely illustrative, and that changes in degree and in the exact design or arrangement of the parts may be resorted to by those skilled in the art without sacrificing the essential principles of our invention. We desire, therefore, that the appended claims shall be given the broadest interpretation consistent with their wording and the prior art.

We claim as our invention:

1. In a vacuum pumping system, the combination with a vessel to be maintained at a high degree of evacuation, of a high-vacuum pump, a fore-vacuum pump, an interstage reservoir therebetween, a mechanically actuated valve between said interstage reservoir and said fore-vacuum pump, and means responsive to the fore-vacuum in said interstage reservoir for intermittently starting and stopping said fore-vacuum pump and opening and closing said valve, whereby the pressure in said interstage reservoir is maintained within predetermined limits.

2. In a vacuum pumping system, the combination with a vessel to be maintained at a high degree of evacuation, of a high-vacuum pump, a fore-vacuum pump, an interstage reservoir therebetween, a valve between said interstage reservoir and said fore-vacuum pump, substantially instantaneously operating closing means for said valve, relatively slowly operating opening means therefor, means responsive to a predetermined maximum pressure in said interstage reservoir for starting said fore-vacuum pump and energizing said valve-opening means, and means for simultaneously deenergizing said fore-vacuum pump and rendering said instantaneous valve-closing means effective.

3. In a vacuum pumping system, the combination with a vessel adapted to be maintained at a high degree of evacuation, of a high-vacuum pump adapted to operate continuously, a fore-vacuum pump adapted to operate intermittently, an interstage reservoir therebetween, a mechanically actuated valve between said interstage reservoir and said fore-vacuum pump, and automatic control means for said valve and for said intermittently operated pump, including means responsive to a predetermined maximum pressure in said interstage reservoir for starting said pump and subsequently effecting the opening of said valve, and means effective at the termination of the desired intermittent operation of said pump to close the valve and subsequently discontinue the effective operation of the pump.

4. In a vacuum pumping system, the combination with a vessel adapted to be maintained at a high degree of evacuation, of a high-vacuum pump adapted to operate continuously, a fore-vacuum pump adapted to operate intermittently, an interstage reservoir therebetween, a mechanically actuated valve between said interstage reservoir and said fore-vacuum pump, and automatic control means for said valve and for said intermittently operated pump, including a relay adapted, upon actuation to its closed position, to energize mechanism for starting said pump and subsequently effecting the opening of said valve, said relay being further adapted, upon moving to its open position, to cause the closing of the valve and the subsequent discontinuance of the effective operation of the pump.

5. In a vacuum pumping system, the combination with a vessel adapted to be maintained at a high degree of evacuation of the order of microns of mercury, of a high-vacuum pump adapted to operate continuously and operative against a fore-vacuum of the order of millimeters of mercury, an interstage reservoir into which said high-vacuum pump discharges, an intermittently operating fore-vacuum pump for maintaining the necessary fore-vacuum in said interstage reservoir, a mechanically actuated valve between said interstage reservoir and said fore-vacuum pump, and automatic control means for said valve and for said intermittently operated pump, including a relay adapted, upon actuation to its closed position, to energize mechanism for starting said pump and subsequently effecting the opening of said valve, said relay being further adapted, upon moving to its open position, to cause the closing of the valve and
the subsequent discontinuance of the operation of the pump, and a mercury manometer responsive to the fore-vacuum in said interstage reservoir and having two contacts above the minimum level of the mercury, connections for causing the upper contact to initiate the closing of the relay and for causing the lower contact to hold the relay closed until after the mercury level falls below said lower contact.

In testimony whereof, we have hereunto subscribed our names this 26th day of July, 1927.

VLADIMIR K. ZWORYKIN:
ERROL B. SHAND.