“LS Series” Dry Vacuum Pumps with High Pumping Speed and Low Power Consumption

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Dry vacuum pumps are used in many production lines, including those for electronic parts and displays. Environmental concerns have led to dry vacuum pumps becoming mainstream thanks to their low power consumption. However, typical dry vacuum pumps with low power consumption tend to have the problem of long pumping down time, since they have a low pumping speed near atmospheric pressure. To solve this problem, ULVAC has developed a new dry vacuum pump series called the LS series that combines high pumping speed with low power consumption. By increasing the pumping speed near atmospheric pressure, ULVAC has realized a dry vacuum pump with high pumping speed that uses the innovative technology developed by the company to reduce power consumption.

1. Introduction

When vacuum equipment is required in order to increase microfabrication density and improve productivity, it is increasingly common to turn to dry vacuum pumps. As a result of environmental concerns, customers are becoming more and more interested in reducing power consumption. At the same time, customers want to reduce pumping time and increase productivity. However, typical dry vacuum pumps that feature low power consumption tend to require long pumping times because of their low pumping speed near atmospheric pressure. To solve this problem, we have developed and are now marketing a series of dry vacuum pumps called the “LS series.” Pumps in this series (see Figure 1) combine high pumping speed with low power consumption. In this article, we introduce the characteristics of the dry vacuum pumps in the LS series.

2. Product specifications

Table 1 shows the product specifications of the dry vacuum pumps in the LS series. We offer four models with different maximum pumping speeds: the LS120A standalone dry vacuum pump (Figure 2) and the LS300A, LS600A, and LS1200A dry vacuum pumps combined with mechanical booster pumps (MBPs) (Figure 3). With each of these models, we offer the low-power-consumption C Type that features built-in ECO-SHOCK technology for application in clean processes (such as air and N_2 pumping), and the L Type that features surface treatment and purge functions for application in light-duty processes (such as evacuation of water vapor and volatile chemicals). Applications for the C Type include sputtering, evaporation, bonding, load lock chamber pumping, and use as an auxiliary turbomolecular pump. Applications for the L Type include vacuum drying, vacuum freeze drying, ashing, and general industrial use. All models in the LS series allow continuous operation across the full range of inlet pressures.

Figure 1 Photos of the “LS Series” dry vacuum pumps

Outline drawings of the pumps are shown in Figures 4 and 5. Table 2 shows the dimensions indicated in each of the pump outline drawings.

3. Need for high pumping speed and low power consumption[1)]

In vacuum processes in manufacturing fields such as semiconductor devices and flat panel displays (FPDs), processes such as chemical vapor deposition (CVD), etching, and sputtering are performed. In addition to the process chamber used for CVD, etching, sputtering, and other processes, vacuum equipment used in mass production also has a load lock chamber that pumps the substrate down from atmospheric pressure to prevent the vacuum process chamber from exposure to the atmosphere due to substrate loading or unloading. The vacuum pump equipment in the load lock chamber includes a dry vacuum pump and an MBP, and typically evacuates the chamber to a pressure that is lower than the maximum inlet pressure of the turbomolecular pump when the next chamber valve is opened.

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Table 1 Specifications of the “LS Series” dry vacuum pump

Model	(C : C Type) (L : L Type)		LS120A		LS300A		LS600A		LS1200A	
			C	L	C	L	C	L	C	L
Max.pumping speed		m^3/h	120		380		600		1000	
Ultimate pressure		Pa	≦0.6		≦0.1					
Power supply			200V Class : 3Phase,50/60Hz,AC200-240V or 400V Class : 3Phase,50/60Hz,AC380-480V							
Power consumption ＊1		kW	0.6	2.0	1.0	2.5	1.3	2.6	1.3	2.7
Cooling water flow rate		L/min	>2.0		>4.0					
Purge gas flow rate ＊2		SLM	-	0～50	-	0～50	-	0～50	-	0～50
Max.water vapor tolerance ＊3		kg/h	-	1.5	-	1.5	-	1.5	-	1.5
Noise		dB(A)	61		61		62		64	
Inlet port			KF50(Horizontal)/VG50(Vertical)		ISO-F-80		ISO-F-80		ISO-F-100	
Outlet port			KF40							
Dimension	W×D×H	mm	311×639×307		311×639×537		311×639×563		311×639×563	
Weight		kg	142		220		242		266	
Applicable standard			CE、cTUVus							
Standard accessory			Instruction manual(CD-R)、Power connector、Waterproof cable clamp、Remote connector、Guard for power connect							
Pump head option			Power supply : 200V Class or 400V Class、Material of seal : FFKM(L type only)							
External option			MBP inlet flange adaptor、Packege Exhaust port、Earthquake-proof Bracket、LR compatible Unit(Inlet、Remote)、Valve for purge gas							

＊1 : At ultimate pressure (reference only)
＊2 : Purge gas is not available with C Type.
＊3 : Max.water vapor tolerance is a value when purge gas is used.
＊4 : C type is not leakless.

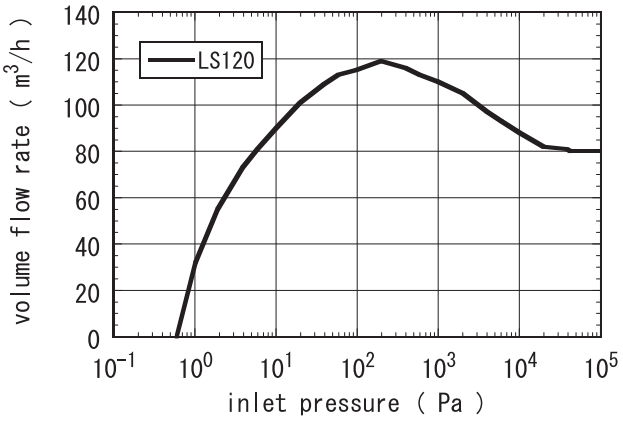

Figure 2 Volume flow rate curve of the “LS120A” model.

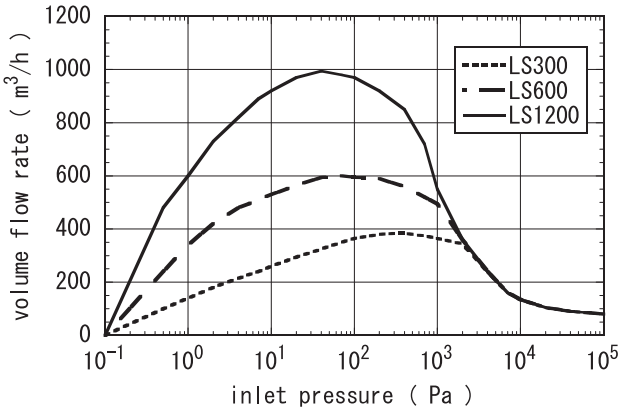

Figure 3 Volume flow rate curve of the“LS300A,” “LS600A,” and “LS1200A” models

To shorten cycle time and improve efficiency in mass production, it is desirable to reduce the time required to evacuate the load lock chamber to the predetermined pressure. To shorten the pumping time of the load lock chamber, the pumping speed of the dry vacuum pump near atmospheric pressure becomes an important factor. This is because when the pressure in the load lock chamber is high, such as several thousand Pa or greater, the boost provided by the MBP will be small, so any change in pumping time will be dependent on the pumping speed of the dry vacuum pump.

3.1 Pumping speed of the dry vacuum pump near atmospheric pressure

In a typical volume transfer-type vacuum pump, space is created between a moving body (such as a rotor) and a fixed body (such as a stator) in order to evacuate the gas. If the target ultimate pressure cannot be achieved using a single stage, a multiple-stage configuration is used. Unlike an oil-sealed rotary vacuum pump with an exhaust valve, the pressure on the exhaust side of a dry vacuum pump is always at atmospheric pressure. Accordingly, to maintain the vacuum at the inlet side, gas flowing to the pump chamber must be pushed back during the compression stroke. The subsequent stage that receives the backflow from atmospheric pressure performs work that greatly impacts the overall power required to push back the gas. In the power-

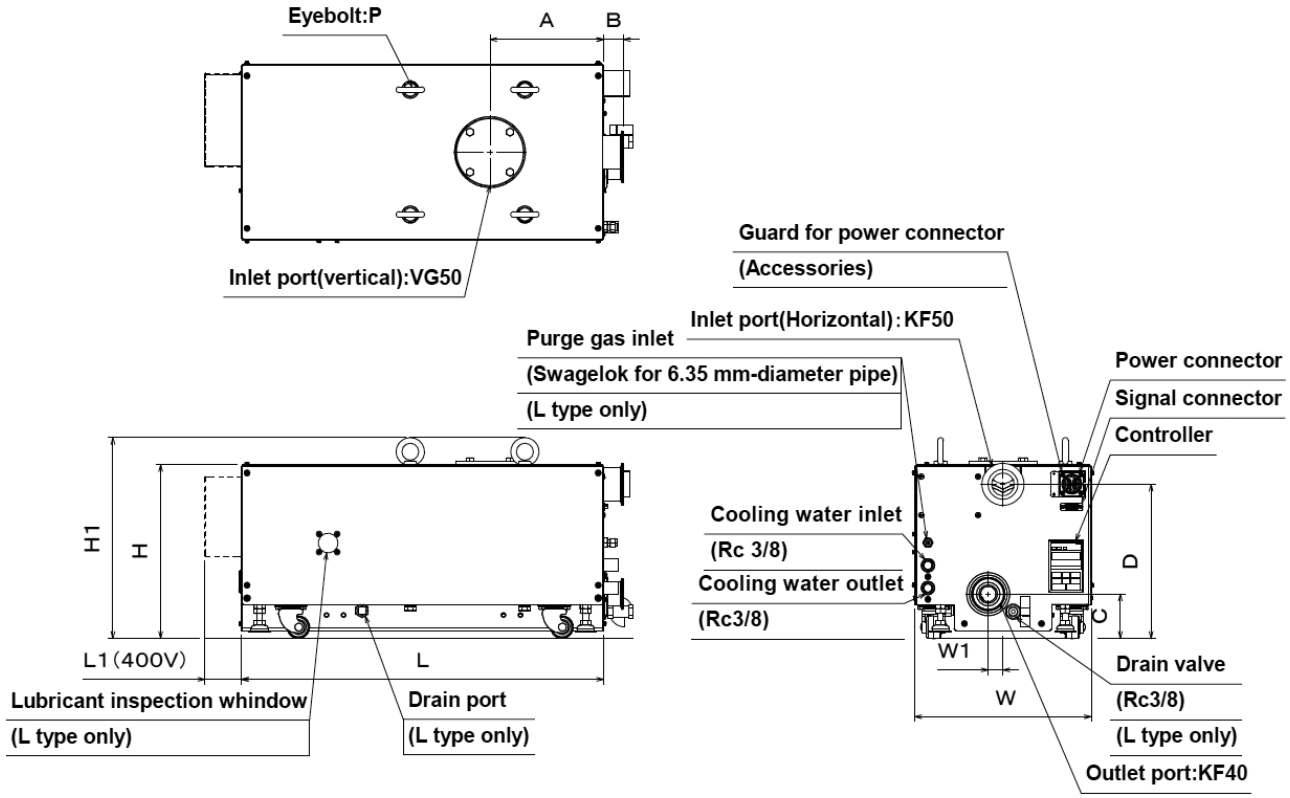

Figure 4 Outline drawing of the "LS120A" model. Its dimensions are shown in Table 2.

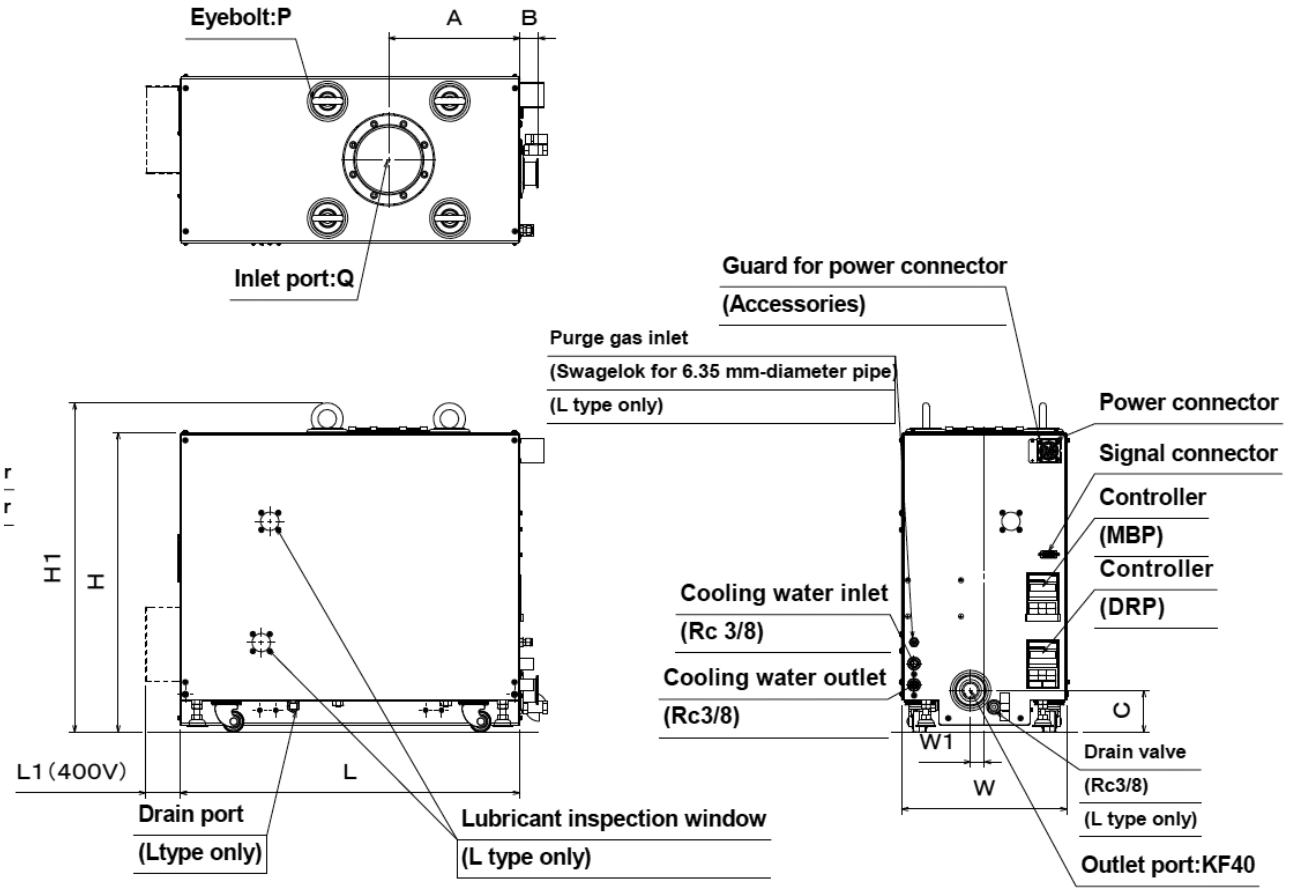

Figure 5 Outline drawing of the "LS300A," "LS600A," and "LS1200A" models. Their dimensions are shown in Table 2.

Table 2 Detailed Specifications of the "LS Series" dry vacuum pump

Type	A	B	C	D	H	H1	L	L1	P	Q	W	W1
LS120A	201	35	78	272	307	355	639	65	4-M12	—	311	26
LS300A	226	35	78	—	537	593	639	65	2-M16	ISO-F-50	311	26
LS600A	201	35	78	—	563	619	639	65	4-M16	ISO-F-80	311	26
LS1200A	247	35	78	—	563	619	639	65	4-M16	ISO-F-100	311	26

saving dry vacuum pump, the volume of the pump chamber in the subsequent stage is reduced to lessen the gas compression work required of the subsequent stage. However, when the inlet pressure is higher than several thousand Pa, pumping speed is lower because of the smaller volume of the subsequent stage. In the case of a multistage configuration, although it is possible to reduce the pumping speed by evacuating the gas from the middle stage, the pumping speed near atmospheric pressure is low when compared with a configuration that has a subsequent stage with a larger volume. There is a great demand for shortening the time required to pump to the predetermined pressure in the load lock chamber. Reducing the volume of the subsequent stage is disadvantageous because the pumping speed near atmospheric pressure greatly impacts pumping time.

3.2 ECO-SHOCK

The ECO-SHOCK® dry vacuum pump Power-Saving Attachment (hereinafter referred to as "PSA") enables a maximum 80% reduction in the power consumption of dry vacuum pumps used in the evacuation of inert gases such as air, nitrogen, or argon from load lock chambers, etc. Reducing power consumption also has the effect of suppressing heat generation by the dry vacuum pump, and so reductions in power consumption by air conditioners and other equipment can also be expected.

The PSA is installed as a check valve and backing vacuum pump in parallel at the exhaust port of the main pump, which is the dry vacuum pump in which reduced power consumption is desired. When the inlet gas flow of the main pump is low, the PSA lowers the pressure inside the main pump, reducing the gas compression work of the main pump and thereby reducing power consumption. We have acquired patents[2)–7)] for backing vacuum pump selection criteria that can achieve efficient power savings for vacuum pump systems in which a backing vacuum pump is used with a main pump and the PSA. A patent also has been acquired for a check valve mechanism to facilitate installation.

3.3 Combining high pumping speed and low power consumption

The C Type has built-in ECO-SHOCK technology, enabling both high pumping speed and low power consumption. In addition, because the main pump is not limited by outlet pressure, continuous operation across the full range of inlet pressures is possible.

4. Comparison of LS120A and the conventional model LR90

To demonstrate LS120A features other than high-speed pumping and low energy consumption, let us compare it with the LR90, another dry vacuum pump marketed by ULVAC that has a similar maximum pumping speed.

4.1 Low noise

The silencer, which is connected externally to the main body of the LR/HR series as optional equipment, is built-in to the pump package as standard equipment. The noise level at ultimate pressure is 66 dB(A) on the LR90, but is reduced to no more than 61 dB(A) on the LS120A.

4.2 Low operating cost

Operation of the LR90 requires 5 L/min of N_2 shaft sealing gas and at least 5 L/min of cooling water flow. On the LS120A, we have developed a compact mechanism that seals the oil from the gear chamber to the pump chamber, eliminating the need for shaft sealing gas and reducing the cooling water flow to 2 L/min. These developments contribute to reducing the operating cost of utility power for pumping operations.

4.3 External dimensions

The LS120A requires only half of the floor space of the LR90. In addition, from an environmental perspective, the LS120A has 40% fewer parts and 40% less mass than the LR90. Also, inlet ports are provided horizontally on the front surface (KF50) and vertically on the top surface (VG50). This enables easy replacement of older models and of oil-sealed rotary vacuum pumps.

The external dimensions of the LS600A and LS1200A are the same, as the dimensions of the older LR600 and LR1200 models were also the same. As compared with the older LR600 and LR1200 models, the LS600A and LS1200A require only 44% of the floor space and 30% of the volume.

4.4 Motors developed by ULVAC

The motors installed in the LS series were developed by ULVAC. Because of this, we were able to use a canned DC brushless motor with a configuration that is suitable for dry vacuum pumps and MBP design. To achieve power savings, we selected for the motor rotor an IPM configuration with powerful magnets that are highly efficient at high rpm. In addition, use of a fluorine resin coating has made the magnets more resistant to corrosion.

5. Long-term reliability and high durability

To ensure stable operation and high durability, we performed various reliability tests from the early stages of development.

5.1 Reliability testing

With high-speed pumping as a central feature, we envisioned the possibility of load lock chamber pumping, and confirmed that there were no problems after pumping in a 0.1-m^3 test container for more than two years, with repeated atmosphere and vacuum cycles. We also confirmed reliability through continuous operation and repeated starts and stops at low temperature atmosphere and high temperature atmosphere at the ultimate operation and maximum load. We also acquired cTUVus certification and CE marking, achieving an internationally competitive product.

5.2 Water vapor pumping

The LS series' L Type enables evacuation pumping, such as of water vapor. Using a purge gas enables exhaust of 1.5 kg/h of water vapor. For water vapor pumping with the LS120A, we performed a durability test with continuous intake of water vapor at 1.5 kg/h, and we confirmed that there were no problems such as pump breakdowns.

5.3 Motor control system development

To reduce the size of the LS series, we developed a new inverter that controls the DC brushless motor. In load lock chamber pumping and other applications, an MBP produces sudden load fluctuations and large temperature changes. Conventional inverters are large because they include numerous parts needed for controlling these variables. To reduce the external dimensions, we had to reduce the size of the inverter that controls the motor. The software for the new inverter is optimized to allow control of the motor with the minimum configuration. Additionally, we conducted various reliability tests that involved use of the motor under all conditions and confirmed that the unit could be operated stably.

6. Conclusion

We have developed a series of dry vacuum pumps called the “LS series” that combines high pumping speed and low power consumption. ULVAC will continue to develop products that meet our customers' needs as we contribute to the ongoing development of industries that rely on vacuum technology.

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