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Energy consumption of milking pump controlled by frequency convertor during milking cycle

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Abstract. The article deals with selected parameters affecting the energy consumption of a vacuum pump in a milking system during the whole milking cycle in variants with and without regulation by a frequency convertor. When put into practice, the latest research of creation, control and stabilization of vacuum in milking devices allows dairy farmers to obtain a vacuum system that ensures maximum stability of milking pressure, which is a basic requirement affecting the health of dairy cows. The choice of vacuum system prioritizes in particular high performance, maximum operational reliability, minimum maintenance, long service life, environmental friendliness and economy. The vacuum pump was a Roots vacuum pump with a rotary piston which is typical for this use. Use of a frequency convertor significantly affected the efficiency of this pump for control of vacuum pressure level and pump performance by varying the rotation frequency according to the actual airflow requirement. Using this control system, only as much vacuum pressure is produced as necessary. By measurement of an experimental setup, it was found that the average power requirement of a setup with a control valve was 3.8 kW compared to 1.7 kW in the case of the variant with frequency convertor. Measurements and calculations have shown that this system is capable of saving more than 50% of electric energy.

Key words: milking cycle, vacuum system, vacuum pump, frequency convertor, energy consumption.

INTRODUCTION

Milking is the process by which milk is obtained from the udders of dairy cow. Milking devices currently in use partly mimic the activity of a calf sucking. These devices harvest milk by exerting suction pressure on the udder of dairy cows. The teats and milk glands are, however, very sensitive to external influences, impurities and injuries. Therefore, milking machines must not adversely affect the health of milk gland (Walstra et al., 1999; Laurs & Priekulis, 2008).

Each milking device must be designed to conform to the characteristics of the dairy cows and be based on anatomical, physiological and hygienic requirements. Milking devices and machines are designed to be gentle to teats and udders, accommodate blood circulation during milking and prevent inflammation and infection of any part of mammary anatomy, allow adequate milk extraction from udder at the time of full oxytocin effect, do not reduce quality of milk, have amiable influence to dairy cows (Doležal et al., 2015, Přikryl et al., 2016).

In order to meet the above mentioned requirements, each milking device must ensure compliance with several principles, such as keeping a stable vacuum, the quality of the milking machine and the quality of the pulsation.

All parts that come into contact with milk must be made of materials that are suitable food contact materials. Each milking device must be equipped with a cleaning and disinfecting system (Chládek et al., 2010). At present, demands for the amount of air supplied to the dairy piping are increasing, as well as the requirements for the performance and efficiency of the vacuum pumps. This is mainly due to increased milking capacity, higher milk yields of dairy cows and increasing the diameter of the milking pipeline (Gaworski & Leola, 2014; Doležal et al., 2015). Higher milk yields can be affected also by the conditions in stables (Šimon et al., 2017).

It is necessary to produce a sufficient supply of vacuum so that it does not fluctuate during milking process. When sanitizing and flushing of milking devices, the vacuum system needs to be powerful enough to create air plugs in the larger diameters of the milk pipeline when transporting the sanitizing solution, thereby ensuring that the piping is cleaned throughout the whole cross-section. At present, the so-called double-pressure system is used, where a lower level of vacuum is used during milking process and higher vacuum is used for sanitation, flushing and drying of the milk pipes for the purpose of more efficient cleaning of larger pipe diameters. All these necessary requirements greatly increases the demands placed on vacuum systems, their equipment, their ability to respond quickly to the immediate need of vacuum, the energy requirements and the associated economy of operation (Doležal et al., 2015).

With regard to the above requirements for a modern milking system, series of measurements was carried out with the following objectives:

1) To determine the energy requirements for creating the necessary air flow at a particular vacuum level with the use of a frequency convertor as a regulator and without the use of a convertor where the regulation of the vacuum is provided by a control valve;

2) Using wattmeter to verify the energy consumption of at least twenty milking processes with and without the use of a frequency convertor;

3) Statistically evaluate the differences in measured energy consumption between two variants of regulation of vacuum, firstly by a frequency convertor and secondly by a control valve and the degree to which the frequency convertor influences the overall efficiency of the vacuum pump motor.

MATERIAL AND METHODS

The measurement described in this article deals with selected parameters of the energy requirements of a milking machine pump complemented with a frequency convertor throughout the whole milking process.

Measurements were done on a parallel milking parlor with 2 rows by 8 milking positions. It is able to process 80 dairy cows per hour. The working vacuum pressure was 42 kPa. Measurements were carried out during all three phases of milking process which are:

1) The first milking phase – disinfection, flushing with lukewarm water and drying of the milking device before milking. The first phase (as measured on site) takes 27 minutes.

2) The second milking phase is milking. This involves the income of cows at the milking parlor standings, the treatment of udder before milking, stimulation, milking, teat treatment after milking and subsequent group leaving of the dairy cows.

3) The third milking phase – disinfection, flushing and drying of the milking device after milking. The third phase contains flushing of the milk system and the milking machines with lukewarm water, flushing with the alkaline solution and flushing with acidic solution. The phase is completed by drying the whole system. The third phase (as measured on site) takes 52 minutes.

Measurements were carried out during individual milking processes under the comparable conditions in the milking parlor to compare the two variants. In particular, this meant keeping the same number of dairy cows and the exact same milking practices performed by the same operator. The measurements were started at the moment of the automatic start of flushing before the milking process and continued until the vacuum pump stopped after flushing and disinfection after milking process.

Measurements were sampled at regular three-minute intervals firstly with regulation and secondly with the frequency convertor disconnected. In the latter case, the working vacuum pressure (42 kPa) was controlled by the control valve. Measured values were read from the frequency convertor display and from the measuring devices (voltmeter, 3 x amp meter and wattmeter) and recorded in tables and subsequently evaluated.

The diagram of the setup with frequency convertor is shown in Fig. 1. Using the frequency convertor, constant motor speed can be set manually. Both of these frequency convertor features were used for the measurement.

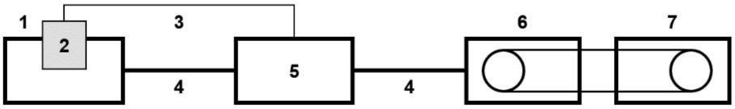

Figure 1. The diagram of the frequency convertor with the vacuum pump motor: 1 – vacuum pipeline; 2 – sensor; 3 – shielded data cable; 4 – power cord; 5 – frequency convertor; 6 – electric motor; 7 – vacuum pump.

In order to verify the measured values and to compare the energy consumptions, longer-term monitoring was carried out for both variants. In the above mentioned measurements, the energy consumption in the first ten days was measured on the existing setup with the frequency convertor and the next ten days it was the variant with the control valve only, which was set to the nominal vacuum pressure 42 kPa. Air suction through this valve was very noisy so the measurements could not take longer than ten days.

The data were used to compare the energy consumption of the two variants. The statistical difference between the measured energy consumptions in the variant when milking with or without the frequency convertor and the possible influence on the efficiency of the vacuum pump motor by using the frequency convertor during the milking cycle was evaluated at the end of the experiment. From the milking cycle, the data of the milking cycle itself (from 36 to 156 min.) were used for statistical evaluation. The descriptive statistic from the program Statistica was used as the first statistical evaluation. By descriptive statistics were calculated the most important statistical characteristics. It was necessary to perform statistical verification before we started the statistical processing of the measured values. In this case were used verification of the shape of the distribution and good compliance tests. These tests allow to confirm the assumption of random probability distributions and thus to use the statistical methods that are subject to this division.

This applies in particular to the normal distribution and tests based on it. In order to confirm the assumption of a normal distribution based on obliquity, a test of the normal distribution was carried out by the Statistica program.

RESULTS AND DISCUSSION

Determination of energy consumption of vacuum generation during the whole milking cycle

The measurements show the average power consumption is 3.8 kW with the control valve arrangement, compared to 1.7 kW for the variant with frequency convertor. Table 1 and 3 show the values measured over the whole milking cycle with frequency convertor and without frequency convertor, respectively. Table 2 and 4 show statistical evaluation of the values with and without frequency convertor, respectively.

Table 1. Average values measured over the whole milking cycle with frequency convertor

	A [min]	B [rpm]	C [Hz]	D [kW]	E [V]	F [A]	G [kPa]		A [min]	B [rpm]	C [Hz]	D [kW]	E [V]	F [A]	G [kPa]
Start of the milking cycle								Milking process	108	764	25.8	1.5	393	2.3	42.0
Flushing before milking	0	0	0.0	0.0	393	0.0	0.4		111	867	29.3	2.3	390	5.8	42.4
	3	1,800	60.8	4.2	390	6.2	46.2		114	696	23.5	1.5	396	0.8	42.0
	6	0	0.0	0.0	393	0.0	0.3		117	752	25.4	1.6	396	1.8	42.0
	9	1,788	60.4	1.8	390	4.2	15.3		120	811	27.4	1.9	396	1.8	42.0
	12	0	0.0	0.0	393	0.0	0.3		123	699	23.6	1.3	393	1.8	42.0
	15	0	0.0	0.0	393	0.0	0.3		126	761	25.7	1.6	390	2.3	42.0
	18	0	0.0	0.0	393	0.0	0.3		129	1,264	42.7	3.3	396	6.7	41.9
	21	0	0.0	0.0	393	0.0	0.3		132	666	22.5	1.4	393	1.3	42.0
	24	1,791	60.5	3.1	393	5.2	23.2		135	820	27.7	1.6	390	2.8	42.0
	27	1,795	60.6	3.2	393	5.3	25.1		138	758	25.6	1.7	393	2.3	42.1
	30	0	0.0	0.0	393	0.0	0.3		141	1,380	46.6	3.6	396	6.3	42.0
	33	0	0.0	0.0	393	0.0	0.3		144	853	28.8	1.7	393	2.3	41.9
Milking	36	1,255	42.4	2.1	390	4.8	42.1		147	675	22.8	1.5	393	1.8	42.0
	39	805	27.2	1.6	390	2.3	42.1		150	663	22.4	1.3	390	1.8	42.0
	42	737	24.9	1.5	390	0.8	42.0		153	666	22.5	1.5	393	1.3	41.9
	45	802	27.1	1.8	393	2.3	42.0		156	648	21.9	1.3	396	1.3	42.1

Table 1 (continued)

48	770	26.0	1.5	393	2.5	41.9		158	1,800	60.7	4.1	393	7.2	44.5
51	787	26.6	1.8	393	2.5	42.0		170	1,800	60.8	4.2	390	7.3	45.7
54	684	23.1	1.4	393	1.8	42.5		173	1,794	60.6	4.0	390	6.3	45.6
57	687	23.2	1.4	393	1.8	42.1		176	0	0.0	0.0	390	0.0	0.3
60	764	25.8	1.6	390	2.3	42.0		179	1,785	60.3	2.1	390	2.8	10.5
63	722	24.4	1.4	390	2.3	42.0		182	0	0.0	0.0	390	0.0	0.3
66	779	26.3	1.5	390	2.3	42.1		185	0	0.0	0.0	390	0.0	0.3
69	728	24.6	1.6	393	2.3	42.0		188	0	0.0	0.0	390	0.0	0.3
72	740	25.0	1.7	390	1.8	42.1		191	0	0.0	0.0	390	0.0	0.3
75	767	25.9	1.6	393	2.8	41.8		194	1,803	60.9	3.8	390	7.3	45.5
78	793	26.8	1.6	390	2.8	42.0		197	1,800	60.8	3.1	393	5.3	37.4
81	785	26.5	1.4	393	1.8	42.0	Flushing after milking	200	1,800	60.8	2.1	390	2.8	30.1
84	737	24.9	1.5	390	2.3	41.9		203	1,800	60.8	1.7	390	2.3	10.5
87	702	23.7	1.4	393	2.3	42.0		206	0	0.0	0.0	390	0.0	0.3
90	773	26.1	1.6	396	2.8	42.0		209	0	0.0	0.0	390	0.0	0.2
93	1,412	47.7	4.1	393	5.8	42.1		212	1,803	60.9	4.2	390	7.5	45.4
96	770	26.0	1.7	396	2.3	42.0		215	1,788	60.4	2.1	390	2.8	21.4
99	767	25.9	1.7	393	2.3	42.0		218	1,788	60.4	1.1	390	2.8	13.0
102	820	27.7	1.7	393	2.8	42.1		220	0	0.0	0.0	390	0.0	0.0
105	758	25.6	1.6	396	2.3	42.0	End of the milking cycle							

Note: A – Time of milking [min]; B – Frequency of motor rotation [rpm]; C – Frequency of output voltage [Hz]; D – Power [kW]; E – Voltage [V]; F – Current [A]; G – Vacuum [kPa].

Table 2. Statistical evaluation of the values measured throughout the milking cycle with frequency convertor

	Frequency of motor rotation [rpm]	Frequency of output voltage [Hz]	Power [kW]	Voltage [V]	Current [A]	Vacuum [kPa]
Average	806.9	27.3	1.7	392.7	2.6	42.0
Average error	28.5	0.96	0.09	0.3	0.2	0.01
Median	763.8	25.8	1.6	393.0	2.3	42.0
Modus	multiple	multiple	1.6	393.0	2.3	42.0
Standard deviation	182.2	6.2	0.6	2.2	1.4	0.1
Variation coefficient [%]	22.6	22.6	33.8	0.6	53.5	0.3
Scatter	33,206.7	37.9	0.35	4.86	1.87	0.01
Spikiness	5.4	5.4	8.6	-1.0	3.2	7.7
Skewness	2.5	2.5	2.9	0.2	1.9	2.2
Difference max-min	764.0	25.8	2.8	6.0	5.9	0.7
Minimum	648.0	21.9	1.3	390	0.8	41.8
Maximum	1,412.0	47.7	4.1	396	6.7	42.5
Total	33,086.6	1,117.6	71.4	16,101.0	104.6	1,723.1
Number	42.0	42.0	42.0	42.0	42.0	42.0
Confidence level (95%)	864.5	29.2	1.9	393.4	2.9	42.1

Table 3. Average values measured over the whole milking cycle without frequency convertor

	A [min]	B [rpm]	D [kW]	E [V]	F [A]	G [kPa]
Start of the milking cycle						
Flushing before milking	0	0	0.0	393	0.0	0.4
	3	1,800	4.1	390	7.5	47.2
	6	1,801	3.8	393	7.4	15.3
	9	1,800	3.1	390	7.5	11.3
	12	0	0.0	393	0.0	0.3
	15	0	0.0	393	0.0	0.3
	18	0	0.0	393	0.0	0.3
	21	1,799	3.9	392	7.2	0.3
	24	0	0.0	393	0.0	25.6
	27	1,800	2.8	393	7.5	11.6
	30	0	0.0	393	0.0	0.3
	33	0	0.0	393	0.0	0.3
Milking process	36	1,800	3.9	393	7.5	42.5
	39	1,800	3.9	390	7.5	42.1
	42	1,800	3.9	390	7.3	42.0
	45	1,800	3.9	393	7.5	42.0
	48	1,800	3.8	393	7.4	41.9
	51	1,800	3.8	393	7.3	42.2
	54	1,800	3.8	393	7.4	42.5
	57	1,800	3.8	393	7.3	42.1
	60	1799	3.8	389	7.5	42.0
	63	1,800	3.8	390	7.5	42.0
	66	1799	3.8	390	7.3	42.1
	69	1,800	3.8	393	7.1	42.1
	72	1,800	3.8	390	7.5	42.1
	75	1,800	3.8	393	7.5	41.8
	78	1,800	3.8	390	7.3	41.8
	81	1,800	3.8	393	7.4	42.3
	84	1,800	3.8	390	7.5	41.9
	87	1799	3.8	393	7.5	42.0
	90	1,800	3.8	396	7.3	42.0
	93	1,800	3.8	393	7.5	42.1
	96	1799	3.8	393	7.4	42.0
	99	1,800	3.8	393	7.3	42.0
	102	1,800	3.8	393	7.4	42.1
	105	1,800	3.8	396	7.3	42.0
Milking process	108	1,800	3,8	393	7,5	42.0
	111	1,800	3.8	390	7.5	42.4
	114	1,800	3.8	396	7.3	42.0
	117	1,800	3.8	393	7.1	42.0
	120	1799	3.8	396	7.5	42.0
	123	1,800	3.8	393	7.5	42.5
	126	1,800	3.8	390	7.3	42.0
	129	1,800	3.8	396	7.2	41.9
	132	1,800	3.8	393	7.5	42.0
	135	1,800	3.8	390	7.3	42.0
	138	1,800	3.8	393	7.6	42.1
	141	1,800	3.8	396	7.5	42.0
	144	1,800	3.8	393	7.5	41.9
	147	1,800	3.8	393	7.3	42.0
	150	1,800	3.8	390	7.5	42.0
	153	1,800	3.8	391	7.6	42.0
	156	1,800	3.8	396	7.5	42.1
Flushing after milking	158	1799	3.1	393	7.1	42.6
	170	1,800	4.2	390	7.5	45.7
	173	1,800	3.9	390	7.3	45.6
	176	0	0.0	390	0.0	0.3
	179	1,800	2.8	390	7.3	10.8
	182	0	0.0	390	0.0	0.3
	185	0	0.0	390	0.0	0.3
	188	0	0.0	390	0.0	0.3
	191	0	0.0	390	0.0	0.3
	194	1,800	4.1	390	7.2	45.5
	197	1,800	3.5	393	7.5	37.4
	200	1,800	2.4	390	7.3	31.2
	203	1,800	2.1	390	7.6	11.6
	206	0	0.0	390	0.0	0.3
	209	0	0.0	390	0.0	0.2
	212	1,800	4.2	396	7.3	45.4
	215	1799	3.2	390	7.5	23.8
	218	1,800	1.1	390	7.2	15.7
	220	0	0.0	390	0.0	0.3
End of the milking cycle						

Note: A – Time of milking [min]; B – Frequency of motor rotation [rpm]; D – Power [kW]; E – Voltage [V]; F – Current [A]; G – Vacuum [kPa].

Table 4. Statistical evaluation of the values measured throughout the milking cycle without frequency convertor

	Frequency of motor rotation [rpm]	Frequency of output voltage [Hz]	Power [kW]	Voltage [V]	Current [A]
Average	1,799.9	3.8	392.6	7.4	42.0
Average error	0.05	0.004	0.3	0.2	0.03
Median	1,800	3.8	393.0	7.5	42.0
Modus	1,800	3.8	393.0	7.5	42.0
Standard deviation	0.3	0.03	2.1	0.12	0.16
Variation coefficient [%]	0.02	0.8	0.5	1.6	0.4
Scatter	0.1	0.001	4.4	0.02	0.03
Spikiness	3.9	6.2	-0.76	-0.04	2.2
Skewness	-2.4	2.8	0.15	-0.7	1.5
Difference max-min	1	0.1	7	0.5	0.7
Minimum	1,799	3.8	389	7.1	41.8
Maximum	1,800	3.9	396	7.6	42.5
Total	73,795	156.2	1,095	303.7	1,724.5
Number	41	41	41	41	41
Confidence level (95 %)	1,800	3.8	393.2	7.4	42.1

Measurement of electric power consumption

Based on the monitoring of the consumption of electric energy in the process of vacuum generation the energy consumption of the variants was compared and percentage of electricity savings were determined in the variant with frequency convertor. Such evaluation of savings has been made for other parlor systems (Pittermann, 2008; Pavelka & Zdenek, 2010). Table 5 lists the measurement results along with other values from the milking parlor system database.

Table 5. Monitoring of electric energy consumption with and without frequency convertor

Measurement of electric energy consumption with frequency converter						Measurement of electric energy consumption without frequency converter					
No. of measurement	Start of milking process[-]	End of milking process[-]	Milking duration [h]	Number of tested dairy cows [pcs]	Energy consumption [kWh]	No. of measurement	Start of milking process [-]	End of milking process [-]	Milking duration [h]	Number of tested dairy cows [pcs]	Energy consumption [kWh]
1	15:10	17:23	2.22	173	6.7	21	15:10	17:23	2.22	172	12.6
2	03:54	6:27	2.55	174	7.0	22	03:54	6:27	2.55	173	12.8
3	15:09	17:25	2.27	173	6.8	23	15:09	17:25	2.27	172	12.6
4	03:49	6:12	2.38	172	6.9	24	03:49	6:12	2.38	171	12.7
5	15:14	17:36	2.37	172	6.9	25	15:06	17:25	2.32	170	12.7
6	03:52	6:12	2.33	172	6.8	26	03:43	6:16	2.55	172	12.8
7	15:12	17:35	2.38	172	6.9	27	15:10	17:27	2.28	169	12.7
8	03:49	6:12	2.38	173	6.9	28	03:47	6:17	2.50	171	12.8
9	15:13	17:39	2.43	174	7.0	29	15:11	17:20	2.15	171	12.6

Table 5 (continued)

10	03:40	6:16	2.60	175	7.1	30	03:46	6:01	2.25	172	12.7
11	15:15	17:28	2.22	173	6.8	31	15:15	17:32	2.28	172	12.7
12	03:42	6:12	2.50	173	7.1	32	03:49	6:14	2.42	173	12.8
13	15:13	17:27	2.23	172	6.8	33	15:03	17:25	2.37	173	12.8
14	03:49	6:10	2.35	171	6.9	34	03:45	6:04	2.32	172	12.8
15	15:10	17:24	2.23	173	6.7	35	15:13	17:27	2.23	172	12.7
16	03:44	6:03	2.32	172	6.8	36	03:49	6:10	2.35	172	12.8
17	15:17	17:26	2.15	172	6.8	37	15:15	17:28	2.22	171	12.7
18	03:41	6:11	2.50	172	7.1	38	03:40	6:16	2.60	171	12.9
19	15:06	17:27	2.35	172	6.9	39	15:13	17:39	2.43	172	12.8
20	03:39	6:03	2.40	172	7.0	40	03:54	6:17	2.38	172	12.7

Statistical evaluation of electricity consumption

Electric energy consumption is different when milking with or without the use of the frequency convertor, as confirmed by the results of the statistical evaluation of the consumption measurement for the individual measurements listed in Table 6.

In measured values and in calculations, it is evident that the use of the frequency convertor for the regulation of the vacuum was advantageous both in terms of energy savings, as well as in terms of noise in operation and the lifetime of the pump. Measurements and calculations have shown that this system saves more than 50% of the electricity. Also, the ecological safety of the vacuum system operation and the saving of oil, which is not necessary for the operation of an air pump, is not negligible (Přikryl et al., 2015, Přikryl et al., 2016).

Table 6. Statistical evaluation of energy consumption measurement with and without frequency convertor

	Statistical evaluation of energy consumption measurement with frequency inverter			Statistical evaluation of energy consumption measurement without frequency inverter		
	Milking duration [h]	Number of dairy cows [pcs]	Energy consumption [kWh]	Milking duration [h]	Number of dairy cows [pcs]	Energy consumption [kWh]
Average	2.35	172.60	6.89	2.35	171.70	12.74
Average error	0.03	0.21	0.03	0.03	0.22	0.02
Median	2.36	172.00	6.90	2.34	172.00	12.70
Modus	2.38	172.00	multiple	multiple	172.00	multiple
Standard deviation	0.12	0.94	0.12	0.12	0.99	0.08
Variation coefficient [%]	5.04	0.54	1.79	5.29	0.58	0.64
Scatter	0.01	0.88	0.02	0.02	0.98	0.01
Spikiness	-0.35	0.98	-0.73	-0.53	1.59	-0.41
Skewness	0.29	0.95	0.29	0.49	-1.01	-0.11
Difference max-min	0.45	4.00	0.40	0.45	4.00	0.30
Minimum	2.15	171.00	6.70	2.15	169.00	12.60
Maximum	2.60	175.00	7.10	2.60	173.00	12.90
Total	47.16	3,452.00	137.90	47.07	3,433.00	254.70
Number	20.00	20.00	20.00	20.00	20.00	20.00
Confidence level (95%)	2.41	173.00	6.95	2.41	172.10	12.77

The high quality of the milking process in modern milking systems, especially represented by milking robots and robotized milking parlors, is nowadays difficult to imagine without the use of frequency convertors (Ströbel et al., 2012; Přikryl et al., 2015). Assessment of indoor environment quality in stables (Herbert et al., 2015) and the application of modern imaging (Libich et al., 2017) and monitoring methods (Hartová et al., 2017b) are going to improve livestock management. Other increase of milking process efficiency could be by better improvement of dairy cow movement and welfare monitoring (Hartová et al., 2017a).

CONCLUSION

The measurements and calculations clearly demonstrate the advantages of running vacuum systems with vacuum regulation by frequency convertors. This system can be recommended to all dairy farmers for creating, controlling and stabilizing vacuum. By measuring it was also found that although the maximum speed of the pump motor is 2,800 rpm, it is not necessary to set this rotation frequency in the basic adjustment of the frequency converter because the increase of the motor speed above 2,600 rpm does not increase pump performance. It is also important to ensure that the rotation speed of the pump does not fall below the minimum rotational speed set by the manufacturer to 1,000 rpm to ensure that the gears and bearings in the vacuum pump are thoroughly lubricated (spray lubrication). It is therefore necessary to set a minimum frequency of 28 Hz when adjusting the basic frequency drive (this is the recommendation for the service personnel who perform the installation and regular maintenance of the vacuum system).

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