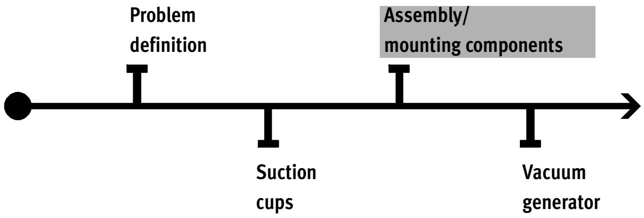
Selecting assembly/mounting attachments



Check list

Workpiece	Vacuum port	Type of connection	Type of mounting
Consideration of the workpiece surface • Angle compensator for very uneven surfaces • Spring-mounted holders for sensitive workpieces as well as varying pick-up heights	Positioning of the vacuum tubing • top • at side	Selecting the vacuum port for the suction cup holder • Thread, push-in connector, barbed fitting	Mounting the suction cup holder on the handling unit, e.g. robot arm • Female/male thread

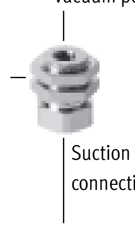
Selecting the suction cup holder

The suction cup holder as well as the “angle compensator” and “vacuum filter” accessories are selected on the basis of the previously defined suction cup diameter.
According to the problem example, the workpieces must be picked up and set down with the aid of a spring.
The vacuum lines should be attached at the side using push-in connectors.

The suction grippers should be mounted with external threads.

- Spring-loaded holders:
  In the event of excess stroke and height tolerances, it is recommended that you use a holder with a height compensator – the same applies for sensitive workpieces that need to be placed gently and with the aid of a spring.

- Choice of vacuum ports [1]:
  - top
  - at side
- 3 connection types [1]:
  - Push-in connector QS
  - Barbed fitting PK
  - Thread G
- Different mounting threads for holder [2]:
  - Female thread
  - Male thread



Round suction cup

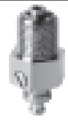
From problem example ↓

Suction cup ∅ [mm]	2	4	6	8	10	15	20	30	40	50	60	80	100	150	200
Holder size	1		2		3		4				5			6	
Suction cup connection [3]	3 mm		4 mm		M4x0.7		M6x1				M10x1.5			M20x2	
Ordering data	→ esh														

Oval suction cup

Suction cup size [mm]	4x10	4x20	6x10	6x20	8x20	8x30	10x30	15x45	20x60	25x75	30x90
Holder size	4							5			
Suction cup connection [3]	M6x1							M10x1.5			
Ordering data	→ esh										

Holder type

						From problem example ↓			
		 HA	 HB	 HC	 HCL	 HD	 HDL	 HE	 HF
→	Height compensation	–	–					–	
	Vacuum port [1]								
	Top		–			–	–		
→	At side	–		–	–			–	–
→	Threaded connection G								
	Push-in connector QS							–	–
	Barbed fitting PK							–	–
	Mounting threads for holder [2]								
	Female thread	–		–	–	–	–	–	–
→	Male thread		–						

Result

Taking all requirements into account:
Suction cup holder HD, size 4

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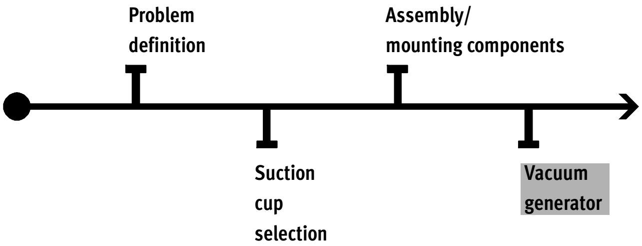
Selecting vacuum generators



The criteria referred to in the check list therefore play an important role in the selection of a suitable ejector.

- Total volume
- Cycle time
- Economy
- Functions
- Design specifications

Note

Almost all Festo vacuum ejectors achieve a vacuum level of approx. 85%, with the exception of the new VN ejectors, which are specially designed for low pressure of approx. 50%.

All ejectors can thus be used for handling tasks involving light to heavy workpieces or loads.

Check list

Total volume

How high is the total volume to be drawn in?

- Take into account the suction cup volume
- Take into account the suction cup holder volume
- Calculate the tube volume

Cycle time

How long does an operation cycle take?

- Calculate the evacuation time
- Determine the handling/return time
- Calculate the air supply time

Economy

How high are the energy costs?

- Calculate the energy costs based on the air consumption and number of operation cycles

Functions

What additional functions should the vacuum generator have?

- Filters, controls, non-return valves, vacuum switches, exhaust function, etc.

Design specifications

What specifications exist?

- Dimensions, weight, mounting position, etc.

Step 1: Determining the total volume of the system (volume to be drawn in)

The suction cup, holder and tube volumes must be determined and added together to form the total volume.

Suction cup volume V_1

The suction cup volumes are specified in the datasheet for the relevant vacuum suction grippers ESG, VAS, VASB.
The suction cup volume may be specified in a table or chart, depending on the product family.
In our sample application we opted for 2 suction grippers:

- Round design
- Suction cup diameter 40 mm
- Breakaway force of 69.6 N

For these suction cups, the datasheet specifies a suction cup volume of 1,566 mm^3 per suction cup.

$$V_1 = 2 \times 1{,}566\ mm^3 = 3{,}132\ mm^3$$

Suction cup holder volume V_2

Because of the huge range of different holder types and connection options, tables listing all of the suction cups and their relevant volumes have been created in the datasheet for the ESG product family.

In our sample application we chose the following suction cup holders:

- Suction cup holder HD
  Size 4 with QS connector

$$V_2 = 678\ mm^3$$

Tube volume V_3

Once the suction cups, suction cup holders and connection options have been defined, the tube volume can be determined.

Tubing PUN:
Outside/inside ∅ [mm]
3.0/2.1
4.0/2.6
6.0/4.0
8.0/5.7
10.0/7.0

The following formula must be used when calculating the volume:

$$V_3 = \pi \times \frac{D^2}{4} \times L$$

D = Tube inside ∅ [mm]
L = Tube length [mm]

In the sample application a suction cup holder with QS-6 couplings is used. A tube with an outside diameter of 6 mm is therefore required.
In order to connect the vacuum generator to both suction cups, a tube length (L) of approx. 1 m (1,000 mm) is required.

$$V_3 = \pi \times \frac{4^2}{4} \times 1\,000$$

$$V_3 = 12\,566\ mm^3$$

Total volume V_T

$$V_T = V_1 + V_2 + V_3$$
$$V_T = 3{,}132 + 678 + 12{,}566$$
$$V_T = 16{,}376\ mm^3\ (16.38\ cm^3)$$

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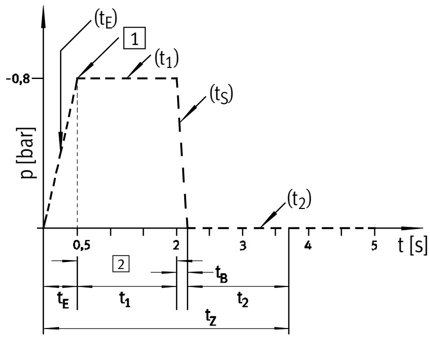
Step 2: Determining the cycle time

T_C = Evacuation time t_E + handling time t_1 + air supply time t_S + return time t_2



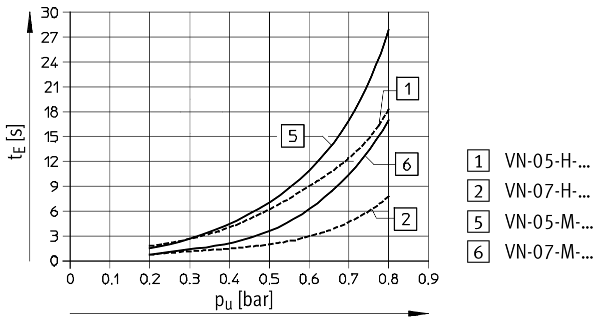
t_E = Evacuation time
t_1 = Transport
t_S = Discharge
t_2 = Return
[1] = Pick-up
[2] = Time saved

An operation cycle can be subdivided into individual time intervals, which must be either measured or calculated. The individual times added together produce the cycle time.

Evacuation time t_E

The evacuation time, i.e. the time taken for a volume to reach a certain vacuum level, is very useful for assessing the performance of a vacuum generator. The evacuation time can be found in the datasheet of the relevant vacuum generator. This example depicts charts for some of the vacuum generators of the VN-... product family.

Evacuation time t_E for 1 litre volume at 6 bar operating pressure p_u



Calculation:
In Step 1 of the sample application we determined a total volume for the vacuum system of V_T = 16.38 cm^3 (17 cm^3). Using a basic rule of three, we can now calculate the evacuation time t_E for this system with any vacuum generator. According to the problem definition, $t_E < 0.5$ s, based on a vacuum level of 80%.

Example 1: VADMI-45
$t_E = V_T \times t_{E1}/1{,}000$
t_E = 17 cm^3 x 25 s/1,000 cm^3
t_E = 0.425 s (0.43 s)

Example 2: VADMI-70
$t_E = V_T \times t_{E1}/1{,}000$
t_E = 17 cm^3 x 11 s/1,000 cm^3
t_E = 0.187 s (0.19 s)

Example 3: VN-07-H
$t_E = V_T \times t_{E1}/1{,}000$
t_E = 17 cm^3 x 8 s/1,000 cm^3
t_E = 0.136 s (0.14 s)

t_E = Evacuation time (V_T)
t_{E1} = Evacuation time (V = 1,000 cm^3)
V_T = Total volume (from example)

Handling time t_1

The time required to handle the workpiece after the end of the suction process (e.g. determined using a stopwatch = 1.5 s).

Air supply time t_S

Time needed by the vacuum system to build up the pressure (vacuum) again and set down the workpiece. The air supply time can be found in the technical data for the relevant vacuum generator.

The specifications apply to 1 litre volume at 6 bar operating pressure at max. vacuum level.

Using a basic rule of three, we can now calculate the air supply time t_S for this system.

t_S = Evacuation time (V_T)
t_{S1} = Evacuation time (V = 1,000 cm^3)
V_T = Total volume (from example)

Example 1: VADMI-45
$t_S = V_T \times t_{S1}/1{,}000$
t_S= 17 cm^3 x 1.9 s/1,000 cm^3
t_S = 0.03 s

Example 2: VADMI-70
$t_S = V_T \times t_{S1}/1{,}000$
t_S= 17 cm^3 x 0.59 s/1,000 cm^3
t_S= 0.01 s

Example 3: VN-07-H
$t_S = V_T \times t_{S1}/1{,}000$
t_S= 17 cm^3 x 1.1 s/1,000 cm^3
t_S= 0.02 s

Return time t_2

The time needed by the vacuum system to return to the initial position after the workpiece has been set down (e.g. determined using a stopwatch = 1.5 s).

Cycle time t_C

Example 1: VADMI-45
$t_C = t_E + t_1 + t_S + t_2$
t_C = 0.43 + 1.5 + 0.03 + 1.5
t_C = 3.46 s

Example 2: VADMI-70
$t_C = t_E + t_1 + t_S + t_2$
t_C = 0.19 + 1.5 + 0.01 + 1.5
t_C = 3.2 s

Example 3: VN-07-H
$t_C = t_E + t_1 + t_S + t_2$
t_C = 0.14 + 1.5 +0.02 + 1.5
t_C = 3.16 s

→ Internet: www.festo.com/catalogue/...

Step 3: Checking economy of operation

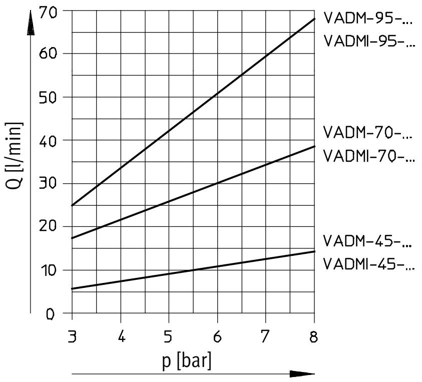
Energy costs are determined on the basis of air consumption.

Determining the air consumption per operation cycle Q_C

These charts are also included in the datasheet for the relevant vacuum generator (e.g. VADM-..., VADMI-...). The VADMI-... vacuum generators have a built-in non-return valve which maintains the vacuum after the vacuum generator has been switched off (prerequisite: there must be no leakage in the system).

When combined with the vacuum switch it provides an air-saving function, i.e. no air is consumed during transport of the workpiece. The VN-... vacuum generators do not have this function. This means, therefore, that the vacuum generator remains in operation so that it can hold the workpiece during transport.

Air consumption Q as a function of operating pressure p



Q_Z = Air consumption per operation cycle
t_E = Evacuation time for application
Q = Air consumption per vacuum generator [l/min]

Example 1: VADMI-45

$$Q_Z = t_E \times \frac{Q}{60}$$
$$Q_Z = 0.43\ s \times \frac{11\ l}{60\ s}$$
$$Q_Z = 0.08\ l$$

Example 2: VADMI-70

$$Q_Z = t_E \times \frac{Q}{60}$$
$$Q_Z = 0.19\ s \times \frac{31\ l}{60\ s}$$
$$Q_Z = 0.10\ l$$

Example 3: VN-07-H

$$Q_Z = (t_E + t_1) \times \frac{Q}{60}$$
$$Q_Z = (0.13\ s + 1.5\ s) \times \frac{28\ l}{60\ s}$$
$$Q_Z = 0.76\ l$$

Determining the number of operation cycles per hour Z_h

Z_h = Operation cycles per hour
t_Z = Time per operation cycle
t_E = Evacuation time for application

Example 1: VADMI-45

$$Z_h = \frac{3,600\ s}{t_Z}$$
$$Z_h = \frac{3,600\ s}{3.46\ s}$$
$$Z_h = 1,040$$

Example 2: VADMI-70

$$Z_h = \frac{3,600\ s}{t_Z}$$
$$Z_h = \frac{3,600\ s}{3.2\ s}$$
$$Z_h = 1,125$$

Example 3: VN-07-H

$$Z_h = \frac{3,600\ s}{t_Z}$$
$$Z_h = \frac{3,600\ s}{3.16\ s}$$
$$Z_h = 1,139$$

Determining the air consumption per hour Q_h

Q_h = Air consumption per hour
Q_C = Air consumption per operation cycle
C_h = Operation cycles per hour

Example 1: VADMI-45

$$Q_h = Q_C \times C_h$$
$$Q_h = 0.08\ l \times 1,040$$
$$Q_h = 83.20\ l\ (0.08\ m^3)$$

Example 2: VADMI-70

$$Q_h = Q_C \times C_h$$
$$Q_h = 0.10\ l \times 1,125$$
$$Q_h = 112.5\ l\ (0.12\ m^3)$$

Example 3: VN-07-H

$$Q_h = Q_C \times C_h$$
$$Q_h = 0.76\ l \times 1,139$$
$$Q_h = 865.64\ l\ (0.87\ m^3)$$

Determining the energy costs per year K_{EA}

K_{EA} = Energy costs per year
Q_h = Air consumption per hour

Costs for compressed air[1]:
1 m³ at 7 bar: € 0.02/m³,
at an electricity price of
€ 0.10/kWh

$$K_{EA} = Q_h \times \text{Compressed air costs}/m^3 \times \frac{t_{operating}}{\text{Day}} \times \frac{t_{operating}}{\text{Year}}$$

Vacuum generator	Air consumption per cycle Q_Z [l]	Cycles per hour Z_h	Air consumption per hour Q_h [m^3]	Energy costs per year K_{EA}[2] [€]
VADMI-45	0.08	1,040	0.08	5.76
VADMI-70	0.10	1,125	0.12	8.64
VN-07-H	0.76	1,139	0.87	62.63

1) Material, depreciation and labour costs, etc. are reflected in the price
2) Energy costs for shift operation 16 hours/day and 220 days/year

Step 4: Taking additional functions/components and design specifications into account

Selecting additional functions/components:

Selection of these components is guided by specific requirements in terms of performance and functionality, as well as by the place of operation and application of the system. All details regarding performance or components are provided in the datasheet on the relevant product.

Solenoid valves

A vacuum system needs solenoid valves for controlling vacuum generation. These switch the vacuum on and off.

Vacuum generator
- VADM-..., VADMI-...
- VAD-M-..., VAD-M...-I-...

Operation cycles can be accelerated and optimised by adding an extra valve as an ejector pulse generator.

Vacuum generator
- VADMI...-
- VADM...-I-...

Note

The nominal flow rate of the solenoid valve must not be lower than the suction capacity of the vacuum generator at atmospheric pressure. (Both specifications can be found in the datasheet for the relevant product.)

Vacuum switch

- Reliability through pressure monitoring
- Adjustable switching point
- Fast hysteresis adjustment
- Digital/analogue signal output
- Display
- Ports

Filter

- Reliability: no contamination of the system
- Extension of the product life cycle and reduction of maintenance intervals

Pressure gauge

- Manual pressure monitoring of the system
- Safety function

Silencers

- Noise pollution kept to a minimum

Taking design specifications into account

The following design specifications must be taken into account when configuring a vacuum system:
- Size
- Weight
- Resistance

Calculation example summary

The cycle time and economy of the ejectors were used as selection criteria.

Selection of suction cups

Taking the mass and force calculations plus all criteria into account, we get the following result:

Quantity	2 units
Design	round
Suction cup ∅	40 mm
Breakaway force	69.4 N
Material	Polyurethane

Selecting assembly and mounting attachments

The result takes all system requirements into account:

Holder type	HD
Size	4

Selecting vacuum generators

We compared three vacuum generators chosen at random from the Festo product range:

Compact ejectors	VADMI-45
	VADMI-70
Inline ejectors	VN-07-H

Result

Compact ejector VADMI-45

Cycle time

All three vacuum generators lay within a reasonable timeframe in the sample application and were below the maximum time of 3.5 seconds specified in the problem definition.

Economy

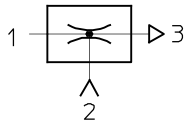
The vacuum generator VADMI-45 came off best in terms of energy consumption and, consequently, energy costs. The two compact ejectors VADMI-45 and VADMI-70 produced almost identical results in relation to energy costs. Although the larger VADMI-70 has a somewhat higher air consumption per unit of time, it can generate the vacuum faster.

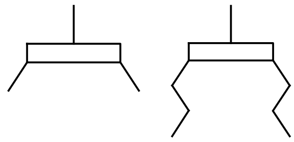
The VADMI-45, on the other hand, has a smaller nozzle diameter and thus significantly lower air consumption. However, it cannot generate the vacuum as quickly as the VADMI-70. The number of cycles per unit of time and the quantities are almost identical for all three vacuum generators.

Basic principles of vacuum technology

Introduction

Products for vacuum technology





Vacuum generator

A vacuum ejector is the central element of any vacuum system. Festo offers an extensive range of vacuum ejectors for all kinds of applications and performance requirements:

Basic and inline ejectors

Vacuum generators

VN-…, VAD-…/VAK-…

Compact ejectors

Vacuum generators

VADM-…/VADMI-…,

VAD-M…/VAD-M…-I-…

Vacuum suction gripper

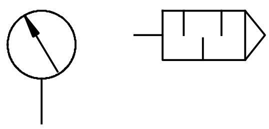
The suction grippers are the connecting element between the vacuum system and the workpiece.

Given the huge variety of surface finishes, shapes and temperatures as well as different workpiece masses, a comprehensive range of suction cups and possible combinations is needed.

With its suction cup range and the modular suction gripper ESG, Festo has a solution for every application:

Modular suction gripper ESG-…

Suction cups VAS-…/VASB-…



Vacuum accessories

Controlling, measuring, checking, filtering, etc. are important functions which, if not already included as standard in a vacuum system, can be added through an extensive range of accessories.

Vacuum security valve ISV-…

Vacuum gauges VAM-…

Vacuum filters VAF-…

Vacuum switches VPEV-…

Other accessories:

Height compensators, adapters

Tubing

QS push-in fittings