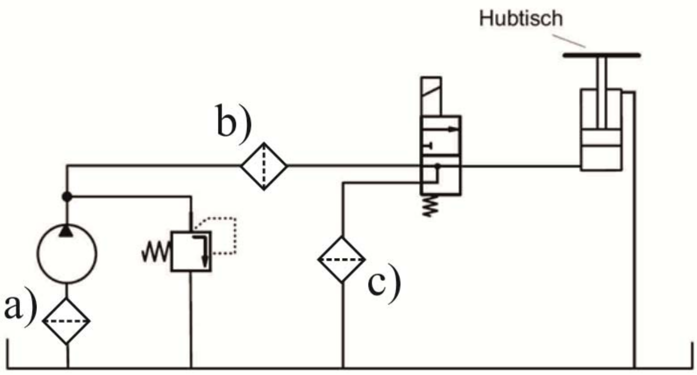
Sample Solution for Exercise: 1 Total Score: 15

subtask		Points
1.1	+ high power density + simple realization of linear movement + good controllability + good time response due to low mass inertia + simple and dependable overload protection + good lubrication and removal of heat losses via the fluid - losses due to friction and internal leakage => power consumption - Sensitivity of the components towards contamination and wear => preventive maintenance of the pressurizing medium - noise emission, leakage, fire hazard => environmental pollution/damage	0.5 0.5 0.5 0.5
1.2	1. volume connection; power transfer 2. lubrication; cooling; particle removal	0.5 0.5
1.3	$p = \frac{F}{A} \Leftrightarrow A = \frac{F}{p} = \frac{(6500\,kg + 850kg) \cdot 9.81\frac{m}{s^2}}{200 \cdot \frac{10^5 N}{m^2}} = 3605.18\,mm^2$ $A = \frac{\pi}{4}d^2 \Leftrightarrow d = \sqrt{\frac{4A}{\pi}} = 67.75\,mm$ Auswahl => Durchmesser 70 mm	1.0 0.5 0.5
1.4	$Q = \dot{x} \cdot A = \frac{150\,cm}{6\,s} \cdot 7^2 cm^2 \cdot \frac{\pi}{4} = 57.73\frac{l}{min}$ $V = \frac{Q}{\eta \cdot n} = 41.38\frac{cm^3}{U}$ Auswahl => Pumpengröße 50 cm³/U	1.0 0.5 0.5
1.5	$p = \frac{F}{A} = \frac{(6500\,kg + 850\,kg) \cdot 9.81\,\frac{m}{s^2}}{0.07^2\,m^2 \cdot \frac{\pi}{4}} = 187.36\,bar$ $T = x \cdot \frac{A}{Q} = \frac{150\,cm \cdot 7^2 cm^2 \cdot \frac{\pi}{4}}{50\frac{cm^3}{U} \cdot 1500\,\frac{U}{min} \cdot 0.93} = 4.97\,s$	0.5 0.5
	Sum:	**8.0**

Sample Solution for Exercise: 1

<table>
<tr><th>subtask</th><th></th><th>Points</th></tr>
<tr><td>1.6</td><td>
<table>
<tr><td>Ordinal number</td><td>Particle size</td><td>Particle count</td></tr>
<tr><td>19</td><td>>4 µm</td><td>5000</td></tr>
<tr><td>18</td><td>>6 µm</td><td>2500</td></tr>
<tr><td>16</td><td>>14 µm</td><td>640</td></tr>
</table>
</td><td>2.0
1 p./ correct column</td></tr>
<tr><td>1.7</td><td>


a) Suction filter
b) High pressure filter
c) Return line/flow filter
d) by-pass filter (including by-pass-circuit pump)</td><td>0.5 for correct symbol

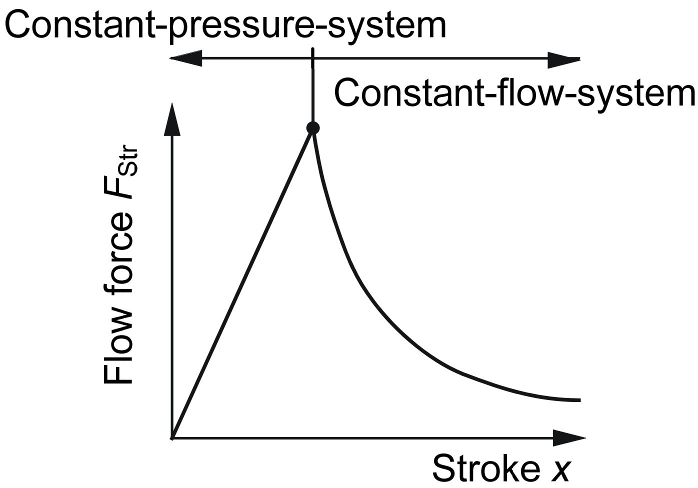
0.5
0.5
0.5</td></tr>
<tr><td>1.8</td><td>
$$L_H = \frac{\Delta p}{\dot{Q}}$$
$$Q = \dot{x} \cdot A \Rightarrow \dot{Q} = \ddot{x} \cdot A$$
$$F = m \cdot \ddot{x} \Leftrightarrow \frac{\Delta p \cdot A}{m} = \ddot{x}$$
$$L_H = \frac{\Delta p}{\dot{Q}} = \cdots = \frac{m}{A^2}$$
</td><td>0.5

0.5
0.5

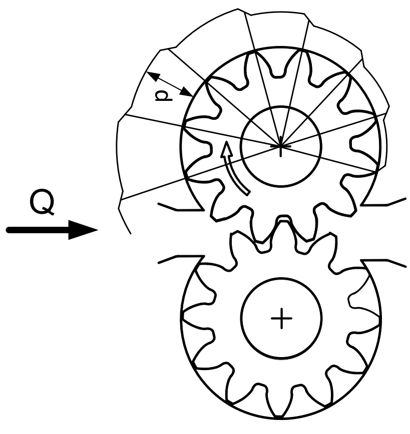
0.5
0.5

0.5</td></tr>
<tr><td></td><td>Sum:</td><td>7.0</td></tr>
</table>

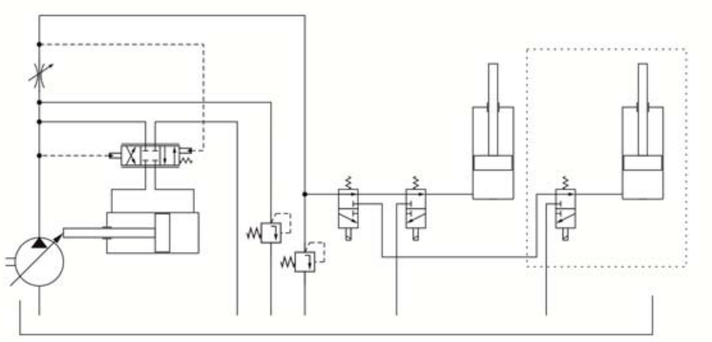
Sample Solution for Exercise: 2 **Total Score: 10**

Subtask	Wb	**Points**
2.1	- Check valve - Directional control valve - Pressure control valve - Flow control valve	2.0
2.2	- Sliding spool - Flapper-nozzle - Jet pipe	1.5
2.3	$Q = \alpha_D \cdot A \cdot \sqrt{\frac{2}{\rho}} \cdot \sqrt{\Delta p} \quad ; \quad A = \pi \cdot d \cdot x$ $x = \frac{Q \cdot \sqrt{\frac{\rho}{2 \cdot \Delta p}}}{\alpha_D \cdot \pi \cdot d} = \frac{60 \, \frac{l}{min} \cdot \sqrt{\frac{870 \, \frac{kg}{m^3}}{2 \cdot 210 \, bar}}}{0{,}6 \cdot \pi \cdot 10 \, mm} = 0{,}241 \, mm$	1.5
2.4	$F_{Str} = \rho \cdot v \cdot Q \cdot \cos(\varepsilon) \quad ; \quad v = \frac{Q}{A \cdot \sin(\varepsilon)}$ $\varepsilon = arc \tan\left(\frac{\rho \cdot Q^2}{F_{Str} \cdot A}\right) = arc \tan\left(\frac{870 \, \frac{kg}{m^3} \cdot (60 \, \frac{l}{min})^2}{66{,}34 \, N \cdot \pi \cdot 10 \, mm \cdot 0{,}241 \, mm}\right)$ $\varepsilon = 60°$	1.5
2.5	in closing direction	0.5
2.6		1.5
2.7	- see 2.6 -	1,0
	Sum:	10

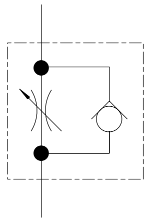
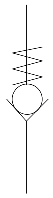
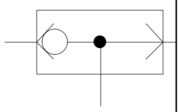
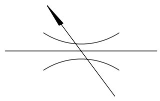
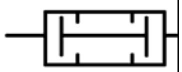
Sample Solution for Exercise: 3 Total Score: 10

Subtask	Sk	Points
3.1	Swash plate pump	0.5
3.2	1. Valve plate, 2. Piston, 3. Swash plate, 4. Slipper, 5. Cylinder block	2.5
3.3	$V = z \cdot A_k \cdot D_k \cdot \sin\alpha$ $V = 9 \cdot 2cm^2 \cdot 2{,}25cm \cdot \sin(18°) = 12{,}515cm^3$	1
3.4	$Q_{compression} = \frac{(V + z \cdot V_{dead}) \cdot \Delta p}{E_{oil}} \cdot n$ $Q_{th} = V \cdot n$ $\frac{Q_{compression}}{Q_{th}} = \frac{(12{,}515 + 9 \cdot 0{,}1)cm^3 \cdot 200bar}{12{,}515cm^3 \cdot 16000bar} = 1{,}33989\%$	2
3.5	$\delta = 1 - \cos(\frac{90°}{z}) = 1 - \cos(\frac{90°}{9}) = 0{,}0152$	1
3.6	$P_{ab-Motor} = P_{th} + P_{Kompression} = V \cdot n \cdot \Delta p + \frac{V \cdot \Delta p^2}{2 \cdot E_{Öl}} \cdot n$ $P_{ab-Motor} = 62{,}575 l/\min \cdot 200bar + \frac{62{,}575 l/\min \cdot (200bar)^2}{2 \cdot 16000bar}$ $P_{ab-Motor} = 20.858W + 130{,}36W = 20.988W$	1
3.7	No, because even with ideal reversing process the death volume inside a piston must be compressed. The throtteling losses occurring in the process can not be regained.	1
3.8	 	1
	Sum:	10

Sample Solution for Exercise: 4 Total Score: 10

Subtask	Di	**Points**
4.1	The system pressure is controlled	0.5
	It is a piloted pressure control	0.5
	It is used for constant pressure systems, load-sensing system and the like	0.5
4.2	Flushing valves are used to change the oil for cooling or filtering.	0.5
	Flushing valves are used in closed circuits, because oil is exchanged in open circuits nevertheless.	0.5
4.3		
	The cylinder for adjusting the pump is integrated.	0.5
	The measuring orifice is integrated.	0.5
	The valve is integrated.	0.5
	The valve is integrated properly.	0.5
4.4	The PRV is integrated in front oft he orifice.	0.5
4.5	The cylinder is integrated and works	0.5
	The cylinder can be operated alternativly to the other one	0.5
4.6	Volume flow: $Q = v\ A$	0.5
	Valve pressure drop: 35 bar for Q=120 l/min,	
	Approach clear and correct	0.5
	Pump pressure: $p_{Pump} = p_{required,cylinder} + \Delta p_{valve}$	
	Drive power: $P = \frac{p_{Pump}\ Q}{\eta_{vol,Pump}\eta_{hm,Pump}}$	0.5
	Drive power P = 45,614 kW	0.5
4.7	Efficiency: $\eta_{hm,cylinder} = \frac{F_{pressure\ force} - F_{friction,cylinder}}{F_{pressure\ force}}$	0.5
	Efficiency: $\eta_{\text{hm, cylinder}}$ = 96,8%	0.5
4.8	Better at motor, worse at pump	0.5
	Neither is the idealisation correct, nor conservativ.	0.5
	Sum:	10

Sample Solution for Exercise: 5 Total Score: 15

<table>
<tr><th>Sub-task</th><th>vG</th><th>Points</th></tr>
<tr><td>5.1</td><td>
<table>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>AND-valve</td></tr>
</table>
</td><td>1</td></tr>
<tr><td>5.2</td><td>
<table>
<tr><td></td><td>Benefit ☺</td><td>Disadvantage ☹</td></tr>
<tr><td>high comressibility</td><td>energy accumulation, elastic drive behaviour</td><td>low static and dynamic stiffness in open control chains</td></tr>
<tr><td>low viscosity</td><td>low flow losses, high operating velocity</td><td>High leakage losses, low damping</td></tr>
</table>
</td><td>2</td></tr>
<tr><td>5.3</td><td>
<table>
<tr><td>2/2-way valve</td><td>3/2-way valve</td><td>5/2-way valve</td><td>4/2-way valve</td><td>4/3-way valve</td></tr>
<tr><td></td><td></td><td>x</td><td>x</td><td></td></tr>
</table>
</td><td>1</td></tr>
</table>

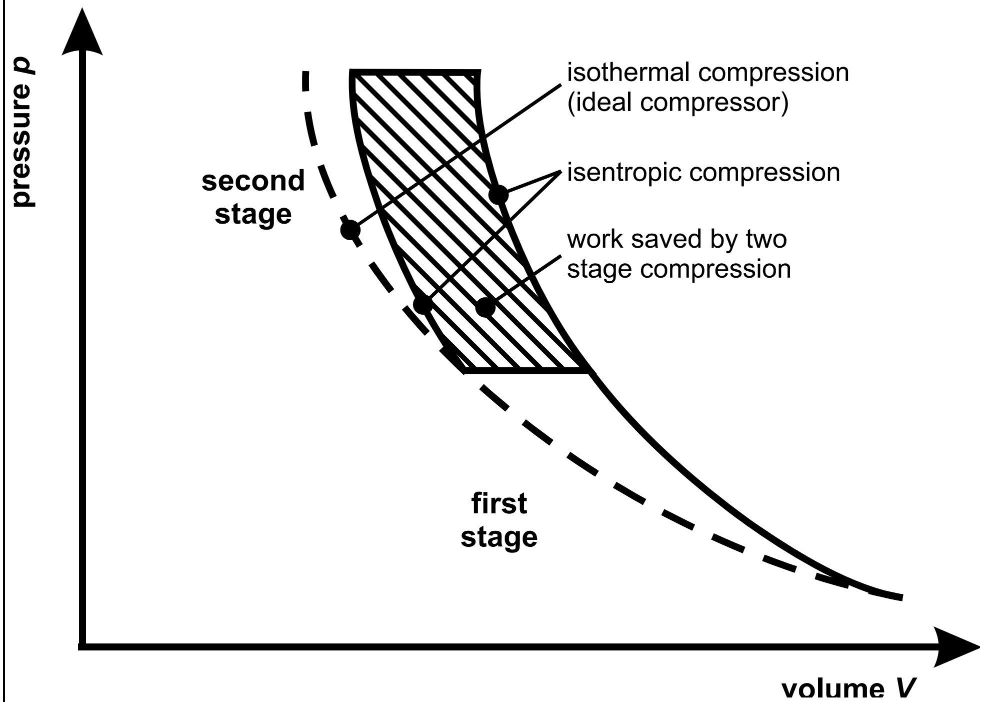
Sample Solution for Exercise: 5 Total Score: 15

<table>
<tr><td>Sub-task</td><td>vG</td><td>Points</td></tr>
<tr><td>5.4</td><td>DC solenoids:
<table>
<tr><td>Benefit ☺</td><td>Disadvantage ☹</td></tr>
<tr><td>avoiding of switching shocks, stuck solenoid does not blow, solenoid is overload-proof</td><td>protection of switching transistor against switch-off voltage is needed when switiching off, rectifier may be</td></tr>
</table>
AC solenoids :
<table>
<tr><td>Benefit ☺</td><td>Disadvantage ☹</td></tr>
<tr><td>short switching times, high tensile force, direct connection to alternating current network possible</td><td>strong temperature rise when in operation, sensitive to underload, winding can blow at overload, windings are sensitive because they are made of thin wires, actions for elimination of vibrations and eddy currents necessary</td></tr>
</table>
</td><td>2</td></tr>
<tr><td>5.5</td><td>
<table>
<tr><td>Supply Air Flow Control X</td><td>Exhaust Air Flow Control</td></tr>
</table>
Using supply air control reduces the acceleration at start, because the pressure buildup is slower compared to the exhaust air flow control.</td><td>1</td></tr>
</table>

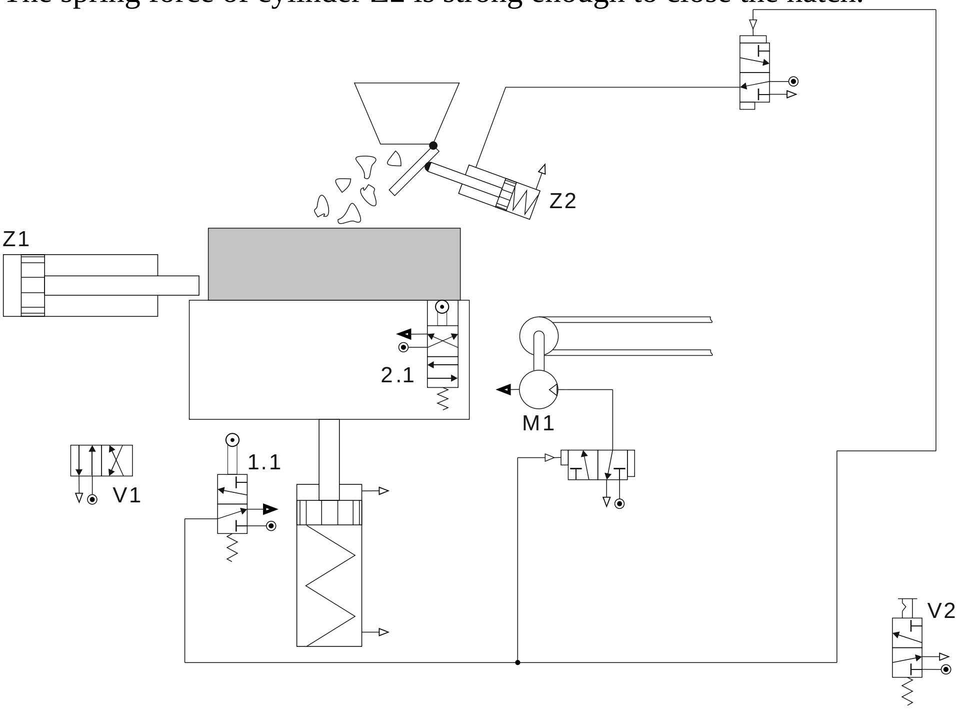
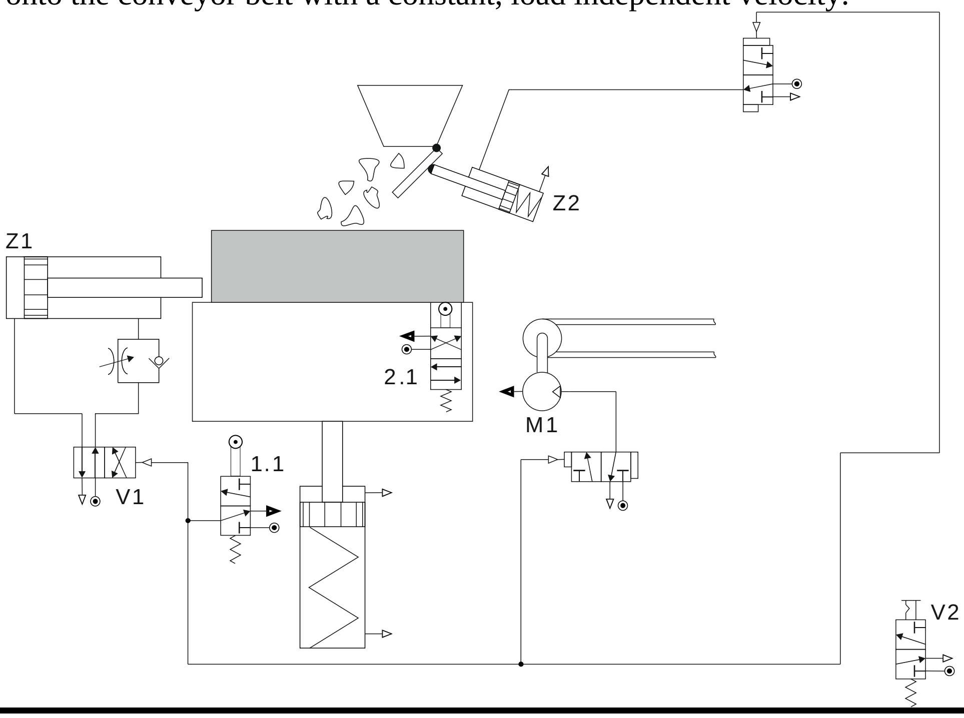
Sample Solution for Exercise: 5 Total Score: 15

5.6	Polytropic equation:	3
	$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = (\varepsilon_1)^{\frac{n-1}{n}}$	
	$T_2 = 293{,}15\ K \cdot 2{,}5^{\frac{0{,}4}{1{,}4}} = 380{,}88\ K$	
	$T_3 = T_2 + \Delta T = 290{,}88\ K$	
	With $T_{4,\max}$ = 393,15 K and $p_2 = p_3$ and isobatic cooling:	
	$\frac{T_{4,max}}{T_3} = \left(\frac{p_4}{p_2}\right)^{\frac{n-1}{n}} = (\varepsilon_2)^{\frac{n-1}{n}}$	
	$\Rightarrow \varepsilon_2 = \left(\frac{T_{4,max}}{T_3}\right)^{\frac{n}{n-1}} = \left(\frac{393{,}15\ K}{290{,}88\ K}\right)^{\frac{1{,}4}{1{,}4-1}} = 2{,}87$	
	$\Rightarrow p_4 = p_1 \cdot \varepsilon_1 \cdot \varepsilon_2$=7,18 bar	
5.7	Stationary flow process:	2
	$w_{12} = \frac{n}{n-1} R \cdot T_1 \cdot \left(\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right)$	
	$= \frac{1{,}4}{1{,}4-1} R \cdot 293{,}15\ K \cdot \left(\varepsilon_1^{\frac{n-1}{n}} - 1\right)$=88,12 kJ/kg	
	Massflow from norm volume flow:	
	$\dot{m} = Q_N \cdot \rho_N = Q_N \cdot \frac{p_N}{R_N \cdot T_N} = Q_N \cdot 1{,}2925 \frac{kg}{m^3} = 0{,}02154 \frac{kg}{s}$	
	Power:	
	$W_{12} = w_{12} \cdot \dot{m} = 1{,}898\ kW \cdot$	

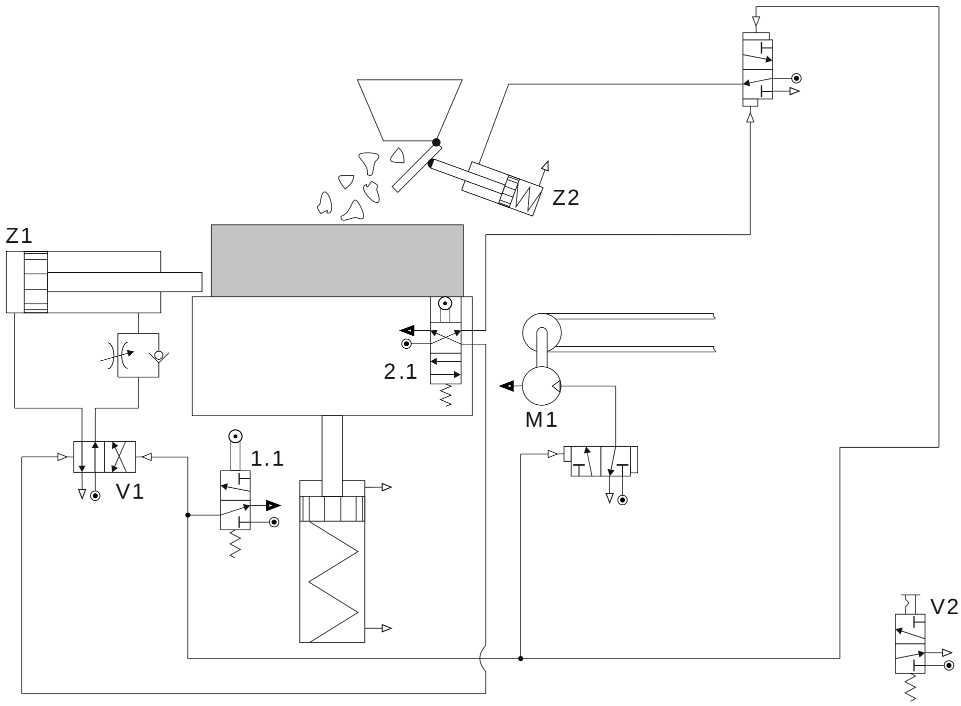
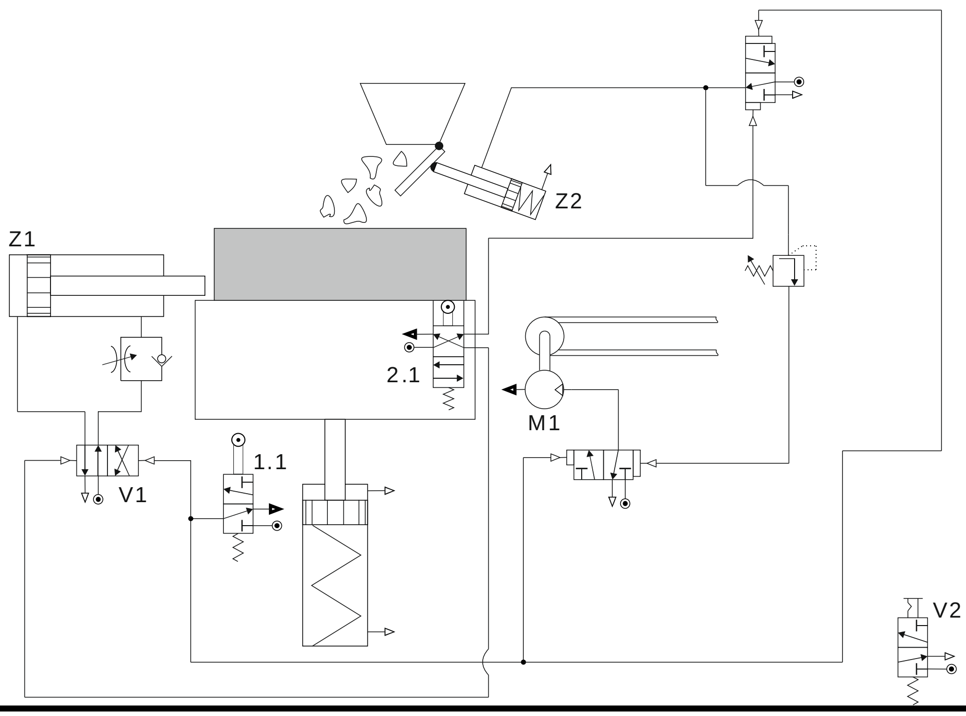
Sample Solution for Exercise: 5 Total Score: 15

Sub-task	vG	Points
5.8	Compression in the pV-diagram  	2
5.9	An isothermal compression is optimal for the compression: see 5.8	1
	Summation:	15

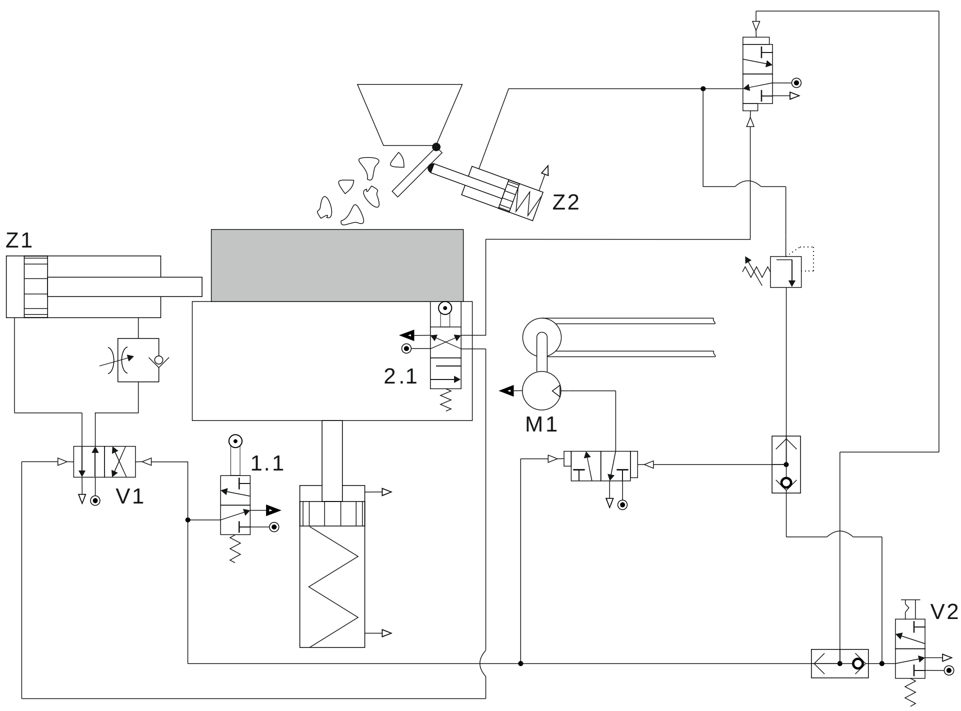
Sample Solution for Exercise: 6 Total Score: 10

Subtask	St	**Points**
6.1	When the box on the scales reaches the final weight, the hatch shall close with the help of cylinder Z2 and the conveyor belt M1 shall start moving. The spring force of cylinder Z2 is strong enough to close the hatch. 	2
6.2	Simultaneously with the operation in 6.1, cylinder Z1 shall push the box onto the conveyor belt with a constant, load independent velocity. 	1,5

Sample Solution for Exercise: 6 Total Score: 10

Subtask	St	**Points**
6.3	As soon as the box has left the scales, cylinder Z1 shall retract quickly. By placing a new box on the scales, cylinder Z2 opens the hatch again. 	1
6.4	When the pressure in cylinder Z2 has reached a defined pressure level during the hatch opening, the conveyor belt M1 will stop. 	1

Sample Solution for Exercise: 6 Total Score: 10

Subtask	St	**Points**
6.5	The activation of the emergency button V2 stops the conveyor belt M1 and closes the hatch Z2. Ensure that this operation is always performable and has a higher priority compared to contradicting operations. 	2
6.6	Checking, at wich pressure level a supercritical flow establishs: $\frac{p_U}{p_1} \leq b \Rightarrow p_1 = \frac{p_U}{b} = \underline{\underline{2{,}22\ bar}}$	0.5

Sample Solution for Exercise: 6 Total Score: 10

<table>
<tr><th>Subtask</th><th>St</th><th>Points</th></tr>
<tr><td>6.7</td><td>Checking, if supercritical flow is established:
$\frac{p_U}{p_1} = 0,33 \leq b \Rightarrow$ supercritical flow is provided
Calculation with mass flow:
Mass flow through throttle at supercritical flow:
$\dot{m} = C \cdot p_1 \cdot \rho_0 \cdot \underbrace{\sqrt{\frac{T_0}{T_1}}}_{1} = 2,17 \frac{Nl}{sbar} \cdot 3bar \cdot 1,1845 \frac{kg}{m^3} = 7,711 \frac{g}{s}$
Masse per rovolution at 3bar:
$m_{\text{mot}} = V_{\text{mot}} \cdot \frac{p_1}{R_0 \cdot T_0} = 4 \frac{l}{U} \cdot \frac{3bar}{288 \frac{Nm}{kgK} \cdot 293,15K} = 14,21 \frac{g}{U}$
Revolutionspeed at motor shaft and velocity of conveyor belt:
$n = \eta_{\text{vol}} \cdot \frac{\dot{m}}{m_{\text{mot}}}$
$v = 2 \cdot \pi \cdot n \cdot r = 2 \cdot \pi \cdot \eta_{\text{vol}} \cdot \frac{\dot{m}}{m_{\text{mot}}} \cdot r = 2 \cdot \pi \cdot 0,75 \cdot \frac{7,711 \frac{g}{s}}{14,21 \frac{g}{U}} \cdot 0,2m$
$v = \underline{\underline{0,511 \frac{m}{s} \geq 0,5 \frac{m}{s}}}$
Alternative calculation with volume flow:
Flow determination through throttle with help of the C-value (sonic conductance, standardized for normal state):
$Q = C \cdot p_0 = 2,17 \frac{l}{s}$
Revolutionspeed at motor shaft and velocity of conveyor belt:
$n = \eta_{\text{vol}} \cdot \frac{Q}{V_{\text{mot}}}$
$v = 2 \cdot \pi \cdot n \cdot r = 2 \cdot \pi \cdot \eta_{\text{vol}} \cdot \frac{Q}{V_{\text{mot}}} \cdot r = 2 \cdot \pi \cdot 0,75 \cdot \frac{2,17 \frac{l}{s}}{4 \frac{l}{U}} \cdot 0,2mv$
$= \underline{\underline{0,511 \frac{m}{s} \geq 0,5 \frac{m}{s}}}$
The conveyor belt velocity can be guaranteed !</td><td>2</td></tr>
<tr><td></td><td style="text-align:right">Sum:</td><td>10</td></tr>
</table>