DRY ICE PRODUCTION UNIT DESIGN

Final Master´s Thesis

Master in Mechanical Engineering

Author: Martínez Gómez, Juan Antonio

Coordinator: D. Dmitrijs Rusovs

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Symbology

°C	Degrees Celsius
Atm	Pressure in atmosphere
Bar	Pressure in bars
Ppm	Parts per million
K	Degrees Kelvin
J	Joules
Mol	moles
G	grams
Pa	Pressure in Pascals
Φ	Diameter
P	Pressure
Cv	Specific heat in constant volume
Cp	Specific heat in constant pressure
T	Temperature
V	Volume
v	Velocity
γ	Ratio heat capacity
n	numbers of moles
H	Enthalpy
h	distance chamber
A	Area
d	Density
U	Internal energy
F	Force
σ	Elastic limit

1. Foreword and objectives of the thesis:

The purpose of this thesis is the 3D design of a dry ice production unit and the explanation of the kinetic and the energy balance of the device. This project is proposed by the Riga Technical University for the obtention of the title of Master in Mechanical Engineering in the Universitat Politécnica de Valencia.

2. What is the dry ice?

Solid CO_2, commonly called dry ice, is formed below the triple point of CO_2, and there are in the market a variety of devices for its production.

Dry ice that can be applied in many industrial areas. It was originally the more important of the two nongaseous forms of carbon dioxide. Its use became popular in the mid-1920s in the United States as a refrigerant for the conservation of food. Dry ice was made from the liquid form, which could only be moved about in cylinders tanks.

The temperature of dry ice extends to -78°C at atmospheric pressure (at reduced pressures lower temperatures can be achieved). The main reasons of solid carbon dioxide as a refrigerant were:

Is not heavy, it leaves no residue on evaporation, and it is nontoxic.

3. Hypothesis and assumptions of the problem.

For the design of this project, various concepts will be assumed. In the following project we will find the thermal and kinetic calculations for the production of dry ice in an adiabatic chamber. The present project will be based only on the design of the adiabatic chamber, the selection of the hydraulic cylinder, the design of components such as the pellet die or the nozzle. The electronics associated with such a device as well as additional elements such as pressure pumps, gas valves, CO_2, vessels, pipes, and the electrical components that will supply electrical energy to the device will be ignored.

The main topic of the present project is the understanding of the CO_2 at different values of pressure and temperature, and the basic 3D design of a mechanism to transform the CO_2 liquid into dry ice with the best performance. Many information about CO_2 will be given in this project for a better understanding of the uses of the CO_2.

4. Uses of Solid Carbon Dioxide

The most common usage of dry ice is beverages, refrigeration of foods, and laboratory biological samples. It is also considered a good way of relieving the greenhouse effect by recycling CO_2, and using it as a refrigerant, which can be regarded as a kind of CO_2 capture and storage.

Another application in medical field is for drug granulation. Nanosized fine drug particles produced by rapid expansion of supercritical solution (RESS) can be agglomerated by dry ice particles produced during the expansion process.

Many industrial cleaning problems can be solve thanks to some specific features of dry ice, such as sublimation and soft property. Contaminants can be removed using dry ice as abrasive blast media (dry ice blasting) by the blasting method. For example, higher concentrations of dry ice particles with sufficient inertia are more effective to remove contaminants. Since dry ice will eventually sublimate after dry ice blasting, the problem of secondary contamination can be avoided.

Among these applications, the structure, the size, and concentration of particles are thought to be important because these physical properties will have a great influence on its application.

5. Obtention of the CO_2

Much of the CO_2 generated in the planet is a by-product of hydrogen and ammonia production, which produce more carbon dioxide than is ever recovered. Other sources are still exploited, but these are financially less attractive and generally less efficient.

As a product of combustion, carbon dioxide is emitted into the atmosphere on such a large scale, that its greenhouse effect leads to an impact on the world's climate. The global average temperature has increased by 0.65 K in the last decade, caused by the rise of greenhouse gas concentrations, therefore predominately CO_2. The maximum allowable atmospheric CO_2 concentration shall not exceed 450 ppm, and the CO_2 output has to be reduced drastically.

To achieve a significant CO_2 emission reduction, we should separate the CO_2 of the power plant before emission to the environment. The IEA has calculated that 60% of the total amount of CO_2 has to be separated to achieve the 450 ppm goal. After the separation, the CO_2 can either be reused in chemical processes or deposited in long term storages, such as in underground reservoirs. In this case, storage or dry ice production is the only feasible solution and is commonly known as carbon capture and storage (CCS).

5.1. Carbon Dioxide from Ammonia and Hydrogen Plants

The process for the production of ammonia is showed in Figure 1. Desulfurization of the natural gas or naphtha is carried out before catalytic steam reforming of the hydrocarbon to give a gaseous mixture of hydrogen, carbon monoxide and carbon dioxide.

Because only nitrogen and hydrogen are required to make ammonia, carbon oxide is removed from the gas stream. Most of the carbon monoxide is catalytically converted to carbon dioxide, and the latter is removed by dissolution under pressure.

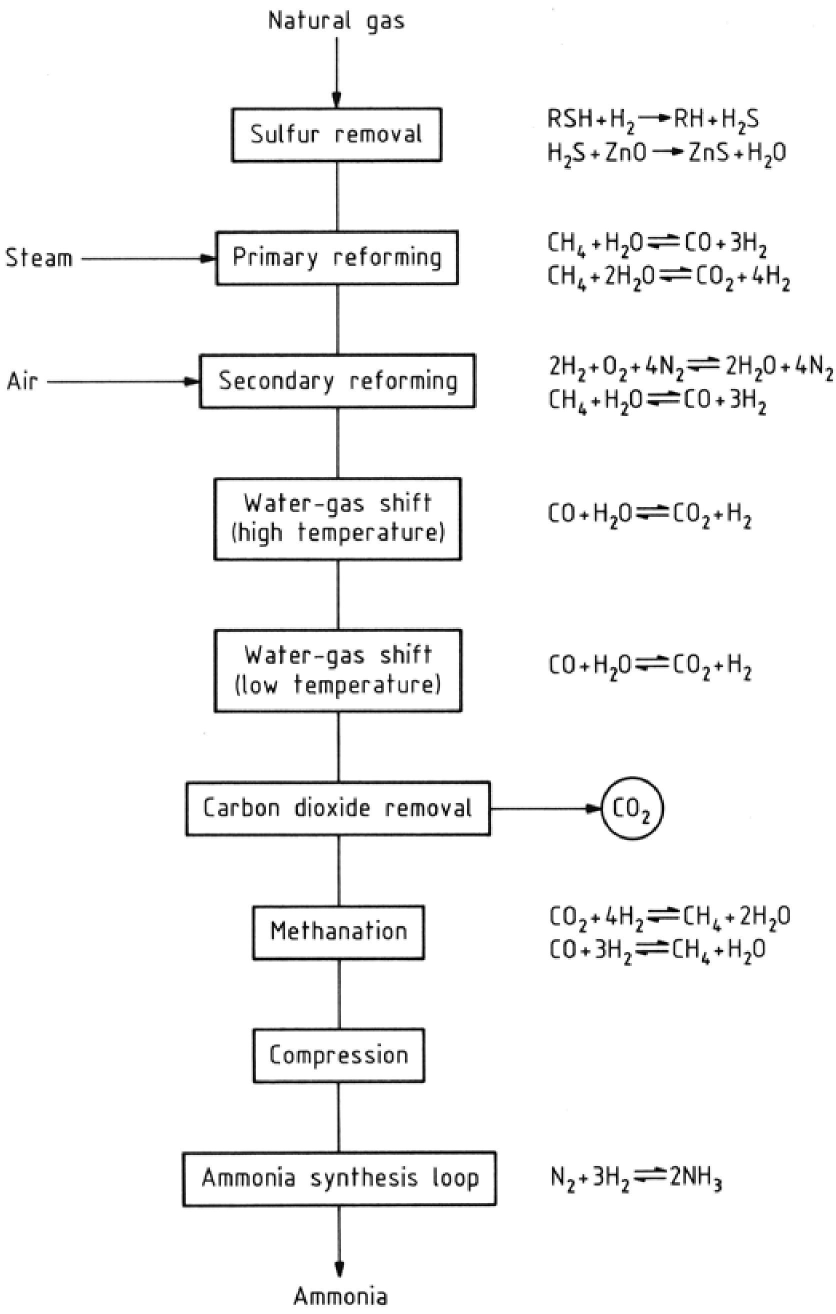

Figure 1. Schematic representation of an ammonia plant [6]

5.2. Carbon Dioxide from Flue Gases

Carbon dioxide is a component of all flue gases produced by the complete combustion of carbonaceous fuels. Typical concentrations of carbon dioxide in such gases are between 10 and 18 vol%. A schematic diagram of the process for recovering the carbon dioxide fraction of the gases is shown in Figure 2. The flue gases, after being cooled and cleaned by passing through a water scrubber, are passed through an alkaline carbonate solution or an amine solution that absorbs carbon dioxide. Unlike carbon dioxide from an ammonia plant, the product obtained from flue gases is generally contaminated with small amounts of sulphur compounds.

Although manufacture of carbon dioxide by this method was once of a considerable commercial importance, it is now seldom economically viable.

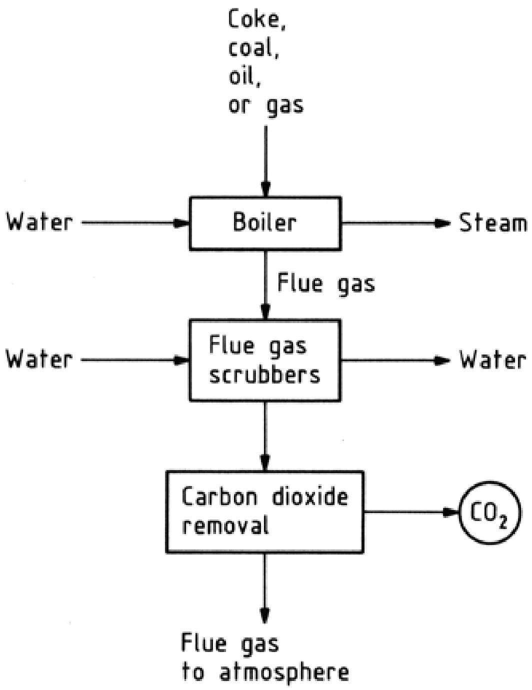

Figure 2. Carbon dioxide production from flue gases [6]

5.3. Carbon Dioxide from Fermentation

During fermentation process, large quantities of carbon dioxide are generated, and up to 80% of this gas may be recoverable. The carbon dioxide must be freed of the impurities before being suitable for further use. Two general methods are available to purify fermentation carbon dioxide. Both use water scrubbers to remove the bulk of the entrained material. The impurities are then taken out by passing through either a solutions of potassium permanganate and potassium dichromate or an activated charcoal bed. The first method involves chemical reactions, whereas the second relies on adsorption.

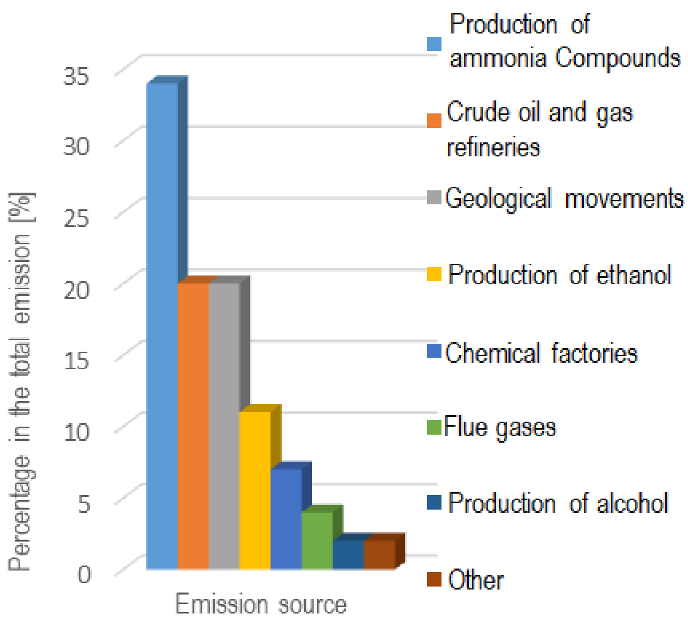

Figure 3. Emission of Co2 from different sources [4]

6. Properties of the CO_2

Gas density (0°C, 0,1 MPa)	$1{,}977\ Kg/m^3 (STP)$	Molar heat (saturated vapor)	
Specific density		solid, at -123°C	$40{,}1\ J\ mol^{-1}K^{-1}$
Compared with air)	1,5291	at -63°C	$53{,}6\ J\ mol^{-1}K^{-1}$
Molar hear cp at 25°C	$37{,}13\ J\ mol^{-1}K^{-1}$	liquid, at -43°C	$82{,}0\ J\ mol^{-1}K^{-1}$
Entropy So	$213\ J\ mol^{-1}K^{-1}$	at -13°C	$90{,}0\ J\ mol^{-1}K^{-1}$
Heat of formation ΔH	$-393{,}51\ KJ/mol$	at +17°C	$130{,}2\ J\ mol^{-1}K^{-1}$
Energy formation ΔGo	$-394{,}2\ KJ/mol$	Critical data	
Specific heat cp (0,1 MPa)		Temperature	31,04°C
at 0°C	$0{,}8277\ J\ g^{-1}K^{-1}$	Pressure	7,383 MPa
at 20°C	$0{,}8459\ J\ g^{-1}K^{-1}$	Density	$468\ Kg/m^3$
at 60°C	$0{,}8833\ J\ g^{-1}K^{-1}$	Triple point	

Specific heat cp (gas 20°C)		Temperature	-56,57°C
at 1 MPa	$0{,}9225\ J\ g^{-1}K^{-1}$	Pressure	518 KPa
at 4 MPa	$1{,}473\ J\ g^{-1}K^{-1}$	Heat of vaporization	347,86 J/g
Heat of fusion	195,82 J/g	Isothermal throttling effect	
Sublimation point		(at 30°C and 243 KPa)	
Temperature	-78,92°C	$\varepsilon = \left(\frac{\Delta H}{\Delta p}\right)T$	$-9{,}04\ cm^3/g$
Pressure	98,07 KPa	Adiabatic throttling effect	
Heat of sublimation	573,02 J/g	(Joule-Thomson effect) at 101,3KPa	
Gas constant R	$8{,}48\ J\ K^{-1}mol^{-1}$	$\mu = \left(\frac{\Delta T}{\Delta p}\right)H = \frac{-\varepsilon}{cp}$	
Correction factor Xo		at -50°C	$24{,}130°C/MPa$
for ideal gas equation	$-9{,}2x10^{-6}$	at -25°C	$16{,}500°C/MPa$
Van del Waals' constants for		at 0°C	$12{,}900°C/MPa$
molar volume		at +50°C	$8{,}950°C/MPa$
a	$3{,}648x10^{-7}MPa\ cm^6mol^{-2}$	Adiabatic throttling effect at 20°C	
		at 0,1013 MPa	$11{,}050°C/MPa$
b	$42{,}672\ cm^3/mol$	at 2,026 MPa	$11{,}355°C/MPa$
		at 6,078 MPa	$1{,}435°C/MPa$

7. Manufacturing of dry ice and its thermodynamics

Dry ice is the solid state of CO_2 with density in the range of 1400 to 1600 kg/ m^3, and it cannot permanently exist at room conditions, i.e. 1 atm and 25 °C. Figure 3 shows the phase diagram of CO_2. When the conditions are below the triple point (−56.4 °C, and 5.13 atm). The process known as sublimation occurs when CO_2 changes from a solid to a gas without intervening liquid state. On the other hand, the process called deposition occurs when the CO_2 changes from the gas to solid state. This phase change, sublimation or deposition will occur at −78.5 °C at 1 atm, enabling its application of gas–solid two phase flow for many industrial purposes.

In addition, CO_2 is generally stored as liquid state in the cylinder tanks for easy transport. Therefore, the manufacturing of dry ice is basically from the liquid CO_2. Dry ice production efficiency will depend on the process where CO_2 changes from liquid state to solid state.

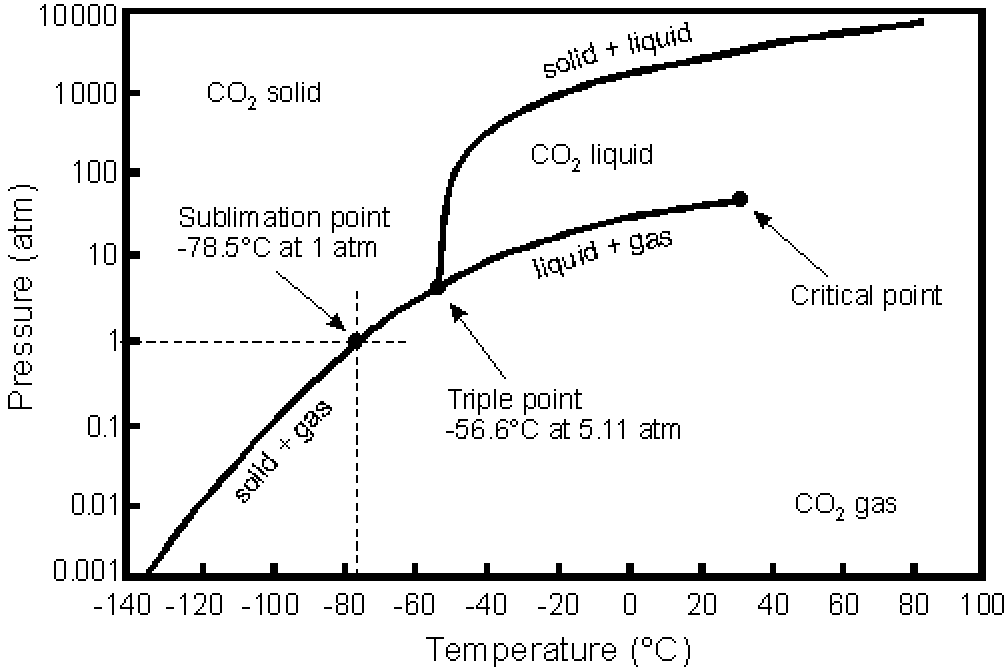

Figure 4. Pressure–temperature phase diagram of CO_2

Dry ice can be produced by the rapidly expansion of the liquid CO_2 through a nozzle based on the *Joule-Thomson effect* in a constant enthalpy process. In this process, the pressure will rapidly decrease and cause the vaporization of some portion of the liquid CO_2. Therefore, fast reduction of temperature occurs, resulting in the solidification of the remaining liquid CO_2. The CO_2 gas–solid two phase flow is therefore produced by the expansion. Dry ice snow can be compressed and extruded to form dry ice pellets as we will show lately. The percentage of dry ice produced can be obtained according to the pressure–enthalpy phase diagram of CO_2, as shown in Figure 5. The pressure of the cylinder tank filled with liquid CO_2 will be consider about 6.5 Mpa (65 Bar) at 25 °C, which is showed at point A in Figure 4 . When expanding the liquid CO_2 through the nozzle, the pressure will decrease without changing the enthalpy to point B, where CO_2 presents in equilibrium of gas and solid state. The percentage of dry ice can therefore be determined according to the final state of CO_2 at point B. The percentage of dry ice varies with the initial state of the liquid. The expansion nozzle is considered an important issue to achieve efficient dry ice snow production, that's why the design of this component is very important for the final results.

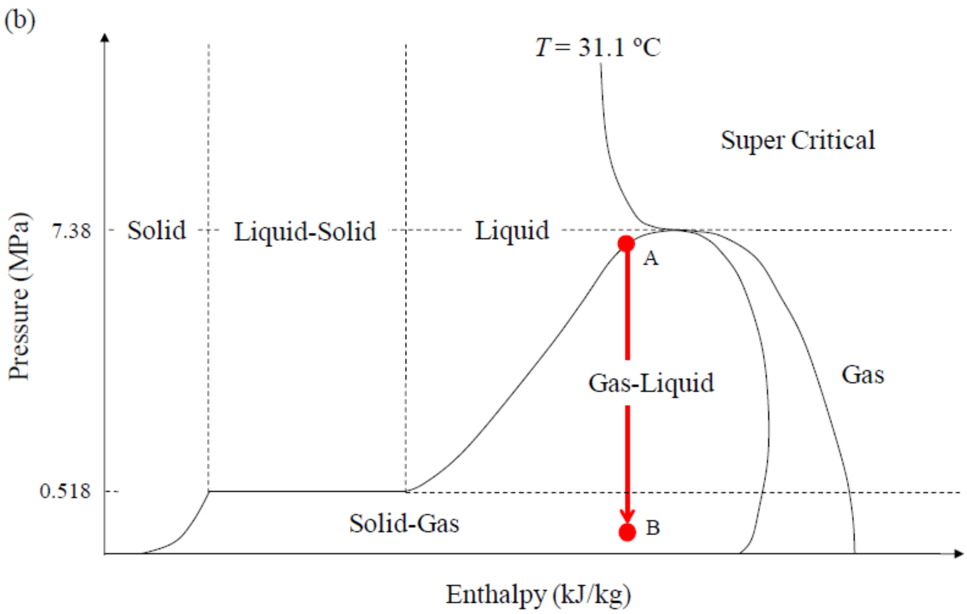

Figure 5. Pressure–enthalpy phase diagram of CO_2

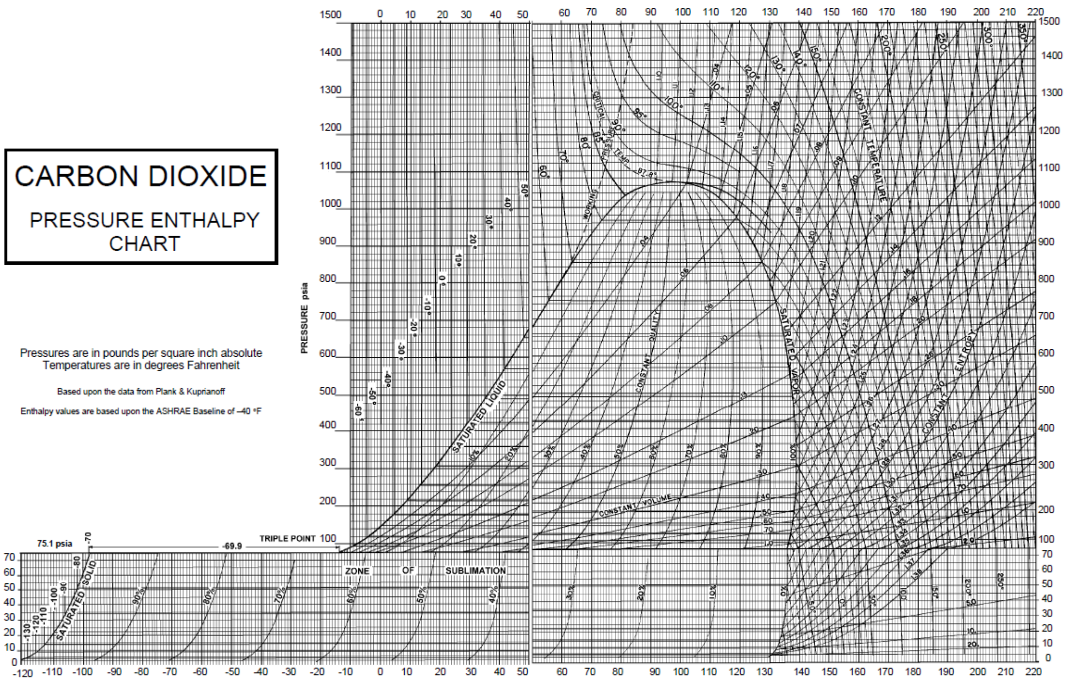

Figure 6. Carbon dioxide Pressure-Enthalpy chart

8. Calculations

In the gas tank, CO_2 is in the liquid state, i.e. ”under pressure liquefied.” The pressure in the cylinder is approximately 65 bar at 25°C.We will consider a frictional losses on the pipe around 5%, therefore, we will consider an initial pressure of 62 bar. When CO_2 is withdrawn from the cylinder through the nozzle, the pressure drops to 1 atm, then gaseous and solid CO_2 are produced.

8.1. Adiabatic expansion nozzle thermodynamic analysis

The expansion that takes place in the nozzle can be described mathematically as the change in cross-sectional area. When the valve is activated, liquid agent is forced up the tube by the vapor pressure of the liquid. The expansion is the change of inside diameter (i.d.) of the nozzle. The expansion factor is calculated in the following equations.

We consider an initial and final diameter of the nozzle as follow:

$$initial.area\ (5\phi\ mm) = A_1 = \pi r^2 = \pi\left(\frac{5}{2}\right)^2 = 19{,}63\ mm^2 \quad \text{[A-1]}$$

$$final.area\ (20\phi\ mm) = A_2 = \pi r^2 = \pi\left(\frac{20}{2}\right)^2 = 314{,}15\ mm^2 \quad \text{[A-2]}$$

$$\text{Expansion factor} = \frac{A_2}{A_1} = \frac{314{,}15}{19{,}63} = 16 \quad \text{[A-3]}$$

For a gas at temperature, pressure and volume, T1, P1, and V1, that undergoes a quasi-static adiabatic expansion to T2, P2, and V2, the pressures are related to volumes as [A-3]:

$$dQ = C_v dT + PdV \quad \text{[A-4]}$$

$$dQ = C_p dT - Vdp \quad \text{[A-5]}$$

Since the process is adiabatic, dQ= 0 so;

$$V\ dP = C_p dT \quad \text{[A-6]}$$

$$PdV = C_v dT \quad \text{[A-7]}$$

Dividing the equation A-6 by equation A-7,

$$\frac{dP}{P} = -\frac{C_p}{C_v}\frac{dV}{V} \quad \text{[A-8]}$$

Denoting the ratio of heat capacities as $\gamma = \frac{C_p}{C_v}$,

$$\frac{dP}{P} = -\gamma \int_{V_1}^{V_2} \frac{dV\prime}{V\prime} \quad \text{[A-9]}$$

$$\int_{P_1}^{P_2} \frac{dP\prime}{P\prime} = -\gamma \int_{V_1}^{V_2} \frac{dV\prime}{V\prime} \quad \text{[A-10]}$$

$$\ln\left(\frac{P_2}{P_1}\right) = -\gamma \ln\left(\frac{V_2}{V_1}\right) \quad \text{[A-11]}$$

$$\ln\left(\frac{P_2}{P_1}\right) = \gamma \ln\left(\frac{V_1}{V_2}\right) \quad \text{[A-12]}$$

$$\ln\left(\frac{P_2}{P_1}\right) = \ln\left(\frac{V_1}{V_2}\right)^{\gamma} \quad \text{[A-13]}$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \quad \text{[A-14]}$$

Since the initial state is $P_1 = \frac{nRT_1}{V_1}$, and the final state is $P_2 = \frac{nRT_2}{V_2}$,

$$\left(\frac{\frac{nRT_2}{V_2}}{\frac{nRT_1}{V_1}}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma} \quad \text{[A-15]}$$

$$\left(\frac{\frac{T_2}{V_2}}{\frac{T_1}{V_1}}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma} \quad \text{[A-16]}$$

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma}\left(\frac{V_2}{V_1}\right) \quad \text{[A-17]}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} or \quad \frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1-\gamma} \quad \text{[A-18]}$$

For CO_2 $\gamma = \frac{C_p}{C_v} = \frac{0,844}{0,655} = 1,310$ [A-5], so

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1-1,310} \quad \text{[A-19]}$$

For the CO_2 nozzle, the expansion volume is $\frac{V_2}{V_1} = 16$, $\frac{T_2}{T_1} = (16)^{-0,310}$, from which

$$T_2 = 126,15\ K$$

$$T_1 = 298\ K$$

The total enthalpy associated with the quasi-static reversible expansion would be

$$\Delta H = C_p \Delta T \quad \text{[A-20]}$$

The nozzle efficiency of conversion of CO_2 to its solid form is calculated as follows:

The heat capacity associated with a drop in temperature from 25°C (298°K) to 126°K is 37,71 Joules/mole·k [A-6], therefore the increment in the enthalpy is 6.42 KJ/mole. Of that amount, the enthalpy change to drop the temperature of the gas to its freezing point, -79°C (194°K). If the heat capacity is 36.37 Joules/mole, the variation in the enthalpy at 194 °K is 3.78 KJ/mole. The remaining 2,64 KJ/mole·k is used to convert the CO_2 to its solid form, dry ice. The heat of fusion for CO_2 is 7.95 KJ/mole [A-7] and the heat of vaporization at 25°C is 16,70 KJ/mole [A-8], so the theoretical efficiency is 2,64/(10,66+7,95) or **14%** conversion.

8.2. Mass flow and production

To calculate the production of dry ice in this device, we are going to fix a mass flow equal to 1 L/s during 2 seconds, so the total mass flow each time is 2 L/s or 0,002 m3/s.

Knowing this assumption, we need to calculate the volume available inside the chamber. This volume will locate the dry ice produced after the conversion of the CO_2 gas to solid state.

From our previous design of the chamber we have calculated a total volume inside the chamber equal to:

$$Area\ (Chamber) = r^2 * \pi = \left(\frac{150}{2}\right)^2 * \pi = 17671{,}46\ mm^2 \qquad \text{[A-21]}$$

$$Volume = h * A = 300\ mm * 17671{,}46\ mm^2 = 5301437{,}60\ mm^3 = 5{,}31 dm^3 = 5{,}31\ L \qquad \text{[A-22]}$$

h= distance from the end of the piston (totally closed) till the pellets plate (300mm)

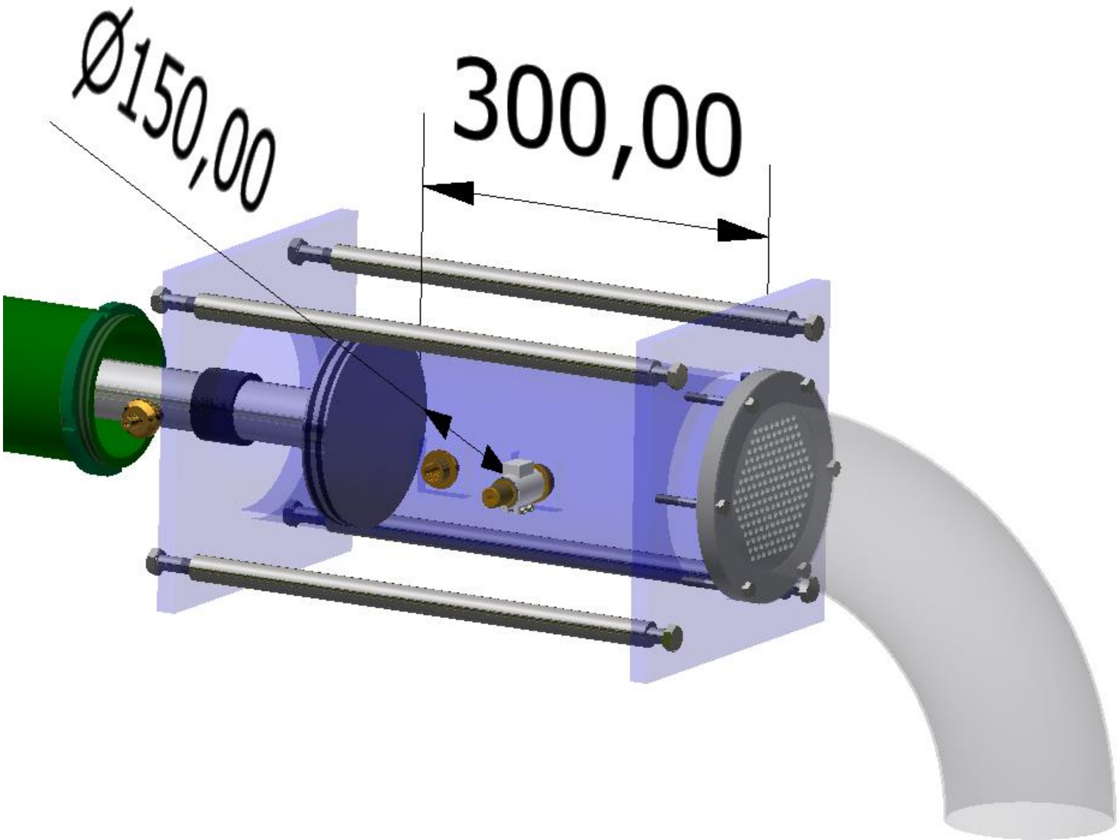

Figure 7. Internal dimensions chamber

Knowing the density of the dry ice, we can calculate the maximum mass of dry ice inside the chamber:

Density dry ice: 1500kg/m3

$$m = d * V = 1500\,\frac{kg}{m^3} * 0{,}005301 m^3 = 7{,}95\ kg \quad \text{[A-23]}$$

This is the theorical total mass of dry ice that we can produce filling all the chamber with dry ice. In reality, this value is very difficult to achieve. To avoid any problem on the device, and to reduce the pressure applied from the hydraulic system, and any blockage in the nozzle, we will inject the CO_2 gas during 2 seconds as we have assumed before. With this assumption, we will increase the production time, but we will reduce any problem in the future.

With a valve, we will control de mass flow in the interior of the chamber. We will set a value of 0,002 m^3 of CO_2 during the 2 second of injection inside the chamber.

If the efficiency of the CO_2 gas conversion to dry is around 14%, the total mass of dry ice inside the chamber after each injection is equal to:

$$dry\ ice: 0{,}14\ x\ 0{,}002\ m^3 = 0{,}00028\ m^3 \quad \text{[A-24]}$$

$$CO_2\ gas: 0{,}002 - 0{,}00028 = 0{,}00172\ m^3 \quad \text{[A-25]}$$

The remaining CO_2 gas will be liberated to the atmosphere. For a future design of the project, a vacuum pump will be installed in the device which will return the remaining CO_2 gas back to the tank increasing its pressure to 65 bars.

To know the total production of dry ice we need to calculate the mass that we can produce during each injection.

$$d = \frac{m}{V}; m = d * V = 1500\,\frac{kg}{m^3} * 0{,}00028\ m^3 = 0{,}42\ Kg \quad \text{[A-26]}$$

Working times:

- Time of injection: 2s
- Time of the piston: 6s *.

* We know that the speed of the piston is equal to 0,1 m/s (technical specification), if the piston has to move during 300mm, the total time to complete this distance forward and backward is 6s.

Total production time: 2+6 = 8s

This means that we will produce a total of 0,42 kg of dry ice each 8 seconds. The total production per hour is equal to:

$$Total\ production: 0{,}42\ kg * \frac{3600s}{8s} = 189\,\frac{kg}{h} \quad \text{[A-27]}$$

9. Design

The result of the CO_2 in solid state is named as a Dry ice because it sublimes without residue. It is formed as a snow when liquid carbon dioxide is allowed to expand to atmospheric pressure. Commercial manufacture of dry ice involves the densification of this loose snow by a hydraulic press to form solid blocks of material of density 1,5–1,6 kg/L. A typical unit for the production of dry ice is shown in Figure 6. Liquid carbon dioxide is piped from a CO_2 tank, and the pressure is reduced in an expansion nozzle. The remaining CO_2 gas is sent to the atmosphere.

A measured dose of the liquid CO_2 is then fed into the chamber, where it is allowed to expand. Solid carbon dioxide and some gas carbon dioxide are formed. This flash gas is sent to the atmosphere. When the chamber is free of gas CO_2, the solid material is compressed and ejected through the pellet plate.

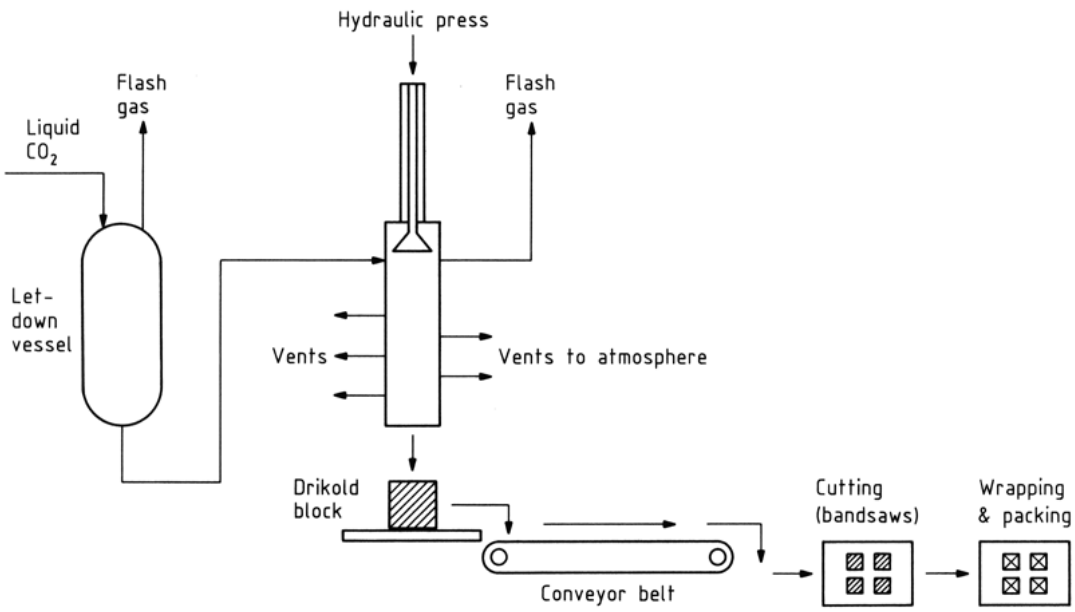

Figure 8. Schematic representation for the production of dry ice

During all the process mention above, loss of carbon dioxide occurs by sublimation.
Therefore, it is very important to schedule the production carefully so that the product is made as near as possible to the time it is used.

9.1. Design of the Nozzle

For an optimal design of the nozzle we use the Joule-Thomson Expansion theory [1].

"Joule-Thomson cooling is the name given to the drop in temperature that occurs when a real gas such as CO_2 expands from high pressure to low pressure at constant enthalpy (i.e., adiabatic expansion)."

$$w = \Delta U = p_1 V_1 - p_2 V_2 \qquad [A\text{-}28]$$

The formation of dry ice particles depends on pressure, temperature and the jet flow conditions. These factors are related to the design of the expansion nozzle; thus the operation conditions must be precisely controlled to match the various application needs. The design of the expansion nozzle has been studied to effectively produce primary dry ice particles, Whitlock et al. [1989] proposed a special apparatus including a plurality of expansion nozzles where a coalescing chamber is connected between. The large droplets were thought to be the precursor of the minute dry ice particles; hence the coalescing chamber for producing large droplets before entering into the second orifice was important. Swain et al. [1992] expanded liquid $\mathrm{CO_2}$ from an orifice into a thermally insulated chamber to form small dry ice particles and then retained the small particles in the chamber until the small particles agglomerated into large ones. In this process, formation of large dry ice particles is beneficial for cleaning a larger surface area per unit time than small dry ice particles.

The large dry ice particles do not sublimate away as rapidly as small ones thereby surviving longer and removing more contaminants along a longer and wider path. Furthermore, each large, rapidly moving dry ice particles possesses more kinetic energy than small ones, and, therefore, more effectively removes contaminants clinging to the surface of substrates being cleaned.

The model was validated using the experimental data obtained by Liu et al. (2012). The release conditions, experimental results and simulation results were tabulated in Table 1. It shows that the model could accurately describe rapid $\mathrm{CO_2}$ expansion in terms of solid particle formation. (Note: storage pressure and temperature are 55 bar and 288 K respectively).

Due to the calculations above, we are going to design a nozzle with an initial diameter of 5 mm and a final diameter of 20 mm. With this size of the nozzle we will provide big particles of dry ice in the interior of the cylinder chamber.

To avoid any freezing in the nozzle, a heater is needed to be installed in the nozzle. This heater will keep a constant temperature in the nozzle avoiding any problems during the production of dry ice (Fig. 9). The technical specification of the nozzle heater can be found in the annexes.

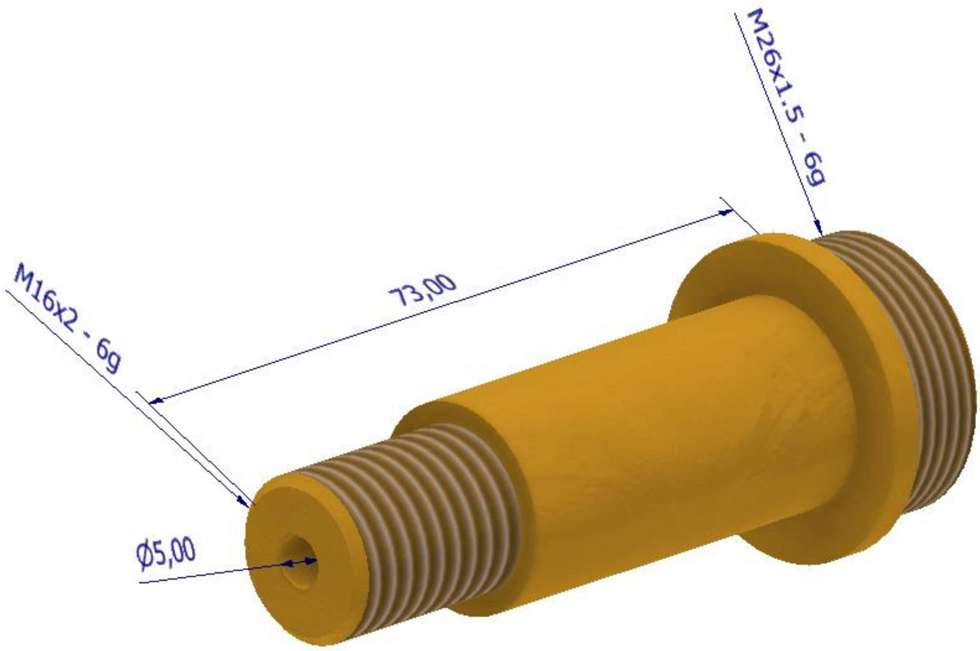

Figure 9. Nozzle 3D view 1.

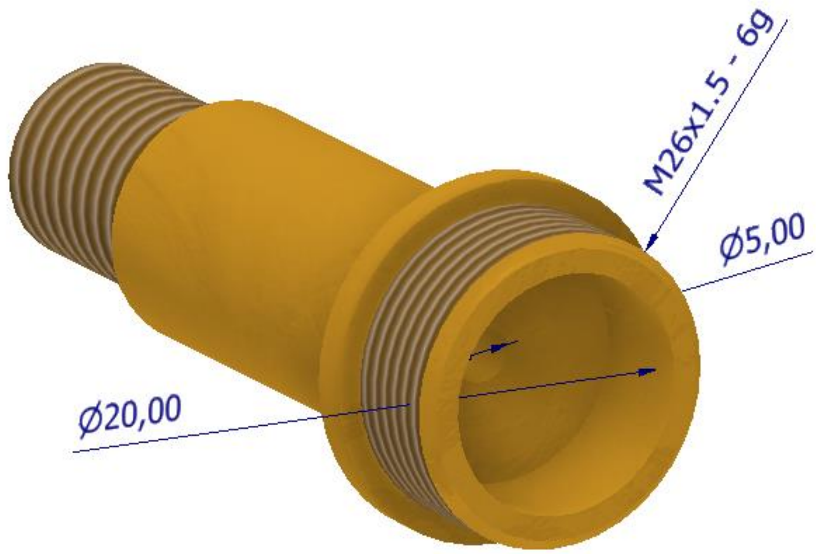

Figure 10. Nozzle 3D view 2.

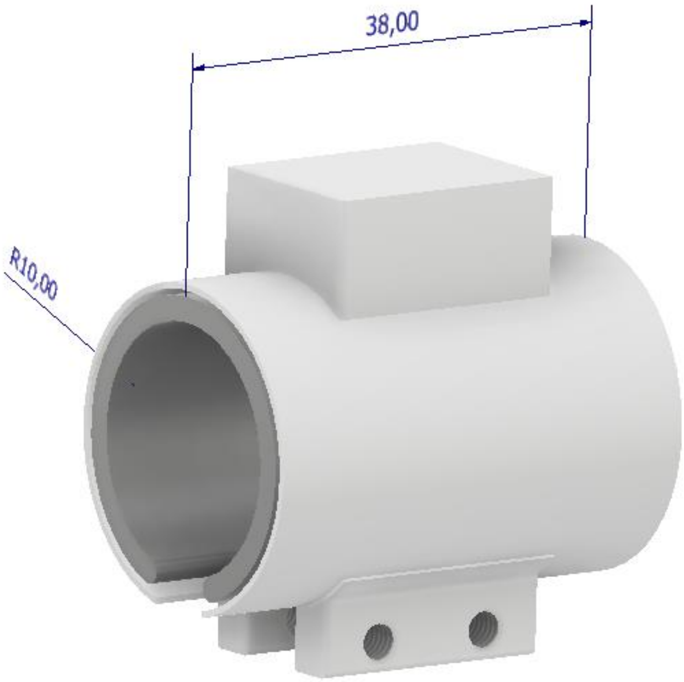

Figure 11. Nozzle's heater

9.2. Selection of the hydraulic cylinder

For the design of the hydraulic cylinder we are going to select a standard unit available in the market. This selection will reduce the final cost of the dry ice machine. For the selection of the optimal hydraulic cylinder we need to consider de volume of the chamber, the total pressure that the cylinder can provided and the stroke.

- Maximum operating pressure up to 210 bar
- Rugged yet compact design with good guiding properties
- Seal groove and diameter according to ISO 5597/1 and DIN ISO 7425/1
- Seals by default for maximum continuous duty temperatures up to 80^{o}C and velocities up to 0,5 m/s

All the specification of the hydraulic cylinder con be found in the Annexes

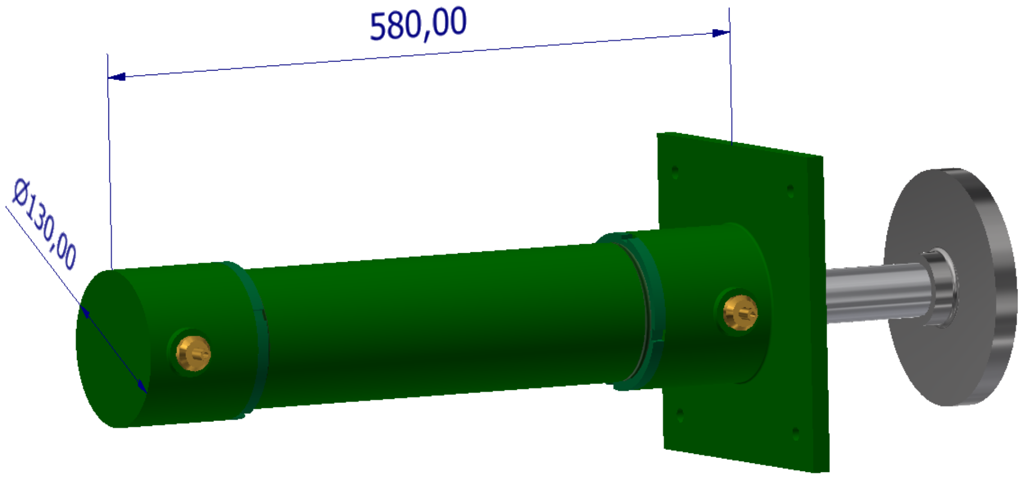

Figure 12. Hydraulic Cylinder 3D view 1.

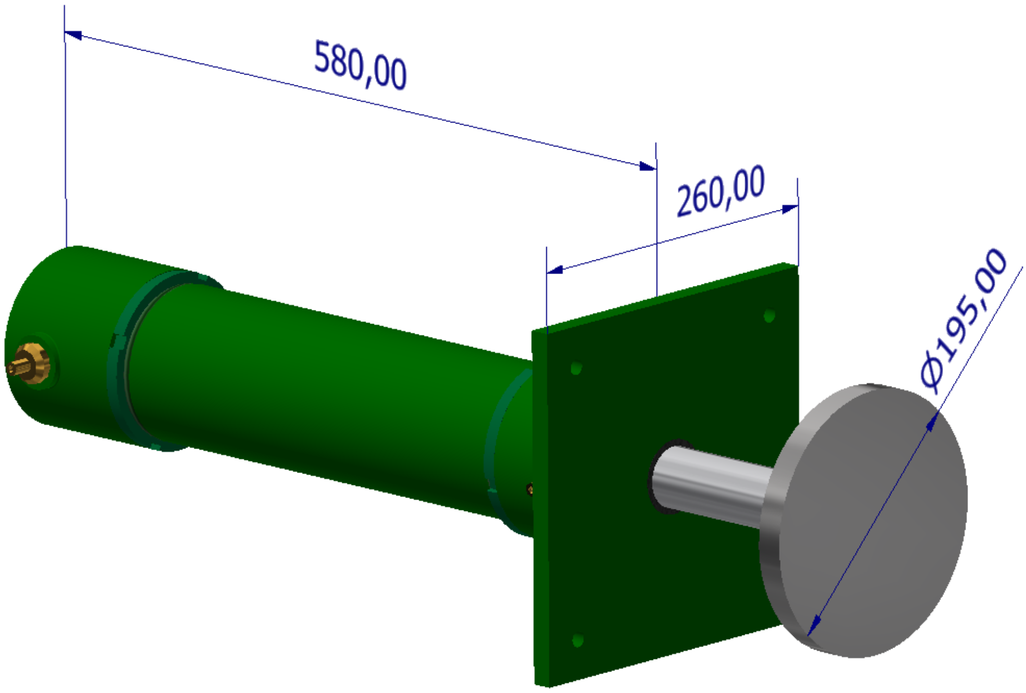

Figure 13. Hydraulic Cylinder 3D view 2.

9.3. Design of the chamber

The dimensions of the chamber have been taken according to a production of 189 kg/h. It consist in a simple design based in an central chamber and two external plates, which are connected one side to the hydraulic cylinder and the other one to the pellets die. It has one inlet gauge to allow the connection of the nozzle and a vent gauge to allow the remaining flash CO_2 gas to leave the chamber. All the dimensions can be found in the technical drawings attached to this project. The material which it is made is carbon steel easy for welding.

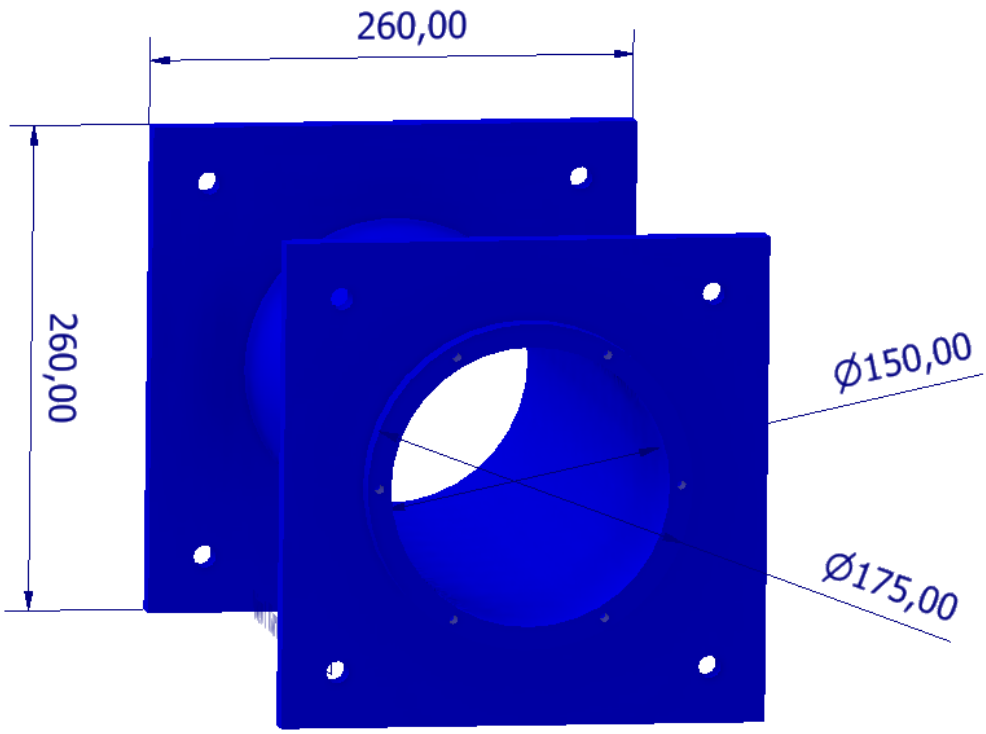

Figure 14. Chamber 3D view 1.

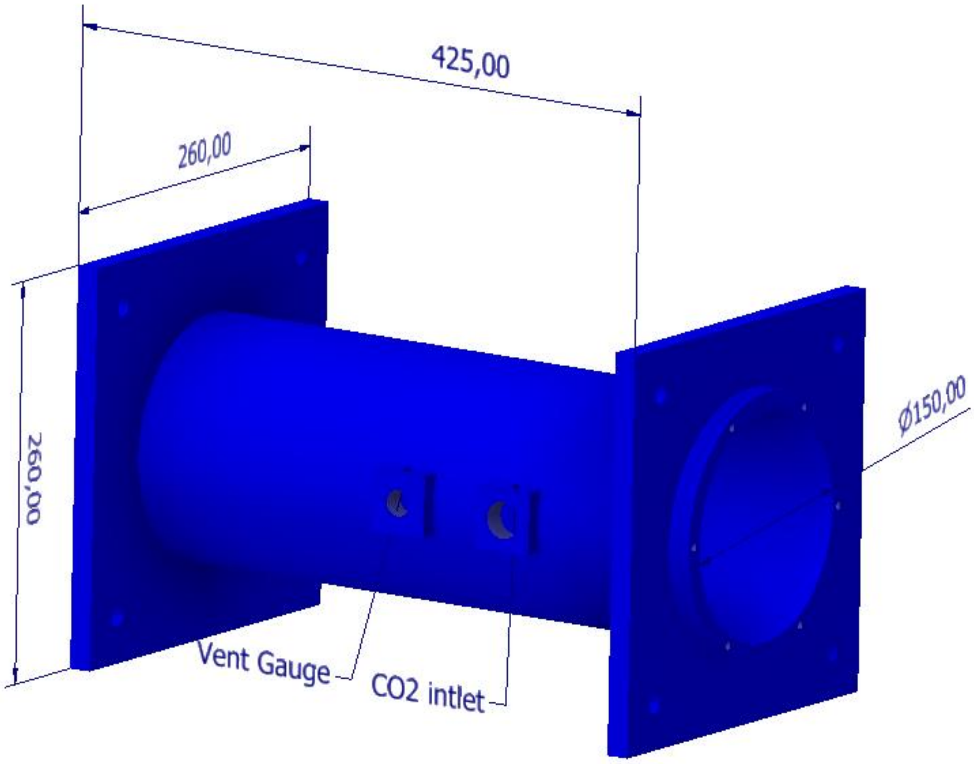

Figure 15. Chamber 3D view 2.

9.4. Design of the piston plate

The hydraulic cylinder is coming with a standard pushing plate. This plate has to be modified for our specific design. It has to seal the interior of the adiabatic chamber avoiding any dry ice to go behind the piston plate. For this porpoise, the piston plate needs a seal ring located between the chamber and the piston. This ring has to keep all its technical properties under low temperatures and high pressures preventing it from dilating and changing its dimensions. The material which is made the ring is a special rubber very common in seal rings for similar purposes.

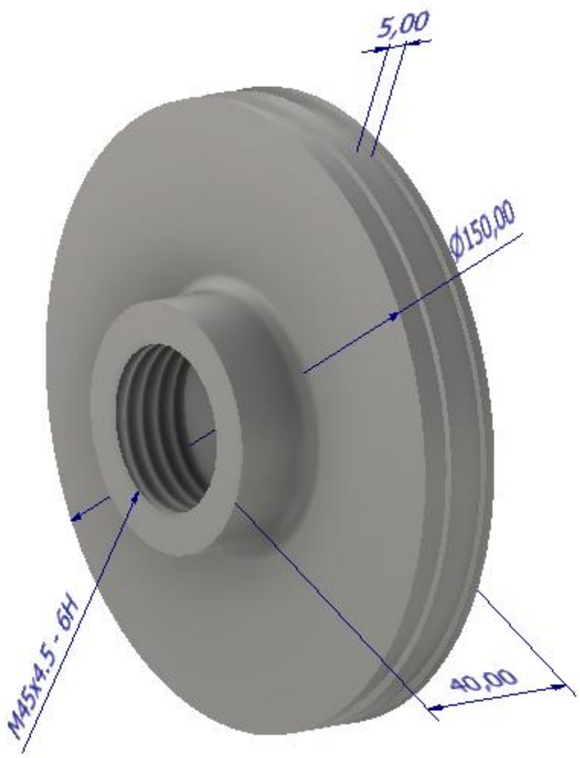

Figure 16. Piston plate 3D view

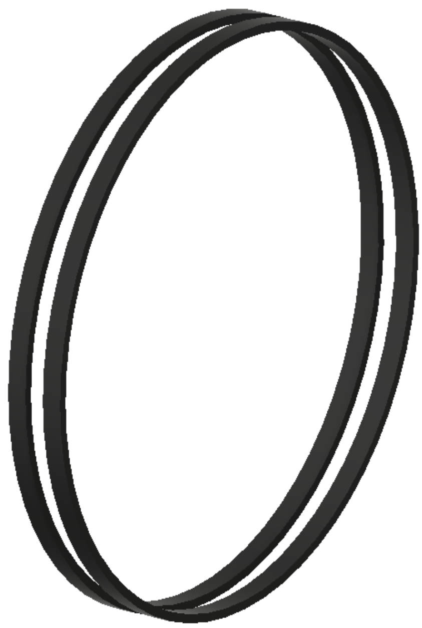

Figure 17. Seal Rings 3D view

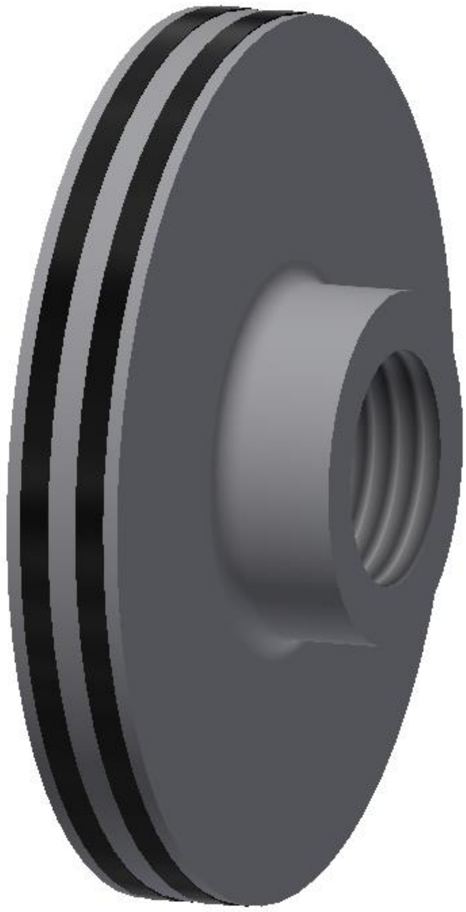

Figure 18. Piston and seal rings assembly

9.5. Design of the pellets die

For the design of the pellets plate, we have design the device in order to make a direct extrusion.

Extrusion is a process used to create objects of a fixed cross-sectional profile. A material (in this case dry ice) is pushed through a die of the desired cross-section. The two main advantages of this process over other manufacturing processes are its ability to create very complex cross-sections, and to work materials that are brittle, because the material only encounters compressive and shear stresses. It also forms parts with an excellent surface finish.

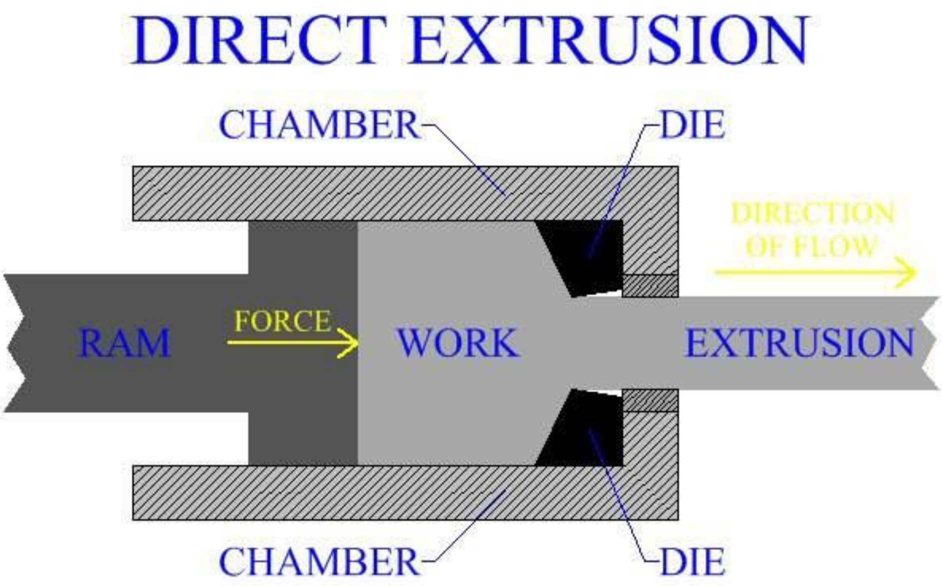

Figure 19. Direct extrusion [7]

9.5.1. Variables od extrusion.

The main process variables that determine the force needed to produce the extrusion are:

- Lubrication
- Temperature
- Extrusion speed
- Extrusion ratio

For this case, we are not going to use any type of lubricant, because at room temperature, dry ice sublimates directly from a solid into a gas. When the dry ice is placed inside the chamber, this sublimation results in a layer of gas between the dry ice and the surface which allows the dry ice to move across the surface with essentially no friction. The temperature of extrusion is -78°C, and the speed is 0,01 m/s.

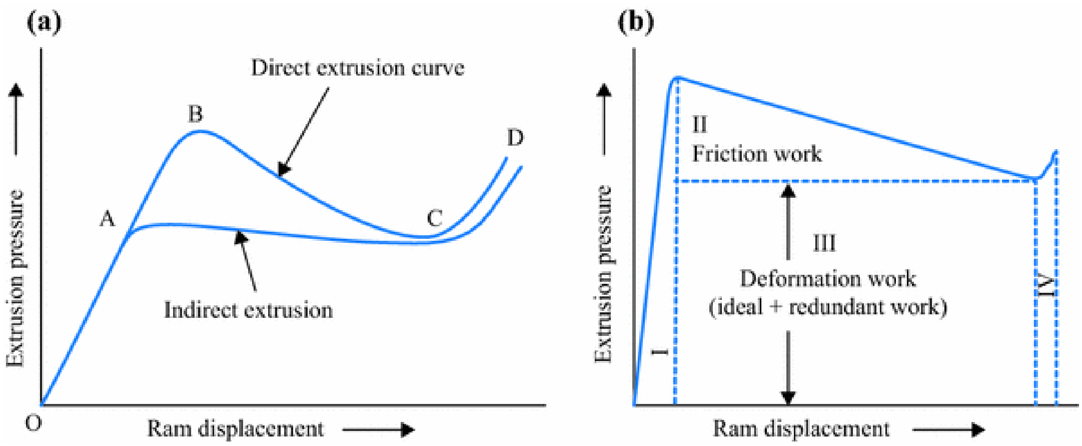

Figure 20. Diagram Pressure-Displacement [7]

The diagram above, shows the relation between the pressure exerted by the pump and the displacement of the piston.

In direct extrusion we can observe how there is a rapid rise in pressure at the beginning of the rod travel.

When the maximum pressure value is reached, the dry ice begins to flow, decreasing the pressure as the extrusion continues, since the friction force decreases as the length of the billet remaining inside the body is smaller.

The direct extrusion curve approaches the indirect extrusion curve when the length of the billet still not extruded approaches 0. The two curves turn sharply upwards when, at the end of the rod travel, an attempt is made to extrude a disk thin billet left in the die.

Since it is not economical to develop the high pressures that would be necessary to fully extrude the billet, a small space has been left between the die and the piston plate.

9.5.2. Extrusion ratio

The extrusion relationship between the cross sections of the billet and the extruded product is:

$$R = \frac{A_0}{A_f} \quad \text{[A-29]}$$

The pressure needed to perform the extrusion is of important consideration, because based on this, the press is selected. Pressure determination is difficult for extrusion of shapes and complicated sections especially those that have thin walls.

Criteria based on experiences have been taken into account to make estimates. Formulas have been developed to estimate the necessary pressure, using friction, shape and other parameters. However, for simple shapes such as round bars and pellets an approach predicts that the extrusion pressure is an approximately linear function of the natural logarithm of the extrusion ratio. The extrusion force is given by the following equation:

$$F = \sigma_0 * A_0 * Ln(R) \quad \text{[A-30]}$$

Where:

- σ_0 It is the elastic limit in the temperature and deformation speed conditions used in extrusion
- R is the extrusion ratio

The pressure required for extrusion is determined by the equation above, but the values obtained are only approaches. This equation predicts an extrusion force that it is lower than the one actually observed, because it does not take into account factors such as non-homogeneous deformation of the billet and the configuration of the extruded product.

The complete analytical treatment of these factors is very difficult and makes it impossible to calculate the exact extrusion forces and pressure. It is common that the effective elastic limit, or constant of extrusion, is calculated by means of an extrusion operation from an observed pressure and the extrusion ratio using the equation.

With the information of the tooling, traction press and physical space available for die design, we are going to calculate the extrusion pressure.

9.5.3. Extrusion pressure.

The extrusion force is given by the following equation:

$$F = \sigma_0 * A_0 * Ln(R) \quad \text{[A-31]}$$

The value of σ_0 is the elastic limit of the material to be extruded in the temperature conditions and strain rate used in extrusion. However, this equation allows us to calculate an approximate value of the required force. Since it is not certain how much is the decrease of σ_0 with the increase in temperature, and considering that the force increases due to other factors such as the non-homogeneous flow of the material, friction existing of the billet with the matrix and the container, the value of σ_0 will be consider at room temperature.

We will estimate the value of the force based on the article [4] DRY ICE COMPACTION IN PISTON EXTRUSION PROCESS. Jan GÓRECKI*, Ireneusz MALUJDA*, Krzysztof TALAŚKA*, Dominik WOJTKOWI

The efficiency of the piston extrusion process depends primarily on the design of the die plate including partly cylindrical and partly conical channels (Fig. 15). The die geometry influences the movement resistance as well as the final shape of the pellet. There are 169 channels, each comprising a conical section of length *1,41 mm* and *90°* angle of convergence followed by cylindrical (barrel) section of length *14 mm* and diameter *6 mm*. Since the die is mounted within a cylindrical extrusion tube, the die plate surface *SPP* is perpendicular to axis Z.

In order to determine the minimum external force *Ft* applied on the piston to effect densification of dry ice snow the test proce-dure described in literature was used (Drzymała, 1988; Górecki et al., 2013; Malczewski, 1992). The test apparatus was MTS strength tester, model Insight 50 kN which allowed recording the force and displacement values at 10 Hz frequency.

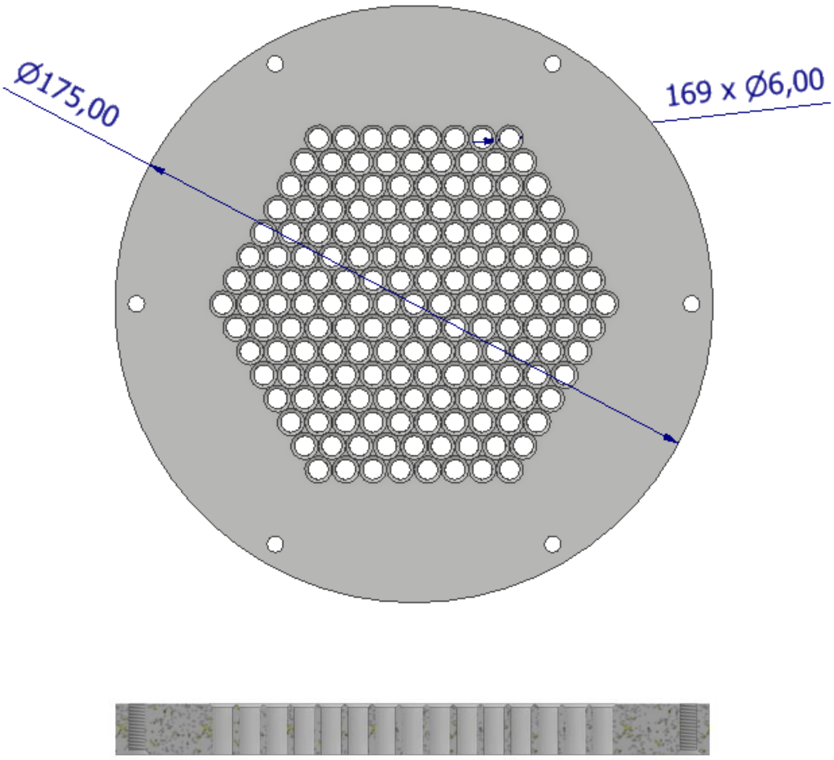

Figure 21. Disposition of the holes in the pellets die

The test was repeated ten times and the results were averaged and presented as compression curves representing the change of force *Ft* as a function of piston displacement Z (Fig. 21).

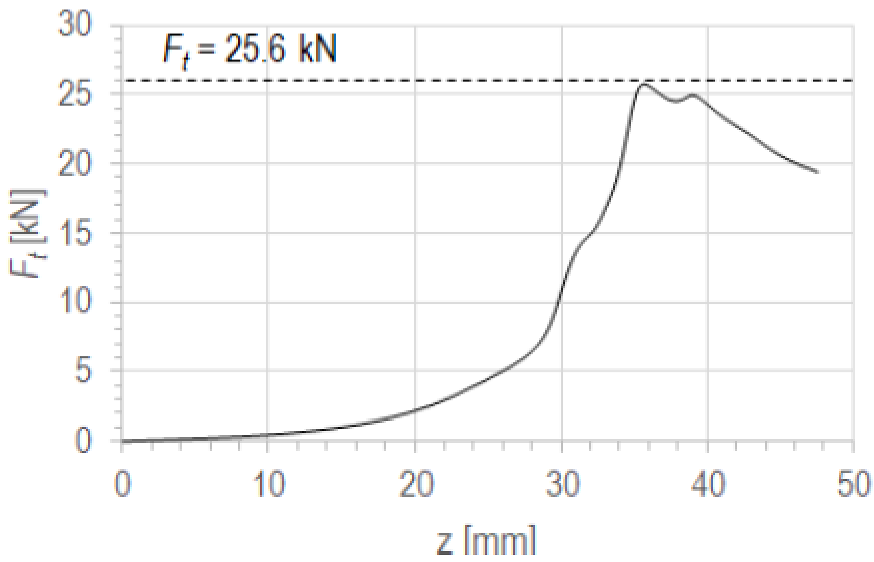

Figure 22. Dry ice compression curve in a multi-channel die extrusion system [4]

The average force *Ft* is 25.6 kN.

The tests of the compression tube reducer described in the patent application No. P.419432 have confirmed its influence on the value of the resistance force *FOP*. As it can be figured out from the diagram, the force decreased by 1.5 kN i.e. by ca. 5.8%.

Considering the value of compression stresses in commercial dry ice extrusion machines there is a need for further research in order to build mathematical models describing the relation be-tween the resistance force *FOP* and the compression tube parameters. These mathematical models will be used to determine the optimum parameters of the compression assemblies of dry ice snow compression machines.

9.6. Selection of the gauge CO_2 regulator.

To control the pressure at the exit of the CO_2 tank, a gauge CO_2 regulator is needed.

For this porpoise we have select a standard dual gauge CO_2 regulator available in the market, compose with a output pressure gauge, tank pressure gauge, adjustment knob, pressure release valve, inlet connection, shut off knob and barbed outlet. The following figure show the description of the gauge.

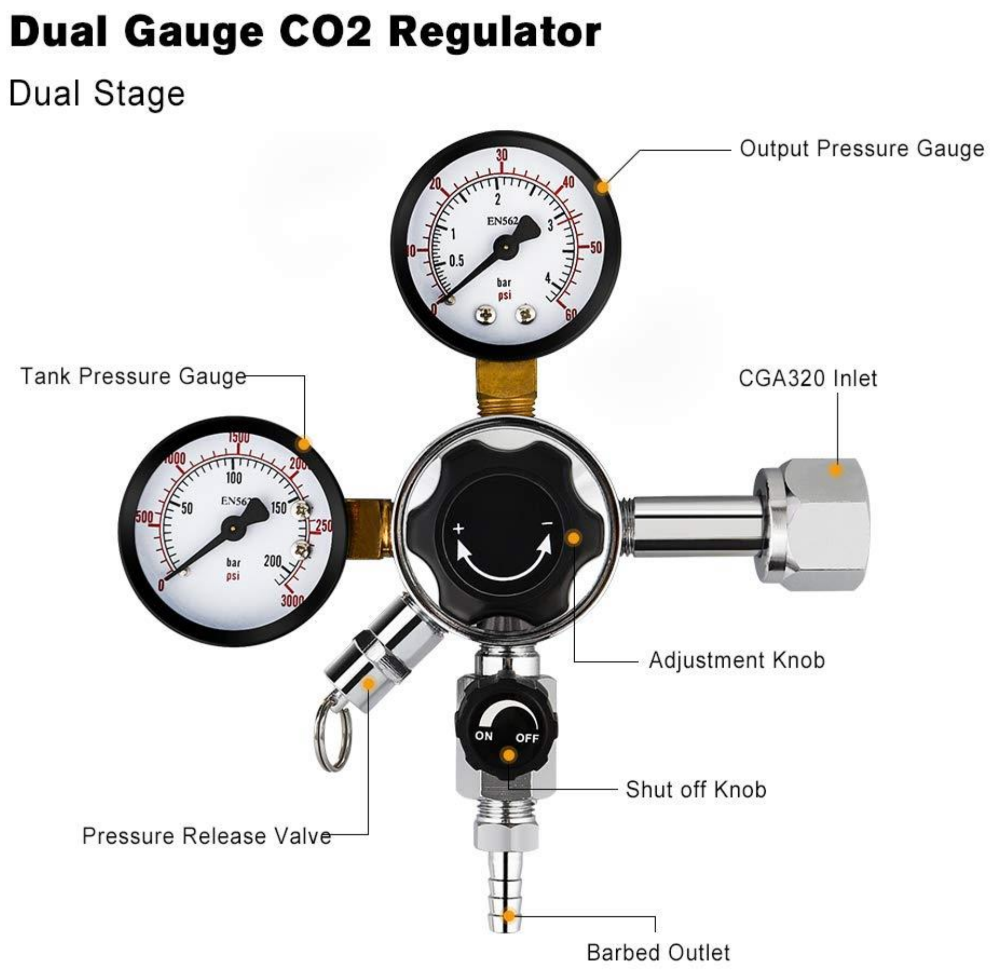

Figure 23. Dual gauge CO2 regulator

9.7. Assembly

Once the injection is complete, the liquid CO_2 is boiled off rapidly in order to obtain the highest possible snow production rate inside the chamber. This rapid vapor exhaust rate necessitates the use of filter media in order to prevent Solid CO_2 from exiting the compression chamber through the one or more venting ports. Filter media is placed over the one or more venting ports of the compression chamber to maximize the vapor exhaust rate from the chamber. Thus, the present block ice press does not require the use of a binding agent mixed with the injected liquid CO_2, which binder is used in present ice block processes and would obstruct the filter media of the present invention. The use of filter media greatly increases the exhaust rate of the present process, which in turn greatly increases the production rate. As the exhaust rate increases, the velocity of the CO_2 vapor inside the chamber increases. The velocity of the vapor in the chamber reaches a point wherein it is high enough to carry solid CO_2 out of the chamber and into the venting ports. This action could also destroy a CO_2 vapor recovery unit if one is being utilized within the present press (future design). The CO_2 vapor recovery would be damaged by the solid CO_2 entering the vapor compressor. Using the filter media of the present invention allows a very high vapor exhaust rate while at the same time contains the solid CO_2 inside the compression chamber.

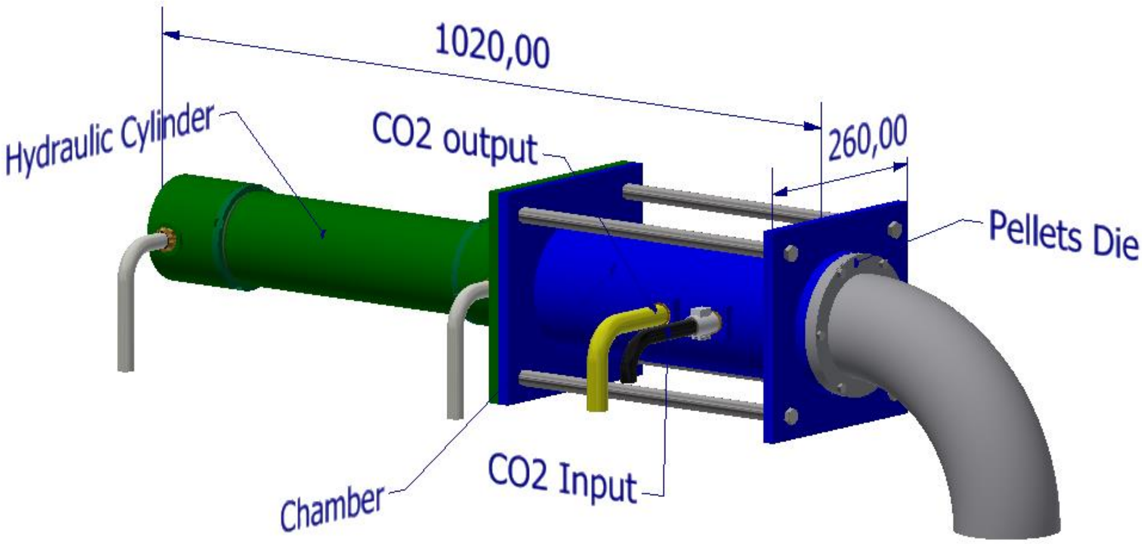

Figure 24. Main parts device

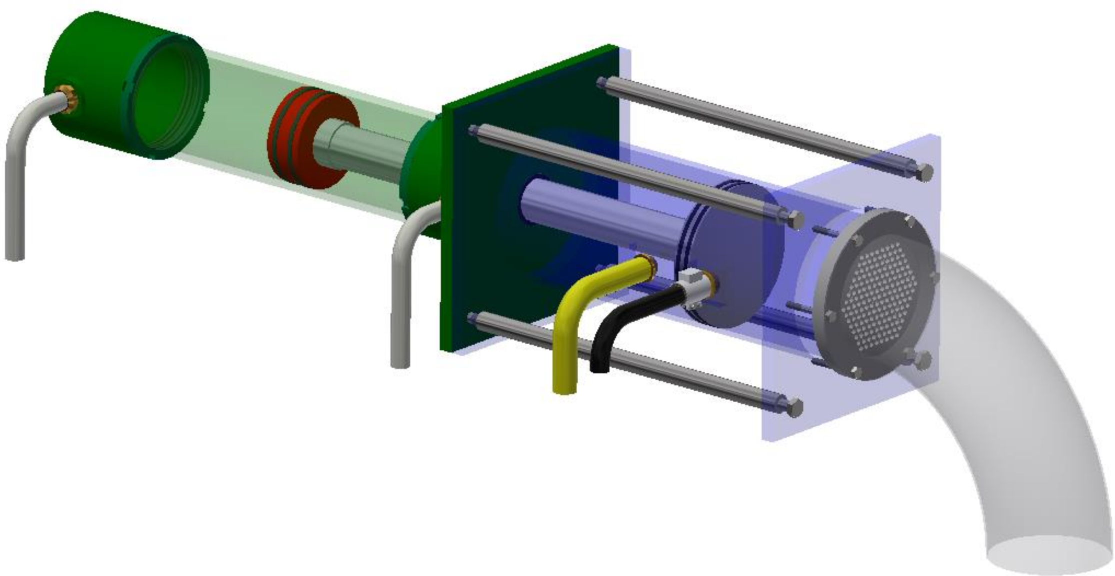

Figure 25. 3D view internal parts

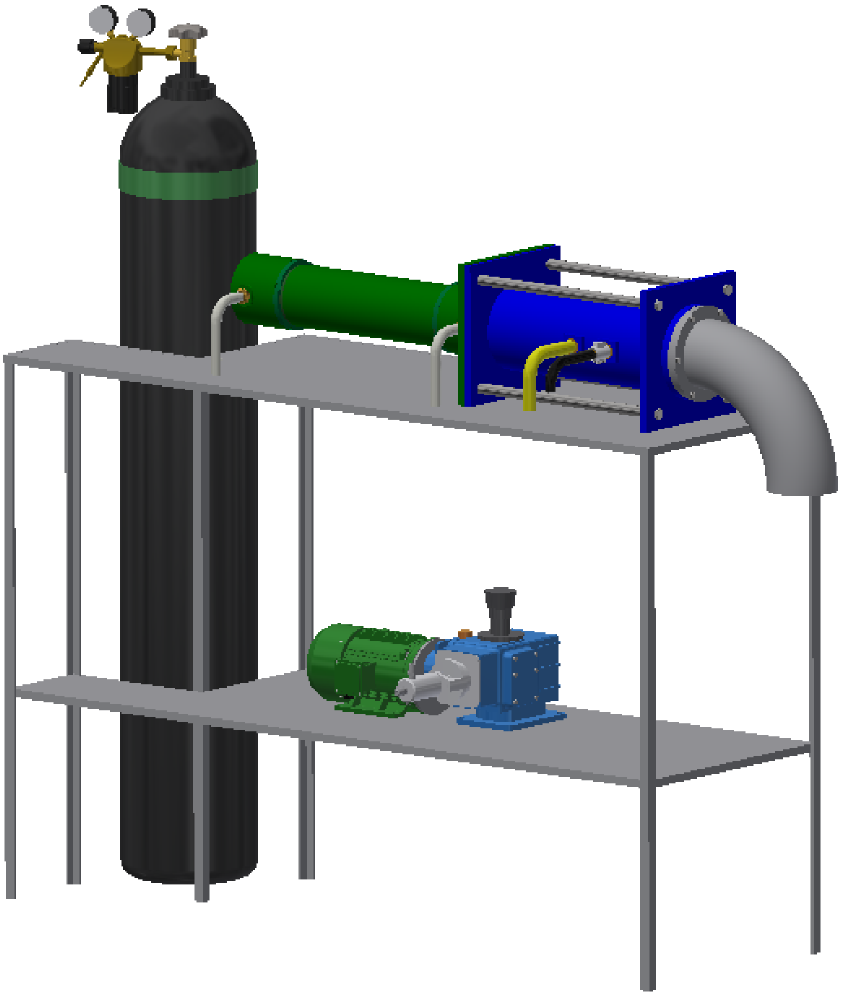

Figure 26. Full assembly dry ice device

10.Comparation with existing models.

After the design of the dry ice pelletizer device, we will compare the results with existing units available in the market.

10.1. ASCO company.

The ASCO Dry Ice Pelletizer A30P [10] having a production capacity of 30kg per hour (66.14lb/h) is suitable for the production of small amounts of dry ice for cooling purposes. The ASCO Dry Ice Pelletizer A30P is driven by a powerful hydraulic unit featuring a push button for instant start of production. All functions are controlled by a PLC. Fully automatic control of oil temperature and dry ice snowing process guarantees continuous dry ice production without any supervision right from push button start.

Benefits of an in-house dry ice production:

- If for dry ice blasting: more efficient cleaning results, because: the fresher the dry ice, the more efficient the cleaning
- Shorter production stops
- Reduction of dry ice lost due to sublimation
- Decreased logistics expense connected with purchasing and disposing of dry ice

Function and applications:

The ASCO Dry Ice Pelletizer A30P requires a liquid CO_2 supply (pressure 13-21 bar (188-304psi) and power supply of 400V/50Hz /3Ph + PE (other voltages available on request). The machine features instant push button start and all functions are controlled by an inbuilt PLC. Dry ice snow is produced in the snowing chamber, pressed and then extruded by a powerful hydraulic unit. Hard, dense dry ice pellets are produced within less than one minute after push button start. To ensure continuous, reliable operation of the pelletizer, oil temperature, cycle time, motor overload, CO_2 inlet pressure and hydraulic pressure are all monitored and displayed on the control panel.

Specifications

- Production capacity: 30kg/h (66.14lb/h) at 17.5 bar(253.82psi) CO2 inlet pressure Voltage: 400V/50Hz / 3Ph + PE (other voltages on request)
- Max. power consumption: 1.6kW (2.15 HP)
- Dimensions pelletizer (L x W x H): 1‘150 x 600 x 700mm (45.28 x 23.62 x 27.56in)
- incl. standard machine base (L x W x H): 1‘150 x 600 x 1‘300mm (45.28 x 23.62 x 51.18in)

- Weight net incl. standard machine base: approx. 147kg (324lb) (with hydraulic oil) approx. 141kg (310.85lb)(without hydraulic oil)
- CO_2 inlet connection: 1/2" BSP female
- CO_2 source: CO_2 storage tank, liquid phase (13- 21bar) (188.5-304.6psi)

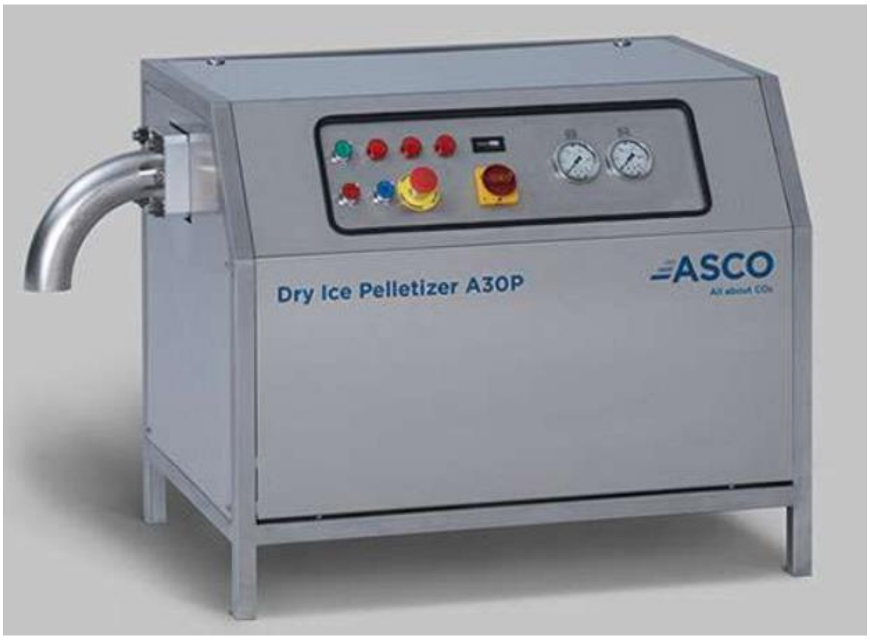

Figure 27. Dry ice Pelletizer A30P. ASCO. [10]

10.2. ICE TECH Company.

The fully automatic PR120H [11] is an efficient pelletizer designed to consistently produce high quality dry ice pellets using liquid CO_2 and electrical power. The PR120H is differentiated by its reduced cost and high quality output. With minimal space requirements, the PR120H can produce up to 120kg/ 265lbs of dry ice pellets per hour. It provides the best conversion factor on the market = 10% better than traditional pelletizers.

Functions and applications:

Produce fresh, high quality dry ice on demand. Reduce wasted dry ice due to sublimation. Eliminate transportation costs. Low ownership and maintenance costs. Stainless steel enclosure reduces noise level below 75 db(A) and protects machine components. Fully automated, one-button operations. Panel PC with built-in 7" touch screen. Sub Cooling technology minimizes CO_2 waste. Quick startup reduces downtime and loss of valuable CO_2. Compact footprint. Free choice of die plates: mm: 3, 10, 16 in: 1/8, 3/8, 5/8

Specifications:

- Rated Output: kg/h: up to 120 lbs/h: up to 265 of high quality dry ice pellets

- Pellet Diameter Range: mm: 3, 10, 16 in: 1/8, 3/8, 5/8 custom die plate design program available
- Dimensions mm/in: Length: 1150/45.3 Width: 650/25.6 Height: 1738/68.4 Weight: kg: 704 / lbs: 1552
- Inlet CO_2 Supply: bar: 16 - 22 psi: 232 - 319
- Compressed air or vapor CO_2 gas supply: bar: 8 – 10 psi: 116 - 145
- Air quality: Class 3 - according to ISO 8573-1
- Back Pressure on Revert Gas: bar: 0 - 1 psi: 0 - 14.5
- Exhaust Gas Pipe: Internal dia. 50 mm (2 inch)
- Power Supply: 3 x 400 V AC + N + PE, 50Hz. TN-S Earthing system Imax.: 16A Ipk: 10 kA. 480V AC Solidly Grounded Wye Source 3 Phase + GND wire, 60Hz Imax.: 16A .Control Panel SCCR: 25kA rms symmetrical 480VAC Max.
- Rated Power: 4.3 kW/ 5.8 Hp
- Noise Level: below 75 db(A)

Figure 28. Dry ice Pelletizer PR120H. ICETECH. [11]

11.Conclusions and future ideas.

During this project, we have design and calculate the performance of a dry ice device. Based on the Pressure and Enthalpy diagrams we have calculated the production of dry ice per hour. We have concluded that the most important part of the device is a good design of the expansion nozzle. For futures ideas and improvements of the device we will consider the use of more than one expansion nozzle and venting ports. With this modification we will increase the dry ice production per hour. Another improvement for this device could be the addition of a vacuum pump, which will recover the flash CO_2 gas remaining inside the chamber and it will be sent it back to the CO_2tank, increasing the performance and reducing the cost in the production of dry ice.

12.Bibliography

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- [3] Solid Carbon Dioxide Formation from Rapid Fluid Expansion using Integration of Computational Fluid Dynamics and Mathematical Modelling https://pdfs.semanticscholar.org/1512/74d5ed476f81d13f05004c72dcf913a3cab8.pdf
- [4] DRY ICE COMPACTION IN PISTON EXTRUSION PROCESS. Jan GÓRECKI*, Ireneusz MALUJDA*, Krzysztof TALAŚKA*, Dominik WOJTKOWI
- [5] The Linde Group. Safety advice. Working with carbon dioxide
- [6] Carbon Dioxide. ULLMANNS'S Encyclopedia of industrial chemistry. https://www.researchgate.net/publication/277696000_Carbon_Dioxide
- [7] Diseño y Construcción de Prototipo de Extrusión Directa para Producir Perfiles de Plomo Artesanal**.** ESCUELA SUPERIOR POLITÉCNICA DEL LITORAL
- [8] United Stated Patent No.: US 6,349,565 B1. CO2 Block press.
- [9] Solid Carbon Dioxide Formation from Rapid Fluid Expansion using Integration of Computational Fluid Dynamics and Mathematical Modelling. Risza Rusli, Eddie J. T. Chang, Hoang H. P. L. Pham and Azmi M. Shariff
- [10] ASCO. All about CO2. https://www.ascoco2.com/en/
- [11] ICETECH. https://www.coldjet.com/es/nuestros-equipos/equipos-de-produccion-de-hielo-seco/pr120h/#top

ANNEXES

hidrokraft

HS210

Hidrokraft Norm Hidrolik Silindirler

Hydraulic cylinders

Hidrokraft norm Hidrolik Silindir

Nominal Basınç:	210 bar
Test Basıncı:	250 bar
Maks. Strok:	3000 mm
Piston Ø:	40 – 100 mm

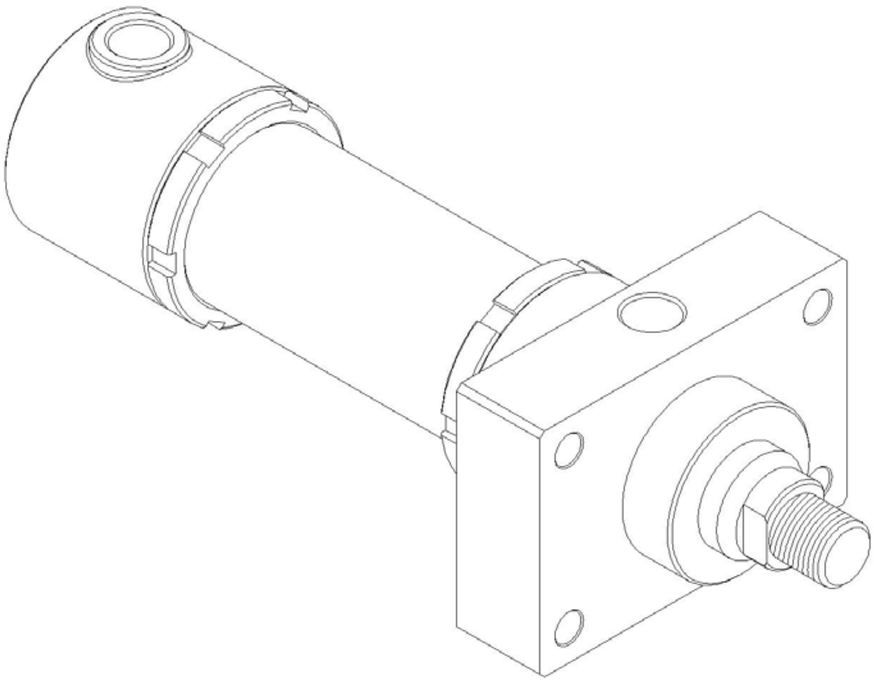
Hydraulic cylinder

Nominal pressure:	210 bar
Test pressure:	250 bar
Max. stroke:	3000 mm
Piston Ø:	40 to 100 mm

hidrokraft

HS210

Hidrokraft Norm Hidrolik Silindirler
Hydraulic cylinders



- **Maksimum çalışma basıncı 210 bar.**
  Maximum operating pressure up to 210 bar
- **40 - 100 mm arasında 5 farklı piston ölçüsü ve 12 farklı bağlantı seçeneği**
  Choice of 5 different piston sizes between 40 and 100 mm and 12 different attachments
- **İyi yataklama özelliklerine sahip sağlam ve kompakt tasarım**
  Rugged yet compact design with good guiding properties
- **Sızdırmazlık ölçüleri ISO 5597/1 ve DIN ISO 7425/1'e göre**
  Seal groove and diameter according to ISO 5597/1 and DIN ISO 7425/1
- **Varsayılan sızdırmazlık elemanlarıyla maksimum sürekli çalışma sıcaklığı ≤ 80□C ve hız ≤ 0,5 m/s**
  Seals by default for maximum continuous duty temperatures up to 80□C and velocities up to 0,5 m/s

Hidrokraft Norm Hidrolik Silindirler
Hydraulic cylinders

Genel açıklamalar

• Hidrokraft norm hidrolik silindirler kompakt gövde yapıları ve vidalı tasarımıyla pek çok çalışma alanı için uygun montaj boyutlarına sahip, robust silindirlerdir. Sert gövde yapıları ve krom kaplı milleriyle aşağıda listelenen çalışma koşulları ile üretilmektedir.

• Piston:
Ø40 - Ø100 mm piston çap aralığında DIN / ISO 3320 normuna göre imal edilir.

• Çalışma basıncı:
Nominal basınç maksimum 210 bar. Yüksek çalışma basınçları için lütfen bize ulaşın.

• Çalışma sıvıları:
Hidrolik yağ, H, HL, HLP DIN 51524/51525 normlarında. Yangın sıvıları ya da su gibi diğer işletim sıvılar istek üzerine kullanılabilir.

• Çalışma sıcaklığı:
Varsayılan olarak, silindir, -10°C ile +80°C sıcaklık aralığında çalışacak sızdırmazlık elemanları ile donatılmıştır. Yüksek sıcaklığa dayanıklı sızdırmazlık elemanları, tasarım değişiklikleri olmadan monte edilebilir.

• Piston hızı:
0.5 m/s maksimum. Yüksek piston hızları için irtibata geçiniz.

• Strok:
Standart stroklar veri sayfalarında listelenmiştir. Ayrıca kullanıcılar tarafından kısaltılabilir. Silindirlerde uzun hareketler de talep edilebilir

• Toleranslar:
Hareket miktarına bağlı toleranslar DIN ISO 2768 –g T1 normunda imal edilir.
Diğer toleranslar DIN ISO 2768- m T1 normundadır.

General description

• Hidrokraft norm hydraulic cylinders are round and robust cylinder in proven screwed cylinder design. By default these cylinders are fabricated with ground and chrome plated rods for the operating conditions as listed below.

• Piston:
Piston Ø40 to Ø100 mm according to DIN / ISO 3320.

• Operating pressure:
Nominal pressure maximum 210 bar, for higher operating pressures please contact us.

• Operating fluids:
Hydraulic oil on the basis of mineral oils for example H, HL, HLP-oils per DIN 51524/51525. Other operating fluids like fire fluids or water may be used upon request.

• Operatin temperature:
By default the cylinder is fitted with seals for a temperature range from -10°C to +80°C. High temperature resistant seals can be fitted without changes in design.

• Piston travel speed:
Maximum of 0.5m/s. Please contact for higher piston travel speeds.

• Stroke:
Standart strokes listed in the data sheets can be reduced user-defined. Hydraulic cylinders are also available with larger stroke.

• Tolerances:
Stroke tolerances and stroke dependent dimensions according to DIN ISO 2768 – g T1.
Other tolerances according to DIN ISO 2768 – m T1.

Teknik data

Technical data

Piston Ø – mm Piston Ø	40	50	63	80	100
Mil Ø mm Ø① mm Piston-rod Ø mm	22	28	36	45	56
Mil Ø mm Ø② mm Piston-rod Ø mm	28	36	45	56	70
Piston baskı alanı - cm^2 Piston area pushing - cm^2	12,6	19,6	31,2	50,2	78,5
Piston çekme alanı ① - cm^2 Piston area pulling – cm^2	8,8	13,5	21,0	34,4	54,0
Piston çekme alanı ② - cm^2 Piston area pulling – cm^2	6,5	9,4	15,3	25,4	40,0

Baskı Kuvveti – daN Piston force pushing - daN

80 bar	1000	1570	2490	4010	6280
100 bar	1260	1960	3120	5020	7850
120 bar	1500	2350	3730	6020	9420
160 bar	2000	3140	4480	8030	12560
200 bar	2520	3920	6240	10040	15700
210 bar	2646	4116	6552	10542	16485

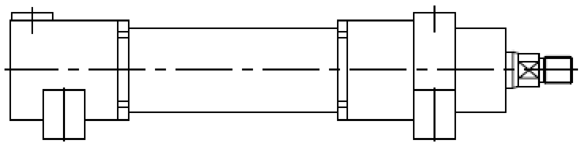
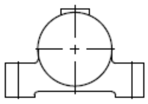
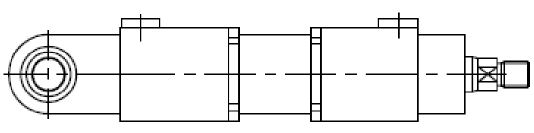
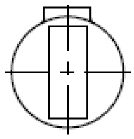
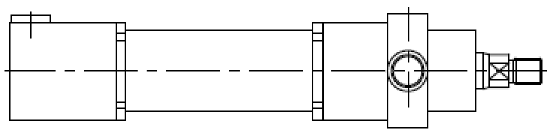
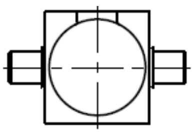
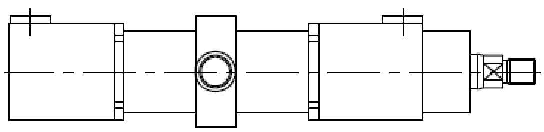
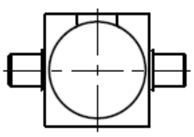
Çekme Kuvveti ① – daN Piston force pulling - daN

80 bar	704	1080	1680	2752	4320
100 bar	880	1350	2100	3440	5400
120 bar	1056	1620	2520	4148	6480
160 bar	1408	2160	3360	5504	8640
200 bar	1760	2700	4200	6880	10800
210 bar	1848	2835	4410	7224	11340

Çekme Kuvveti ② – daN Piston force pulling - daN

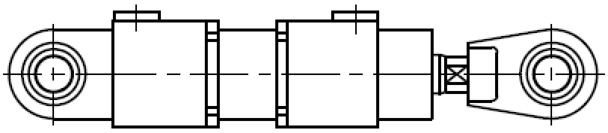
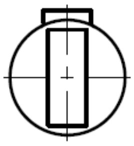
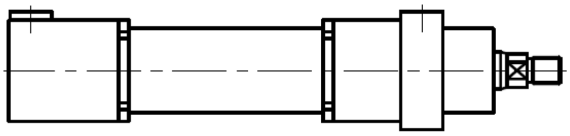
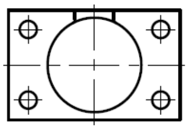
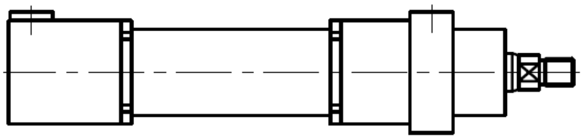
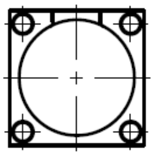
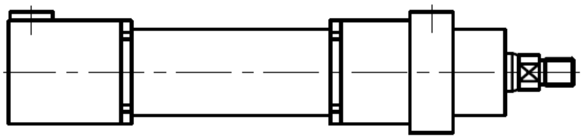
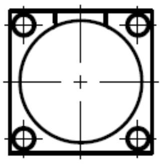
80 bar	520	752	1224	2048	3200
100 bar	650	940	1530	2560	4000
120 bar	780	1128	1836	3072	4800
160 bar	1040	1504	2448	4096	6400
200 bar	1300	1880	3060	5080	8000
210 bar	1365	1974	3213	5334	8400

Gövde yapıları Construction forms

		Kod Code	Açıklama Description
		**AB** **01**	Ayak Bağlantı Radyal montaj. Boydan boya açılmış 4 delik ile bağlanır. Hidrolik bağlantı delikleri BSPT. Foot mounting Radial attachment. Adjusted with four through holes. Port threads are BSPT.
		**AM** **02**	Arka Mafsal Bağlantı Küresel veya silindirik mafsal bağlantılı. Hidrolik bağlantı delikleri BSPT. Pivot eye mounting With bronze bushing or ball and socket joint at cylinder bottom. Port threads are BSPT.
		**BM** **03**	Boğaz Mafsal Bağlantılı Mil tarafında muylu bağlantılı. Hidrolik bağlantı delikleri BSPT. Head trunnion mounting Trunnion in front. Port threads are BSPT.
		**GM** **04**	Göbek Mafsal Bağlantılı Gövde muylu bağlantılı. Yeri müşteriye bağlıdır. Hidrolik bağlantı delikleri BSPT. Centre trunnion mounting Trunnion in centre, position variable. Port threads are BSPT.

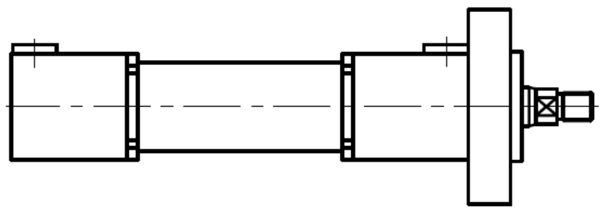
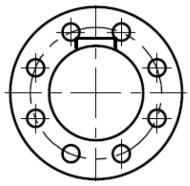
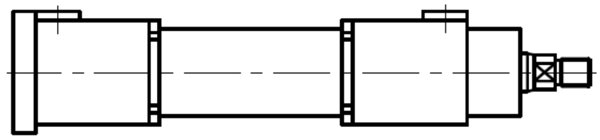
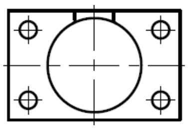
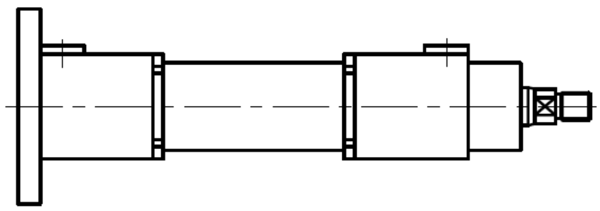
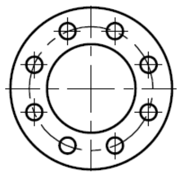
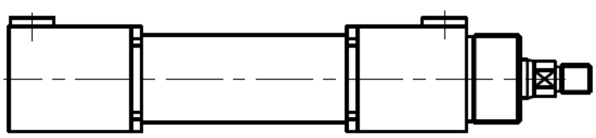
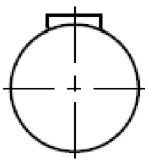
Gövde yapıları

Construction forms

		Kod Code	Açıklama Description
		**ÖAM** **05**	Ön-Arka Mafsal Bağlantı Küresel veya silindirik mafsal bağlantılı. Hidrolik bağlantı delikleri BSPT. Rod-end eye mounting With ball and socket or bronze bushings both ends. Port threads are BSPT.
		**ÖFB** **06**	Ön Flanş Bağlantı Flanş üzerinde boydan boya açılmış 4 delik ile bağlanır. Hidrolik bağlantı delikleri BSPT. Rectangle Flange at fronf Connected with 4 holes on the rectangle flange. Port threads are BSPT.
		**ÖFB** **61**	Ön Kare Flanş Bağlantılı Flanş üzerinde, mil tarafından veya karşısından açılmış 4 adet diş ile bağlanır. Hidrolik bağlantı delikleri BSPT. Square Flange at fronf Connected with 4 threaded holes on rod or bottom side. Port threads are BSPT.
		**ÖFB** **62**	Ön Kare Flanş Bağlantılı Flanş üzerinde boydan boya açılmış 4 delik ile bağlanır. Hidrolik bağlantı delikleri BSPT. Square Flange at fronf Connected with 4 holes on the square flange. Port threads are BSPT.

Gövde yapıları

Construction forms

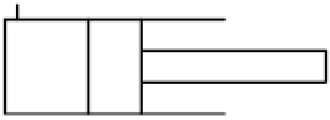
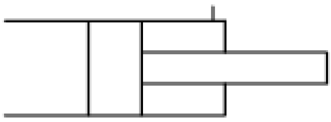
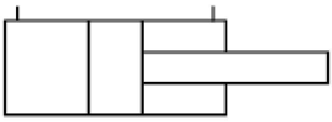
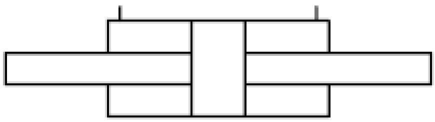
		Kod Code	Açıklama Description
		**ÖFB** **63**	Ön Yuvarlak Flanş Bağlantı Yuvarlak flanş üzerinde boydan boya açılmış 8 delik ile bağlanır. Hidrolik bağlantı delikleri BSPT. Round Flange at fronf Connected with 8 holes on the round flange. Port threads are BSPT.
		**TF** **7**	Dikdörtgen Taban Flanş Bağlantı Taban Flanş üzerinde boydan boya açılmış 4 delik ile bağlanır. Hidrolik bağlantı delikleri BSPT. Rectangle Flange at base Connected with 4 holes on the rectangle flange at base. Port threads are BSPT.
		**TF** **71**	Yuvarlak Taban Flanş Bağlantı Yuvarlak Taban Flanş üzerinde boydan boya açılmış 8 delik ile bağlanır. Hidrolik bağlantı delikleri BSPT. Round Flange at base Connected with 8 holes on the round flange at base. Port threads are BSPT.
		**VB** **77**	Vida Bağlantılı Mil tarafından merkezleme faturasına açılmış olan diş ile bağlanır. Hidrolik bağlantı delikleri BSPT. Thread fixation Adjusted with threaded blind holes by groove side. Port threads are BSPT.

Operasyon şekilleri

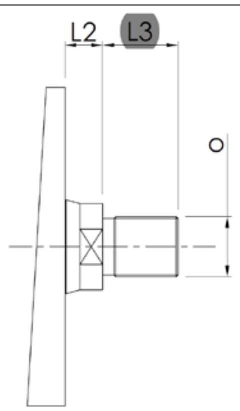
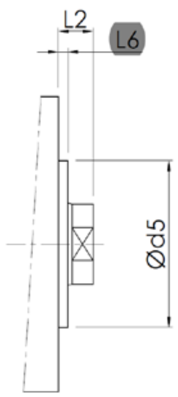
Modes of operation

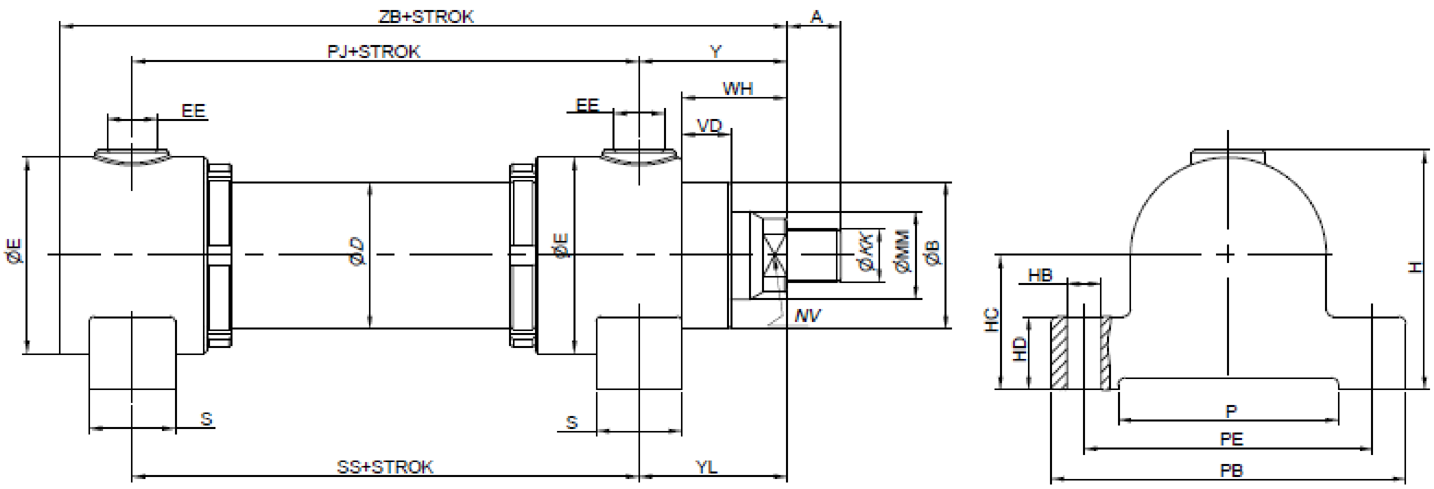
Semboller DIN/ISO 1219/1'e göre

Symbol according to DIN/ISO 1219/1

Tek etkili, basmaya çalışma, dış etki ile dönüş		**200**	single-acting, pushing action, return by external force
Tek etkili, Çekmeye çalışma, dış etki ile dönüş		**201**	single-acting, drawing action, return by external force
Çift etkili, her iki tarafta aynı ortam		**206**	double-acting, on both sides the same medium
Çift etkili, Çift milli		**214**	double-acting, continous piston-rod

Opsiyonlar Options

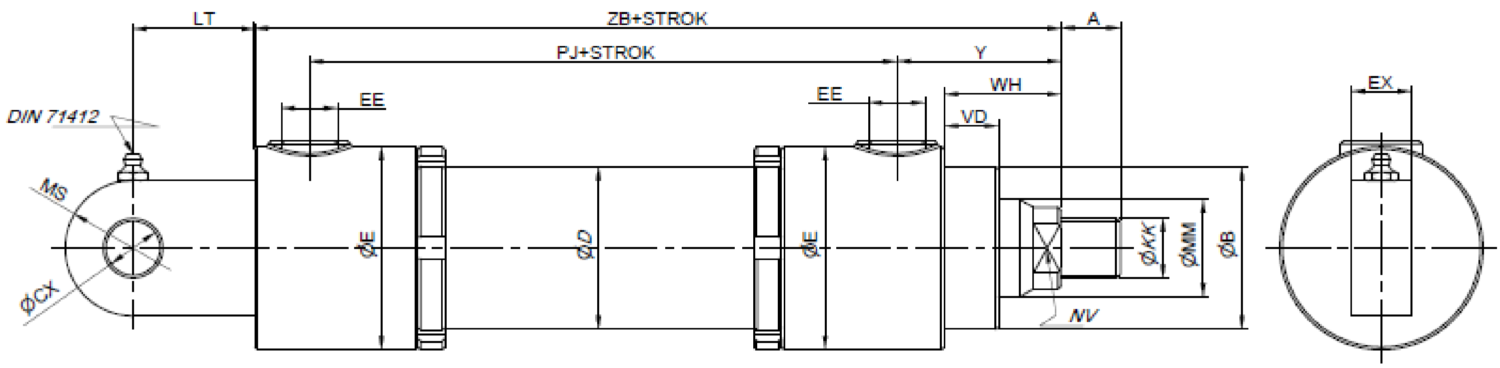
	Kod Code	Açıklama Description
FKM (Viton ®) Sızdırmazlık Hidrokrfaft HS210 seri hidrolik silindirler standart olarak 80˚C'ye kadar olan ortamlar için uygundur. 180˚C'ye kadar ortamlar için FKM (Viton ®) sızdırmazlık elemanları tercih edilmelidir.	**V**	FKM (Viton ®) seals Hidrokrfaft HS210 series hydraulic cylinders are suitable for environments up to 80°C as standard. For media up to 180°C FKM (Viton ®) seals should be preferred.
	**D**	Dıştan dişli mil ucu. Piston-rod end with external thread.
	**Z**	Merkezleme faturası With centering collar



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
H	78		100		117		137		160	
HB Ø	12		14		18		22		26	
HC	42 ±0,15		55 ±0,15		63 ±0,15		75 ±0,25		85 ±0,25	
HD	28		30		35		40		45	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NV	AA17		AA24		AA32		AA41		AA46	
P	70		90		100		120		150	
PB	120		145		175		210		260	
PE ±0.2	98		118		140		175		215	
PJ +1.5	48,5		63,5		74,5		85		102,5	
S	25		35		35		40		45	
SS +1.5	32		49		55		61		78	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
YL	62,5		60,5		63,5		80		92,5	
ZB +1.5	127		147		161		189		218	

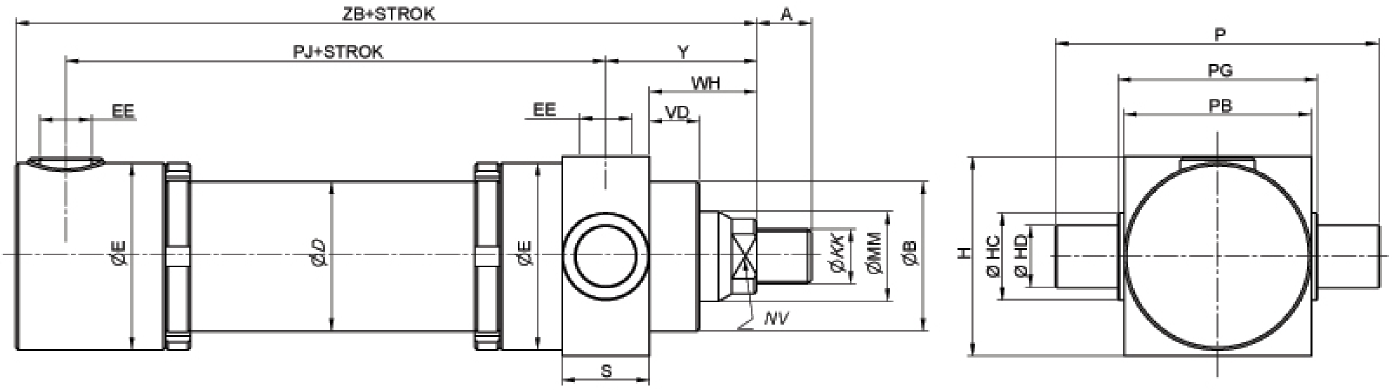
Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	**22**	**28**	**28**	**36**	**36**	**45**	**45**	**56**	**56**	**70**
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
CX $_{H7}$ Ø	20		20		30		35		40	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
EX	20		22		30		35		35	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
LT	45		45		55		60		65	
MM Ø	22	28	28	36	36	45	45	56	56	70
MS	R25		R25		R30		R40		R45	
NV	AA17		AA24		AA32		AA41		AA46	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1,5}$	127		147		156		188		218	

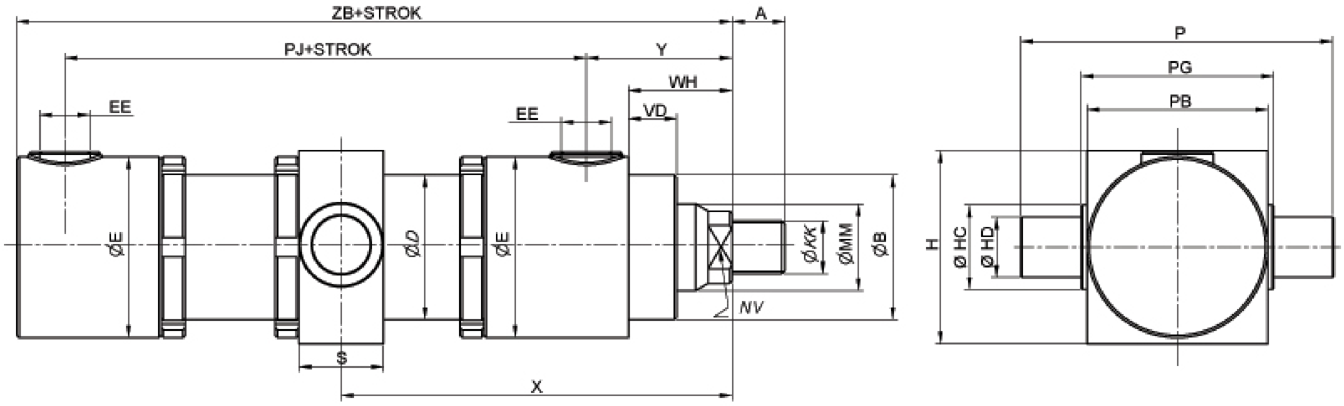
Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	**22**	**28**	**28**	**36**	**36**	**45**	**45**	**56**	**56**	**70**
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
H	70		90		100		125		150	
HC Ø	25		35		35		40		45	
HD $_{-0,05}$ Ø	20		25		30		35		40	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NV	AA17		AA24		AA32		AA41		AA46	
P	110		130		150		180		200	
PB	65		75		95		115		130	
PG	70		80		100		120		135	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
S	25		35		35		40		45	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1,5}$	127		147		156		188		218	

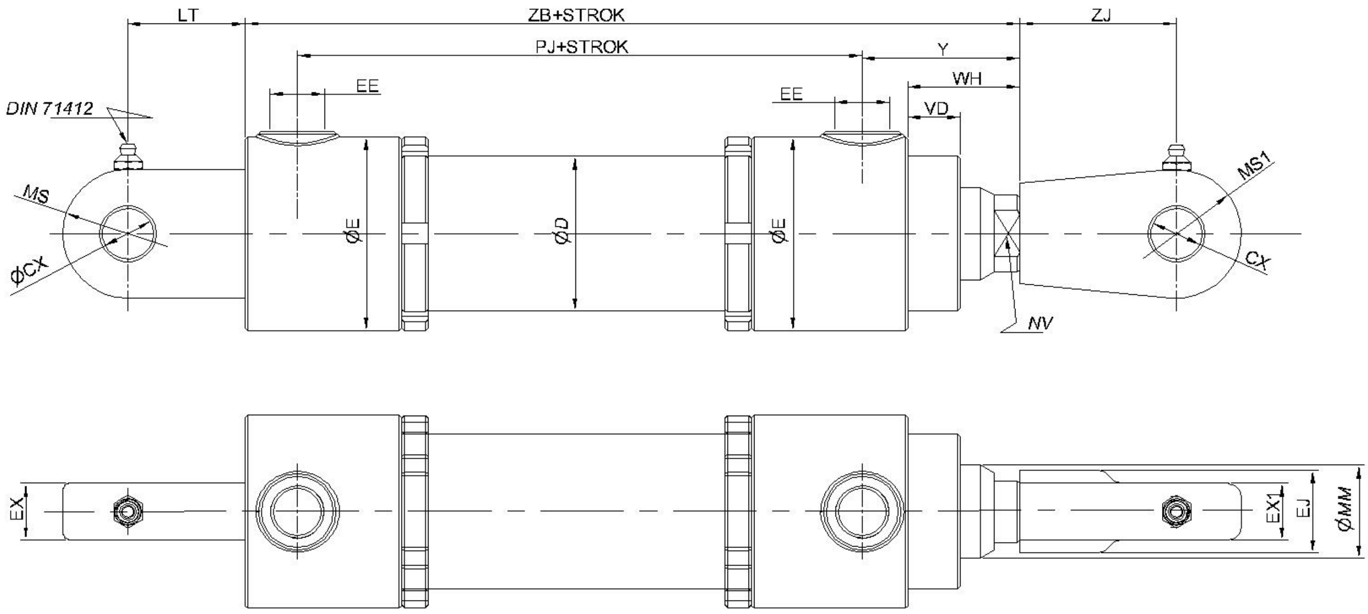
Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8”		G1/2”		G1/2"		G1/2"		G1/2"	
H	70		90		100		125		150	
HC Ø	25		35		35		40		45	
HD $_{-0.05}$ Ø	20		25		30		35		40	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
Minimum Strok	107		110		114		120		114	
NV	AA17		AA24		AA32		AA41		AA46	
P	110		130		150		180		200	
PB	65		75		95		115		130	
PG	70		80		100		120		135	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
S	25		35		35		40		45	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
X	Müşteri tarafından verilir | On request, please state the dimension required in your order.									
X $_{max}$	Strok+35		Strok+40		Strok+44		Strok+59		Strok+84	
X $_{min}$	142		150		158		179		204	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1,5}$	127		147		156		188		218	

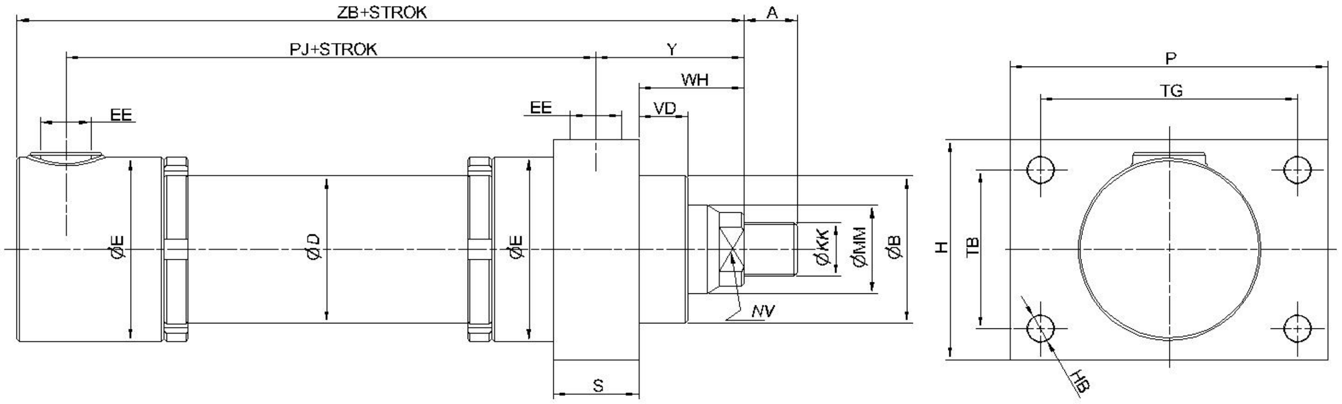
Not : Minimum strok silindir çapına göre değişiklik göstermektedir. Tabloda belirtilmiştir.
Minimum stroke for operating mode is given by the table above.



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
CX H7	20		20		30		35		40	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
EJ	30		32		42		47		70	
EX	20		22		30		35		35	
EX1	20		22		30		35		37	
LT	45		45		55		60		65	
MM Ø	22	28	28	36	36	45	45	56	56	70
MS	R25		R25		R30		R40		R45	
MS1	R25		R25		R30		R40		R50	
NV	AA17		AA24		AA32		AA41		AA46	
PJ +1,5	51,5		66,5		72,5		85		103	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB +1,5	127		147		156		188		218	
ZJ	60		60		70		80		105	

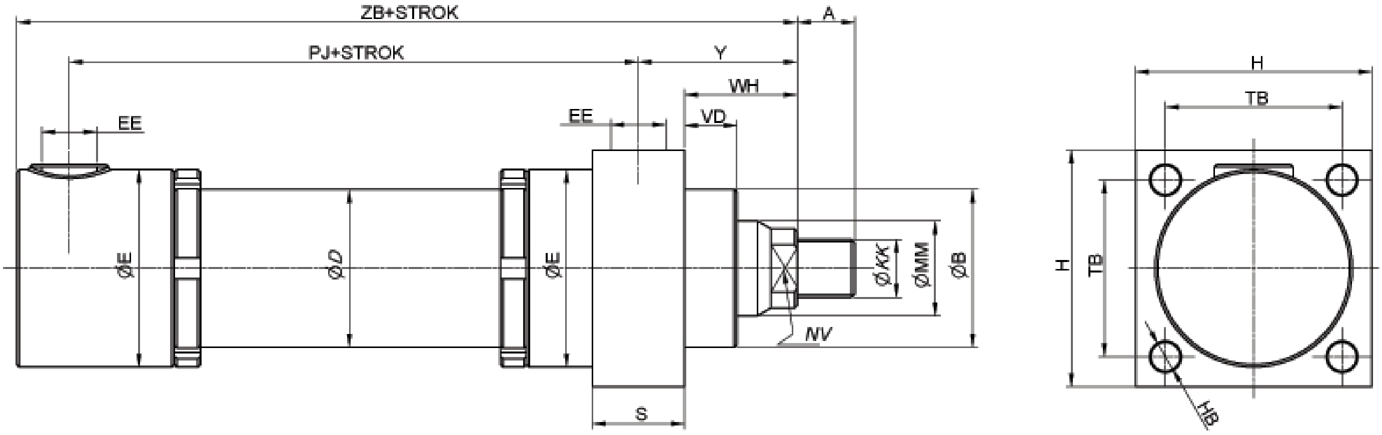
Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	**22**	**28**	**28**	**36**	**36**	**45**	**45**	**56**	**56**	**70**
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8”		G1/2”		G1/2"		G1/2"		G1/2"	
H	70		90		100		125		150	
HB Ø	11		11		13		17		21	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NV	AA17		AA24		AA32		AA41		AA46	
P	110		130		150		180		200	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
S	25		35		35		40		45	
TB	45		65		70		90		100	
TG	85		105		120		150		160	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1,5}$	127		147		156		188		218	

Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	**40**		**50**		**63**		**80**		**100**	
Mil Ød / rod Ø	**22**	**28**	**28**	**36**	**36**	**45**	**45**	**56**	**56**	**70**
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
H	70		90		100		125		150	
HB Ø	M8		M10		M12		M16		M20	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NV	AA17		AA24		AA32		AA41		AA46	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
S	25		35		35		40		45	
TB	54		68		80		98		116	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1,5}$	127		147		156		188		218	

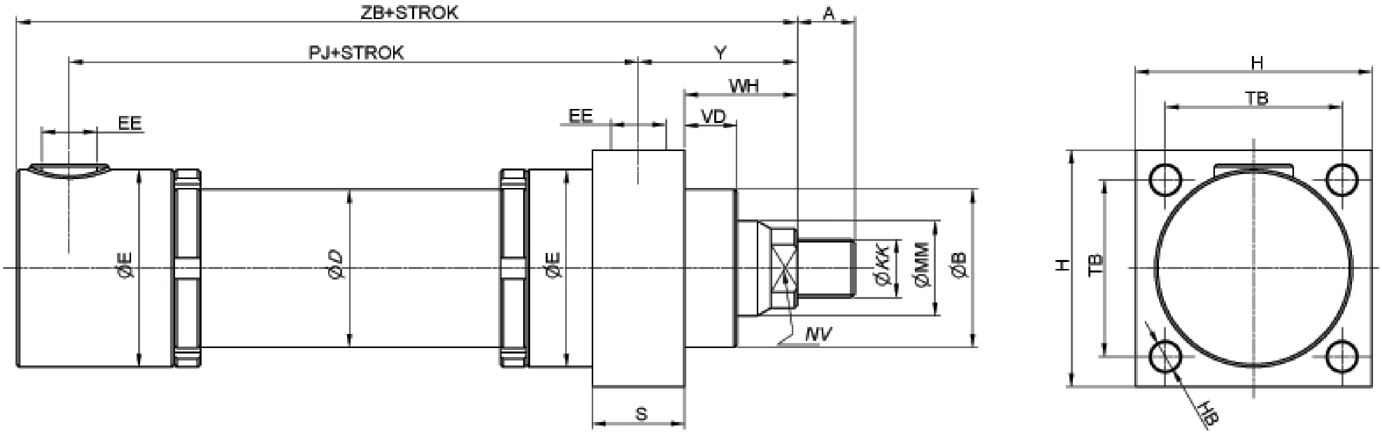
**** Flanş üzerinde, mil tarafından veya karşısından açılmış 4 adet diş ile bağlanır.**
Connected with 4 threaded holes on rod or bottom side.

Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70

hidrokraft

62

HS210 ÖFB KARE

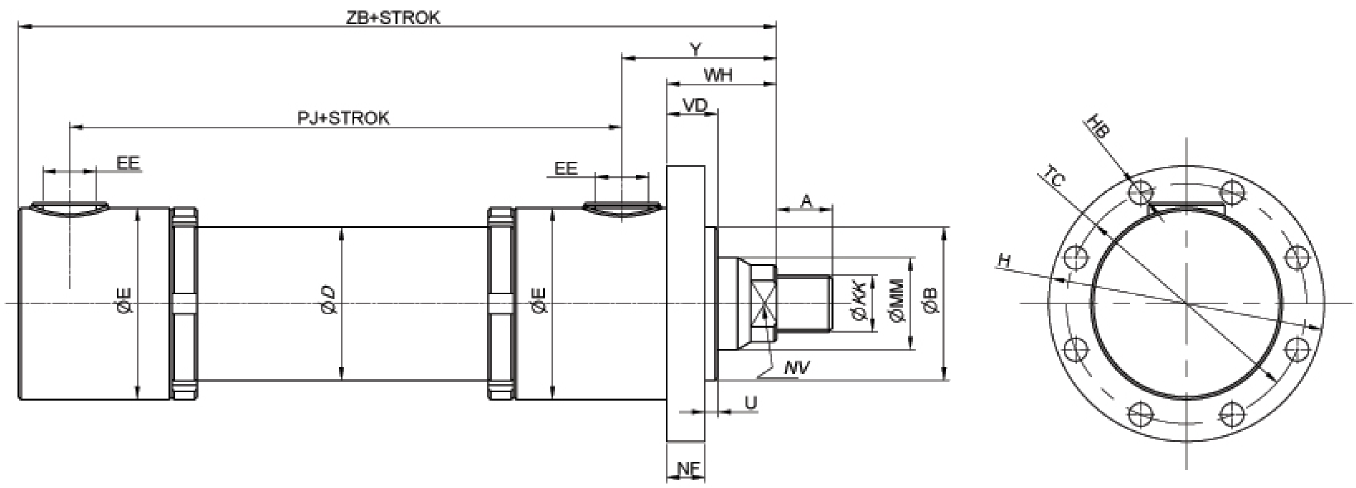


Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
H	70		90		100		125		150	
HB Ø	9		11		13		17		21	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NV	AA17		AA24		AA32		AA41		AA46	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
S	25		35		35		40		45	
TB	54		68		80		98		116	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1,5}$	127		147		156		188		218	

**** Flanş üzerinde, boydan boya açılmış 4 delik ile bağlanır.**
Connected with 4 holes on the square flange.

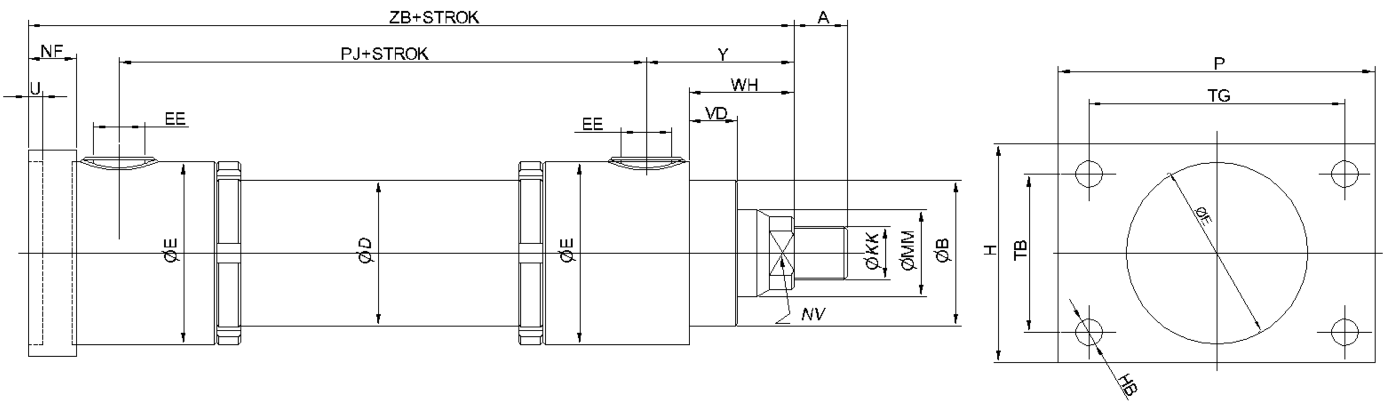
Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
A	20		22		28		35		45	
B Ø	45		75		90		110		130	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8”		G1/2”		G1/2"		G1/2"		G1/2"	
H Ø	120		135		150		170		200	
HB Ø	9		9		11		13		17	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NF	25		20		25		30		35	
NV	AA17		AA24		AA32		AA41		AA46	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
TC Ø	100		105		120		140		165	
U	5		5		5		5		5	
VD	30		25		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1.5}$	127		147		156		188		218	

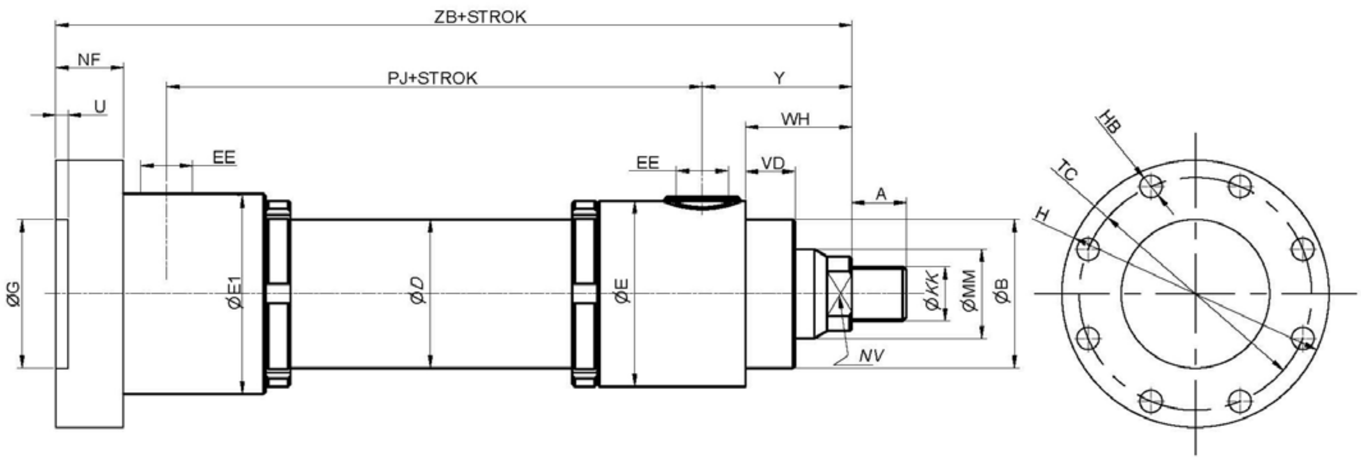
Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
E1 Ø	65		75		90		110		130	
EE	G3/8”		G1/2”		G1/2"		G1/2"		G1/2"	
H	70		90		100		125		150	
HB	11		11		13		17		21	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NV	AA17		AA24		AA32		AA41		AA46	
P	110		130		150		180		200	
PJ $_{+1,5}$	51,5		66,5		72,5		85		103	
NF	15		25		30		35		40	
TB	45		65		70		90		100	
TG	85		105		120		150		160	
U	5		5		5		5		5	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1,5}$	147		169		183		220		255	

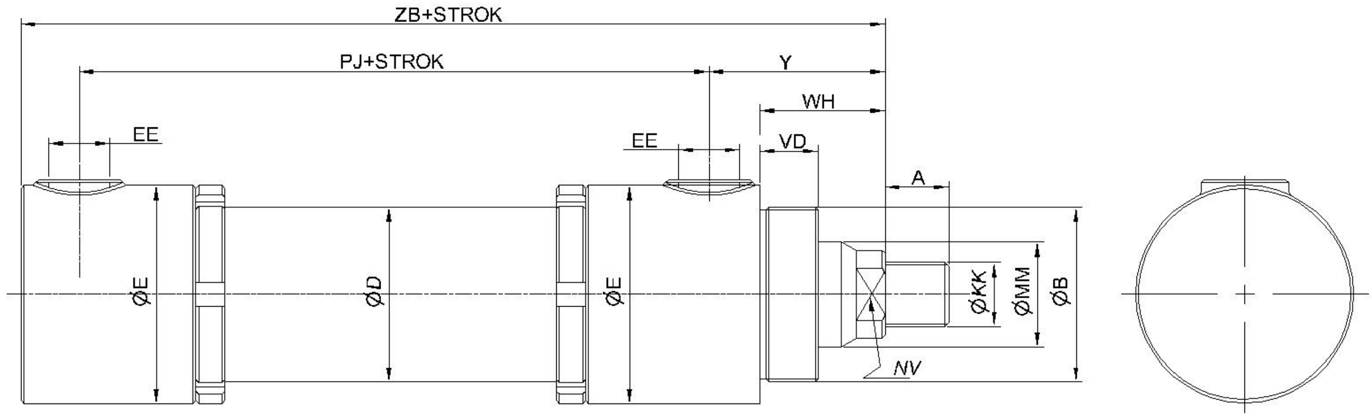
Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
A	20		22		28		35		45	
B Ø	50		60		70		85		100	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
E1 Ø	65		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
G Ø	50		75		90		110		130	
H Ø	120		135		150		170		200	
HB Ø	9		9		11		13		17	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NF	18		20		30		35		40	
NV	AA17		AA24		AA32		AA41		AA46	
PJ $_{+1.5}$	51,5		66,5		72,5		85		103	
S	25		35		35		40		45	
TC Ø	100		105		120		140		165	
U	5		5		5		5		5	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB $_{+1.5}$	147		164		183		220		255	

Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70



Ölçüler Dimensions

Piston Ø – mm / Piston Ø	40		50		63		80		100	
Mil Ød / rod Ø	22	28	28	36	36	45	45	56	56	70
A	20		22		28		35		45	
B Ø	50		75		90		115		106	
D Ø	50		60		75		95		115	
E Ø	60		75		90		110		130	
EE	G3/8"		G1/2"		G1/2"		G1/2"		G1/2"	
HB Ø	9		9		11		13		22	
KK Ø	M16x2		M22x1,5		M28x1,5		M35x1,5		M45x1,5	
MM Ø	22	28	28	36	36	45	45	56	56	70
NF	25		20		25		30		35	
NV	AA17		AA24		AA32		AA41		AA46	
P	110		130		150		180		200	
PJ +1,5	51,5		66,5		72,5		85		103	
S	25		35		35		40		45	
TC Ø	100		105		126		164		200	
U	5		5		4		5		5	
VD	30		20		25		35		40	
WH	50		43		46		60		70	
Y	62,5		60,5		63,5		80		92,5	
ZB +1,5	127		147		156		188		218	

Not : STROK ≤ 70 mm → ZB+STROK = ZB+70 PJ+STROK = PJ+70

Kodlama

Codification

Piston Ø – mm Piston Ø	**40**	**50**	**63**	**80**	**100**
Mil Ø mm Ø① mm Piston-rod Ø mm	22	28	36	45	56
Mil Ø mm Ø② mm Piston-rod Ø mm	28	36	45	56	70

HS210	50	/	28	/	100	/	01	/	V

- **Silindir Tipi** Cylinder Type
- **Piston Çapı Ø mm** Piston Ø mm
- **Mil Çapı Ø mm** Piston-rod Ø mm
- **Strok mm** Stroke mm
- **Gövde Yapısı** Construction form
- Opsiyon Option

Sipariş Örneği

Example of order

HS210 50 / 28 / 100 / 01 / V

HS210 seri Hidrokraft Silindir
Piston çapı Ø50mm
Mil çapı Ø28mm
Strok 100 mm
Gövde yapısı 01 Ayak Bağlantı
FKM sızdırmazlık

Hidrokraft HS210 serie cylinder
piston Ø50mm
piston-rod Ø28mm
stroke 100 mm
construction form 01 Foot mounting
with FKM seals

Datasheet

ENGLISH

RS Pro Nozzle Band Heater, 440 W, 230 V, 70mm Diameter

Stock No: 920-9988

Product Details

RS Pro Nozzle heaters are designed with the highest quality materials used for optimal performance. The heaters are most commonly used in the plastic industry but are also suitable to use in applications of up to 1000°F.

•High temperature oxidation resistance metal sheath
•Highest grade mica insulation provides excellent electrical insulation at high temperature and is resistant to moisture
•Clamping band is low thermal expansion steel construction designed to maintain clamping pressure at elevated temperatures
•Nickel/Chromium resistance wire evenly wound for uniform heat distribution and reliable accuracy
• Standard 10 in fibreglass lead wire.

Multi-Purpose Process Heaters

In order to obtain optimum performance from these products, it is advised that temperature sensing and control elements be used with them.

Warning

These heaters shall only be used where adequate electrical, thermal and mechanical barriers are provided to prevent access to hazardous parts without the use of a tool.

Specifications

RS Article	Diameter (mm)	Wattage (W)	Voltage (V)
9209931	20	65	230
9209934	25	85	230
9209947	30	135	230
9209940	30	85	230
9209944	30	155	230
9209950	30	200	230
9209972	30	225	230
9209922	35	125	230
9209938	35	150	230
9209953	35	185	230
9209956	38	235	230
9209969	40	270	230
9209975	40	300	230
9209984	60	375	230
9209988	70	440	230
9209978	44	310	230
9209962	50	345	230
9209981	50	390	230
9209997	70	560	230
9209966	60	415	230

Band Heater Type:	Nozzle Heater
Power Rating:	440 W
Supply Voltage:	230 V
Band Dimensions:	38 x 70mm
Height:	38mm
Diameter:	70mm

THE LINDE GROUP

Safety Advice.
12 – Working with Carbon dioxide CO_2.

1. Introduction

Working safely with carbon dioxide means understanding the characteristics of this gas and taking suitable safety precautions. This Safety Advice is a recommendation based on practical experience; it supplements, but does not replace, mandatory safety stipulations.
Carbon dioxide is sometimes referred to as "carbonic acid". In this Safety Advice, the term "carbonic acid" is used only to refer to an aqueous solution of carbon dioxide (CO_2 in H_2O).

2. Properties

Chemical Properties

Carbon dioxide is non-flammable and, under atmospheric conditions, chemically stable and inert. Combustion reactions are inhibited or completely suppressed by CO_2.

Carbon dioxide can react vigorously with certain substances, such as ammonia or amines.

Carbon dioxide dissolves in water to produce carbonic acid, which reacts as a weak acid and has a corrosive effect on carbon steel and a few non-ferrous metals.

Physical Properties

As a gas at atmospheric pressure, carbon dioxide is approximately 1.5 times as heavy as air. CO_2 therefore tends to flow downward, and can collect in pits, basements, or natural depressions. If there is little air movement, these pools of CO_2 can persist for many hours.

The physical states of carbon dioxide, which depend on pressure and temperature, deserve particular attention:

- At atmospheric pressure, CO_2 is gaseous.
- At temperatures between −56.6 and +31.1°C, and pressures of at least 5.2 bar, CO_2 can exist in liquid form. Liquid CO_2 cannot exist at atmospheric pressure (1 bar).
- At temperatures below −56.6°C, CO_2 can occur in the solid state.
- All three physical states are possible only at the "triple point" (-56.6°C, 5.2 bar).

These physical states can easily change:

In the gas cylinder CO_2 is in the liquid state, i.e. "under pressure liquefied." The pressure in the cylinder is approximately 57 bar at 20°C. When CO_2 is withdrawn from the cylinder through a regulator set at an outlet pressure of less than 5.2 bar, gaseous CO_2 is produced: 1 kg of liquid expands to about 550 litres of gas at atmospheric pressure.

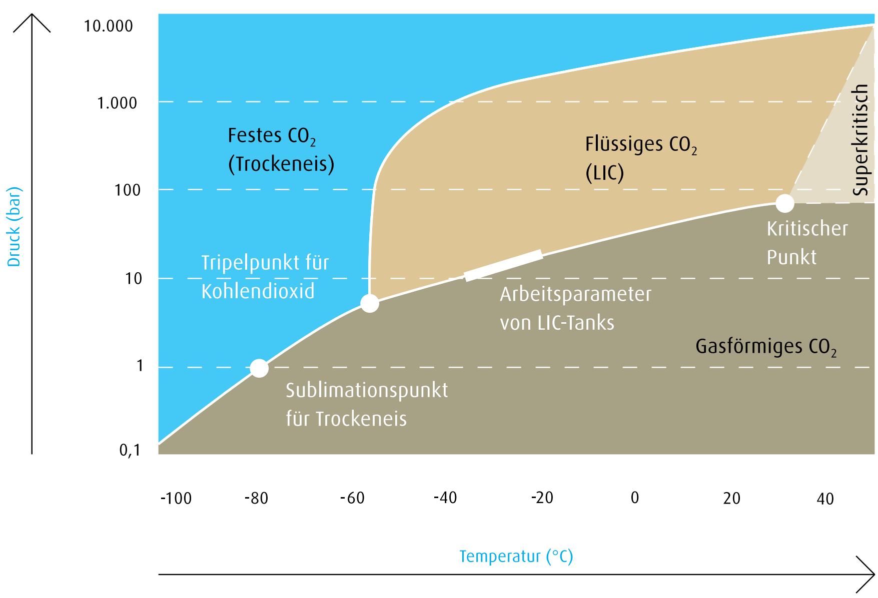
Under certain conditions it is also possible to withdraw CO_2 from the cylinder in liquid form (see section 3). If liquid CO_2 is abruptly depressurised during withdrawal, it is intensively cooled, producing a mixture of CO_2 gas and CO_2 snow.

Physiological Effects

As a gas, carbon dioxide is colourless and essentially odourless and tasteless. It is therefore practically impossible to detect with the human senses.

Carbon dioxide is considered nontoxic. It is not a hazardous substance as defined by the Dangerous Substances resp. Preparations Directive. The air we brethe contains about 0.03 vol.% carbon dioxide. This concentration is essential for life, since it stimulates the respiratory centre and controls the volume and rate at which we breathe. At higher concentrations, CO_2 can

States of aggregation depending on pressure and temperature



be unhealthy. When the air we breathe contains 3 – 5 vol.% CO_2, we experience headache, respiratory disturbances and discomfort. At 8 – 10 vol.%, cramps, unconsciousness, respiratory arrest, and death can occur.At this point the oxygen content of the air is still 19 vol.%, which is still sufficient. The physiologically harmful effect of these high CO_2 concentrations therefore results not from lack of oxygen, but from the direct effect of carbon dioxide. A maximum workplace concentration (equivalent to TLV) of 0.5 vol.% has therefore been defined for CO_2.

Caution: Danger of asphyxiation

Carbon dioxide can also be dangerous to humans because of cold. When cryogenic liquefied CO_2, or CO_2 that has been cooled by expansion, comes in contact with human skin as a spray or snow, it can produce painful "cryogenic burns." Sensitive tissues such as the cornea are particularly at risk. Large areas of freeze burning can cause death. (See Linde Safety Advice 1, "Handling of cryogenic liquefied gases")

Properties of Dry Ice

Dry ice consists of compressed CO_2 snow that has been produced by depressurising liquid CO_2. At atmospheric pressure the temperature of dry ice is –79°C. When dry ice heats up at atmospheric pressure, it does not melt but instead evaporates completely ("sublimes") to form gaseous cabron dioxide hence the name "dry ice." Depending on how much it is compressed, 1 kg of dry ice yields 300 – 400 litres of CO_2 gas. A considerable pressure build-up can therefore occur if dry ice evaporates in a gas-tight vessel.

3. Safety Measures

Health Precautions

Inhalation of CO_2 in concentrated form is dangerous to humans. CO_2 therefore must not be present in high concentrations in the air. The following safety precautions are advisable:

- Keep CO_2 systems gas-tight. Seal any leaks immediately.
- Any CO_2 discharge from an operating facility of a safety valve must be vented outdoors.
- Rooms containing CO_2 systems must have effective ventilation.
- Rooms in which large quantities of CO_2 have collected must be entered only with self-contained breathing apparatus. This applies even if persons have been overcome and urgently require assistance.
- If a sudden CO_2 emission occurs, give priority to immediate evacuation of low-lying areas (pits, basements), where the danger of CO_2 accumulation is especially severe.
- Fixed CO_2 extinguishing systems must be operated, for testing or actual use, only when no one is present in the threatened area. If the carbon dioxide can reach other rooms through ducts, wall openings, ventilation, or air-conditioning systems, these are also considered part of the threatened area.

Handling of CO_2 Cylinders

Important advice for working with any type of gas cylinder is provided in Linde Safety Advice 7 "Safe handling of gas cylinders and cylinder bundles", and 8 "(Re-) Filling Gases".

For CO_2 cylinders, also note the following:

Unauthorised transfer of carbon dioxide from one gas cylinder to another constitutes a safety risk, for the following reasons: Cylinders being filled must meet certain requirements so they can reliably withstand the pressure. In general, only the properly trained personnel of an authorised filling facility can determine whether a cylinder is suitable for use. In addition, it is absolutely mandatory that the contents be monitored and defined by weighing during filling. According to the Pressure Vessel Code, a cylinder may contain a maximum of 0,75 kg CO_2 per litre of cylinder volume. This fill factor guarantees that the pressure in the CO_2 cylinder will not reach the test pressure of 250 bar below a temperature of 65°C. If the filling factor is exceeded, the pressure inside the cylinder increases substantially with even a slight rise in temperature. An overfilled CO_2 cylinder can burst if it is merely exposed to sunlight. It is highly inadvisable to transfer carbon dioxide from one cylinder to another.

The pressure in a CO_2 cylinder depends solely on temperature. At 20°C, for example, it is 57 bar. Even an almost empty CO_2 cylinder remains at 57 bar at 20°C, as long as it contains the liquid phase. This means that the contents of a CO_2 cylinder cannot be determined by measuring its pressure, but only by weighing.

CO_2 cylinders are generally made of carbon steel. This material is corroded by carbonic acid (CO_2 dissolved in H_2O) a dangerous loss of strength. CO_2 cylinders must therefore be protected from water or aqueous fluids (beer, lemonade, etc.).

In the filling plant, CO_2 cylinders must be checked for water prior to filling, and dried if necessary. But users should also make sure that liquids do not enter their CO_2 cylinders. One possible safety precaution is to install a backflow preventer.
There is another, very simple safety precaution, which can keep moisture out of CO_2 cylinders: they should be emptied only down to a residual pressure of about 5 bar; then keep the cylinder valves closed. This prevents moist air from entering into the cylinder.

CO_2 cylinder valves shall have a overpressure safety device in the form of a bursting disk that is secured to the valve with a coupling nut. To prevent inadvertent and dangerous discharge of CO_2, this device must never be tampered with.

Withdrawing Gas from CO_2 Dip Tube Cylinders

CO_2 dip tube cylinders contain a dip tube which extends from the cylinder valve to just above the bottom of the cylinder. Provided it remains vertical, a dip tube cylinder always yields CO_2 in liquid form. Note the following particular characteristics when using these cylinders:

- CO_2 dip tube cylinders are clearly marked as such by the filling plant. The user must specifically note that the cylinder is a CO_2 dip tube cylinder.
- CO_2 dip tube cylinders must be used only when the user intends to withdraw liquid carbon dioxide.
- CO_2 dip tube cylinders must not be fitted with a regulator, sine the pressure drop woul cause the liquid caarbon dioxide to solidify into CO_2 snow, clogging the regulator and disabling it.
- CO_2 dip tube cylinders must be standing upright while gas is being withdrawn, so that the opening of the dip tube remains below the CO_2 liquid level. Thsi is the only way in which almost the entire contents of the cylinder can be withdrawn in liquid form as intended.
- Liquid carbon dioxide emerges from a CO_2 dip tube cylinder at full cylinder pressure. The withdrawal device must therefore be appropriately pressure-

resistant and designed for liquid CO_2. It would be potentially fatal, for example, to connect a CO_2 dip tube cylinder to a beer keg without a regulator. The keg would be completely incapable of withstanding the pressure of the evaporating liquid CO_2, and would burst.

- Pipe sections for liquid CO_2 equipped with shutoff devices must also be equipped with a safety valve.
- When liquid carbon dioxide withdrawn from a dip tube cylinder expands to atmospheric pressure, CO_2 snow is produced. Dip tube cylinders are therefore used primarily in instances where CO_2 snow is required, for example to refrigerate foodstuffs. CO_2 snow can be dangerous in several ways. If it contacts human skin while emerging, there is a danger of cryogenic burns. Minimum protection should therefore consist of safety glasses for the eyes. The CO_2 snow can also clog the supply system. When a plug of CO_2 snow is suddenly loosened, for example by striking the supply hose, the backedup liquid CO_2 abruptly deprssurises. This can cause the hose to fly around or burst, injuring people of damaging property.
- A very specific hazard can arise when CO_2 is used to inert flammable gases or vapours. In a flowing mixture of gaseous CO_2 and CO_2 snow,the "snowflakes" can become electrostatically charged and can ignite an explosive gas / air mixture by sparking. CO_2 should therefore never be sprayed directly into a cloud of flammable gas or vapour. This important instruction applies to CO_2 cylinders with or without a dip tube.

Withdrawing Gas from CO_2 Cylinders Without Dip Tubes

In CO_2 cylinders without dip tubes, carbon dioxide is withdrawn from the top of the cylinder. When the cylinder valve is opened, the pressure in the cylinder decreases. CO_2 continously evaporates from the liquid phase and emerges as a gas. One important application for CO_2 cylinders without dip tubes is in beverage dispensing.
CO_2 cylinders without dip tubes must be used with a regulator to dispense gas, so the pressure can be reduced to a level appropriate for the intended purpose.
CO_2 cylinders without dip tubes must be vertical while gas is being withdrawn. A horizontal cylinder would release liquid CO_2, which might cause the supply apparatus to clog up with CO_2 snow.
The rate at which CO_2 can be withdrawn from cylinders without dip tubes is limited,

Low temperature warning

since the CO_2 must evaporate from the liquid phase. This process absorbs heat from the environment, which means that the gas cylinder and especially the valve can ice up. This may make the valve difficult to operate. To prevent this, multiple cylinders should be used when large amounts of CO_2 are needed, or the cylinder can be heated with warm water (maximum 50°C). The cylinder should never be heated with a flame.

Handling of Dry Ice

Because of its low temperature and the formation of gaseous CO_2, a few special safety precautions must be taken when handling dry ice:

- Dry ice is not edible. Do not lick it or place it directly in beverages. The cold and subsequent pressure might have unpleasant effects on the human body. Keep dry ice out of the reach of children!
- Because of its low temperature, dry ice must not be handled with bare hands. Wearing gloves or using appropriate tongs will protect against freeze burning. When manually chopping up dry ice with a suitable implement, protect the eyes from flying particles by wearing safety glasses.
- Dry ice must not be stored or transported in tightly sealed containers. The pressure

resulting from evaporation could burst the container.

- No one should enter a room in which dry ice is being stored until the accompanying gaseous CO_2 has been removed by adequate ventilation.
- Dry ice in larger quantities must be transported only in vehicle cargo compartments that are isolated in a gas-tight manner from the cab or passenger compartment.

4. Conclusion

Carbon dioxide, in all its forms, can be used for many purposes. it is important to use its capabilities correctly in order to achieve the desired effect and eliminate hazards. Our gas specialists can tell you how to do that.
Consultation in all business and technical problems is made available by the experts of our Sales Offices.

Linde AG
Linde Gas Division, Linde Gas Germany, Seitnerstraße 70, 82049 Pullach
Phone 018 03.85 000-0*, Fax 018 03.85 000-1, www.linde-gas.com

Dry Ice Production

ASCO Dry Ice Pelletizer A30P-D3

part no. 900600

The **ASCO** Dry Ice Pelletizer A30P having a production capacity of 30 kg per hour (66.14 lb/h) is suitable for the production of small amounts of dry ice for cooling purposes.

The **ASCO** Dry Ice Pelletizer A30P is driven by a powerful hydraulic unit featuring a push button for instant start of production. All functions are controlled by a PLC. Fully automatic control of oil temperature and dry ice snowing process guarantees continuous dry ice production without any supervision right from push button start.

Benefits of an in-house dry ice production:

- if for dry ice blasting: more efficient cleaning results, because: the fresher the dry ice, the more efficient the cleaning
- shorter production stops
- reduction of dry ice lost due to sublimation
- decreased logistics expense connected with purchasing and disposing of dry ice

Extruder plate for 3 mm (1/8 in) pellets
The dry ice pelletizer A30P-D3 is standardly equipped with an extruder plate for the production of pellets with a diameter of 3 mm (1/8 in).

Specifications

Production capacity:	30 kg/h (66.14 lb/h) at 17.5 bar (253.82 psi) CO_2 inlet pressure
Voltage:	400 V / 50 Hz / 3 Ph + PE (other voltages on request)
Max. power consumption:	1.6 kW (2.15 HP)
Dimensions pelletizer (L x W x H):	1‘150 x 600 x 700 mm (45.28 x 23.62 x 27.56 in)
incl. standard machine base (L x W x H):	1‘150 x 600 x 1‘300 mm (45.28 x 23.62 x 51.18 in)
Weight net incl. standard machine base:	approx. 147 kg (324 lb) (with hydraulic oil) approx. 141 kg (310.85 lb)(without hydraulic oil)
CO_2 inlet connection:	1/2“ BSP female
CO_2 source:	CO_2 storage tank, liquid phase (13 - 21 bar) (188.5 - 304.6 psi)

(We recommend to choose additionally a machine base as option to the pelletizer, see following pages)

ASCO Dry Ice Pelletizer A30P-D3: Special features

Function and Applications

The **ASCO** Dry Ice Pelletizer A30P requires a liquid CO_2 supply (pressure 13-21 bar (188- 304 psi) and power supply of 400 V / 50 Hz / 3 Ph + PE (other voltages available on request). The machine features instant push button start and all functions are controlled by an inbuilt PLC. Dry ice snow is produced in the snowing chamber, pressed and then extruded by a powerful hydraulic unit. Hard, dense dry ice pellets are produced within less than one minute after push button start. To ensure continuous, reliable operation of the pelletizer, oil temperature, cycle time, motor overload, CO_2 inlet pressure and hydraulic pressure are all monitored and displayed on the control panel.

Remark: Can only be run with low pressure tank (15-21 bar / 217-305 psi) - not with cylinders.

Options

The **ASCO** Dry Ice Pelletizer A30P-D3 is standardly equipped with an extruder plate for the production of pellets with a diameter of 3 mm (1/8 in). Such pellets are used especially for dry ice blasting purposes. Optional extruder plates for pellets with a diameter of 6 mm (1/4 in) , 10 mm (3/8 in) and 16 mm (5/8 in) are available. The A30P, however, can also be delivered standardly equipped with extruder plates for 6, 10 or 16 mm (1/4, 3/8 or 5/8 in) pellets.

Pellet size	 3 mm (1/8 in)	 6 mm (1/4 in)	 10 mm (3/8 in)	 16 mm (5/8 in)
Operating range	Dry ice blasting	Cooling purposes	Cooling purposes	Cooling purposes

ASCO Dry Ice Pelletizer A30P-D3: Standard scope of supply

Extruder plate for 3 mm (1/8 in) pellets — **part no. 4044517**

Pellets for **blasting purposes**

ASCO Dry Ice Pelletizer A30P-D3: Options

Pos. 001

Extruder plate for 6 mm (1/4 in) pellets

part no. 4044519

Pellets for **cooling purposes**

Pos. 002

Extruder plate for 10 mm (3/8 in) pellets

part no. 4044518

Pellets for **cooling purposes**

Pos. 003

Extruder plate for 16 mm (5/8 in) pellets

part no. 4044516

Pellets for **cooling purposes**

Pos. 004

Standard machine base

part no. 4063029

For filling of dry ice storage containers or an
ASCOJET 1701 or 2001RX

Increases the total height by 600 mm (23.62 in)

Pos. 005

Higher machine base

part no. 4044520

For filling of higher storage containers or dry ice blasting units

Increases the total height by 800 mm (31.5 in)

Pos. 006

Spare parts kit

part no. 4044521

Containing a selection of recommended spares for approx.
one to two years of normal operation

PR120H

ICE TECH
powered by Cold Jet

Production of High Quality Dry Ice Pellets

The fully automatic PR120H is an efficient pelletizer designed to consistently produce high quality dry ice pellets using liquid CO_2 and electrical power. The PR120H is differentiated by its reduced cost and high quality output. With minimal space requirements, the PR120H can produce up to 120kg/ 265lbs of dry ice pellets per hour. It provides the best conversion factor on the market = 10% better than traditional pelletizers. Producing dry ice on demand has never been easier!

Unique Features:

- Stainless steel enclosure reduces noise level below 75 db(A) and protects machine components
- Fully automated, one-button operation
- Panel PC with built-in 7" touch screen
- Sub Cooling technology minimizes CO_2 waste
- Quick startup reduces downtime and loss of valuable CO_2
- Compact footprint
- Free choice of die plates:
  mm: 3, 10, 16
  in: 1/8, 3/8, 5/8

Benefits of Dry Ice Production:

- Produce fresh, high quality dry ice on demand
- Reduce wasted dry ice due to sublimation
- Eliminate transportation costs
- Low ownership and maintenance costs

PR120H

Production of High Quality Dry Ice Pellets

PR120H Technical Data

Rated Output:
kg/h: up to 120
lbs/h: up to 265
of high quality dry ice pellets

Pellet Diameter Range:
mm: 3, 10, 16
in: 1/8, 3/8, 5/8
custom die plate design program available

Dimensions mm/in:
Length: 1150/45.3
Width: 650/25.6
Height: 1738/68.4

Weight:
kg: 704 / lbs: 1552

Inlet CO_2 Supply:
bar: 16 - 22
psi: 232 - 319

Compressed air or vapor CO_2 gas supply:
bar: 8 – 10
psi: 116 - 145

Air quality:
Class 3 - according to ISO 8573-1

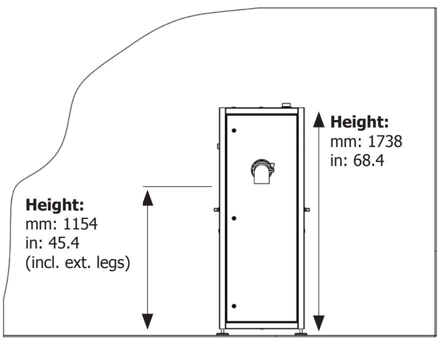
Back Pressure on Revert Gas:
bar: 0 - 1
psi: 0 - 14.5

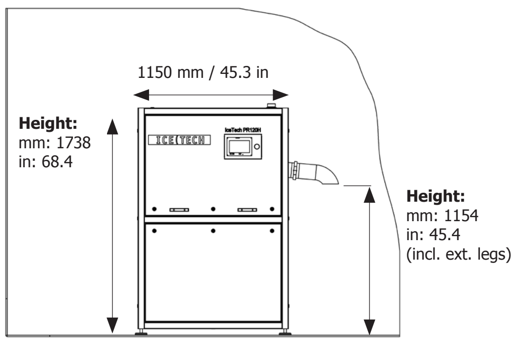
Exhaust Gas Pipe:
Internal dia. 50 mm (2 inch)

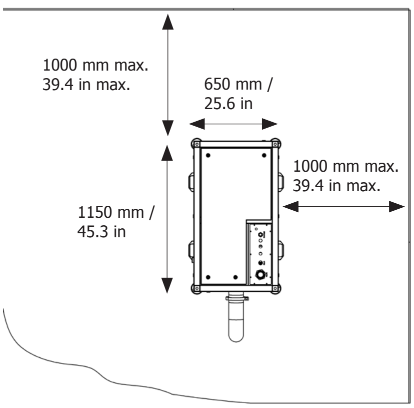
Power Supply:
3 x 400 V AC + N + PE, 50Hz
TN-S Earthing system
Imax.: 16A
Ipk: 10 kA
480V AC Solidly Grounded Wye Source
3 Phase + GND wire, 60Hz
Imax.: 16A
Control Panel SCCR: 25kA rms symmetrical
480VAC Max.

Rated Power:
4.3 kW/ 5.8 Hp

Noise Level: below 75 db(A)







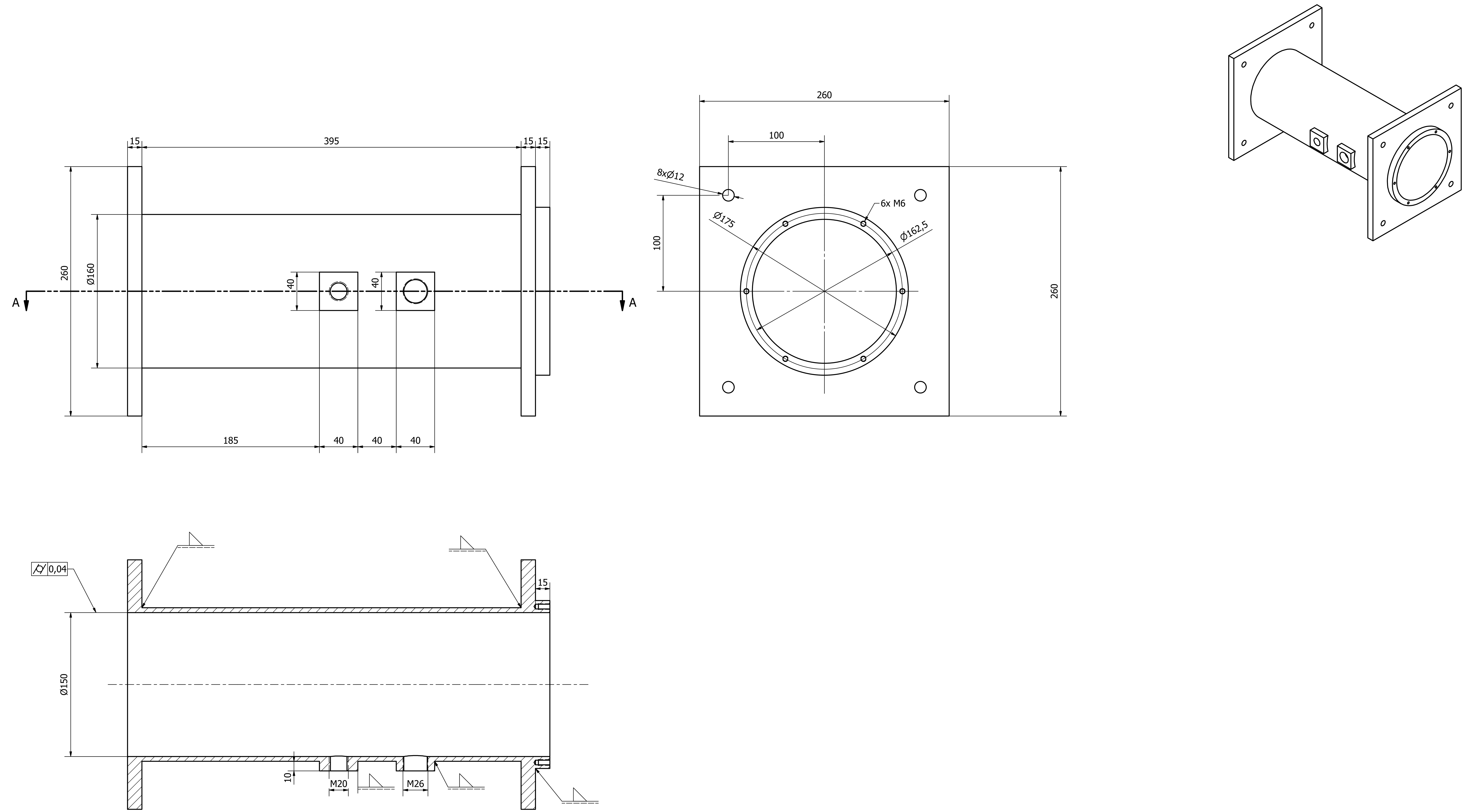
Floor Characteristics and Minimum Clearance Distances

The pelletizer must be placed on a horizontal concrete floor with an adequate load-carrying capacity. The floor must be free of cracks and structural deficiencies. The minimum clearance distances must be observed to provide sufficient space for opening the cabinet doors and servicing the pelletizer.

Installation

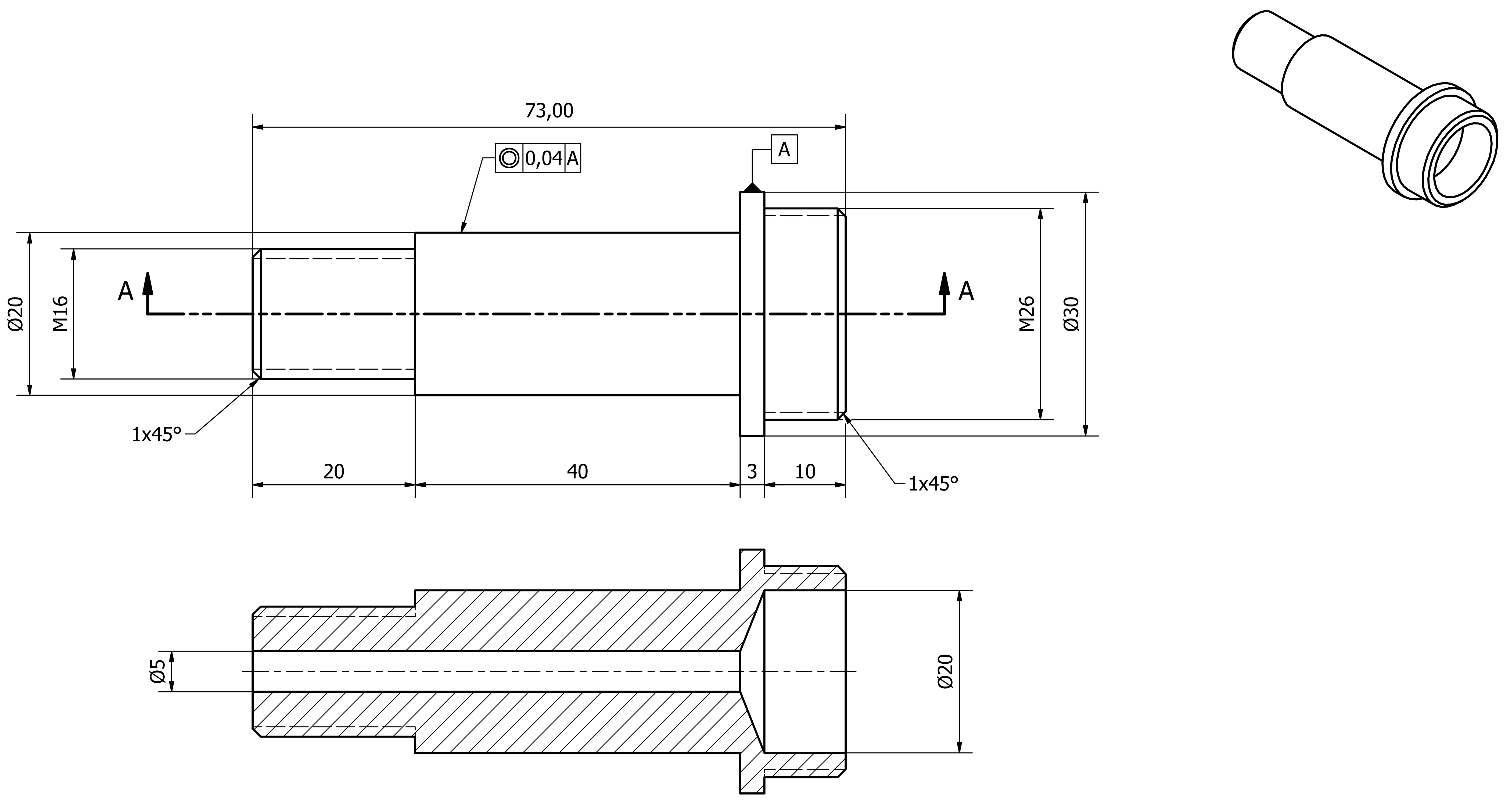
The installation of the pelletizer must be carried out by one of Cold Jet's service technicians or by a technician approved by Cold Jet.

TECHNICAL DRAWINGS



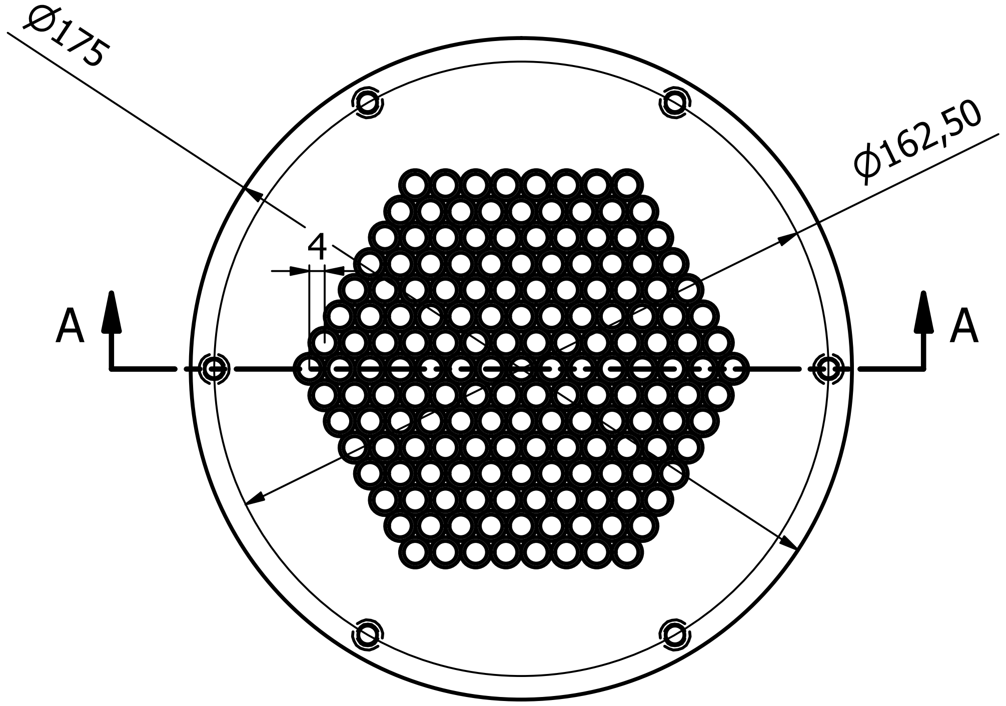
SECTION A-A
SCALE 1 / 2

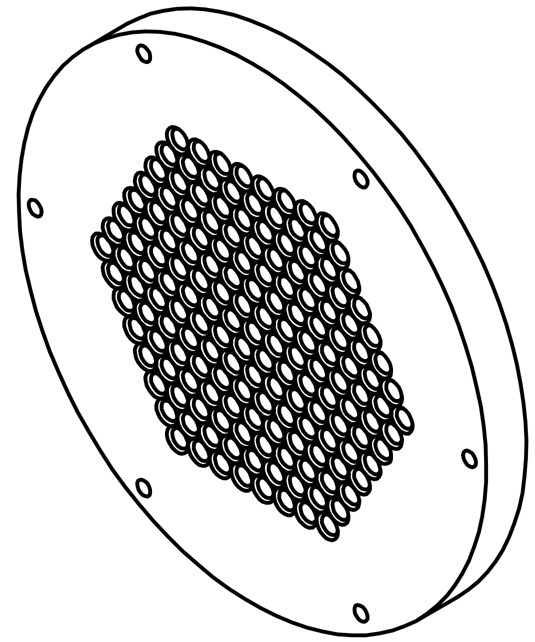
DRAWN Juan Martínez	17/12/2019	
CHECKED		TITLE Chamber
QA		
MFG		
APPROVED		SIZE D · DWG NO Chamber_Cylinder · REV
		SCALE 1 / 2 · SHEET 1 OF 1



SECTION A-A
SCALE 2 : 1

DRAWN Juan Martínez	17/12/2019	
CHECKED		TITLE nozzle
QA		
MFG		
APPROVED		
		SIZE A3 · DWG NO Nozzle_Cylinder · REV
		SCALE 2 : 1 · SHEET 1 OF 1





SECTION A-A
SCALE 1 / 2

Number of channels: 169

DRAWN Juan Martínez	17/12/2019	
CHECKED		TITLE Pellets Die
QA		
MFG		
APPROVED		SIZE A3 · DWG NO Pellet_die · REV
		SCALE 1 / 2 · SHEET 1 OF 1