Centrifugal Compressor Technology

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Refrigeration Compressors

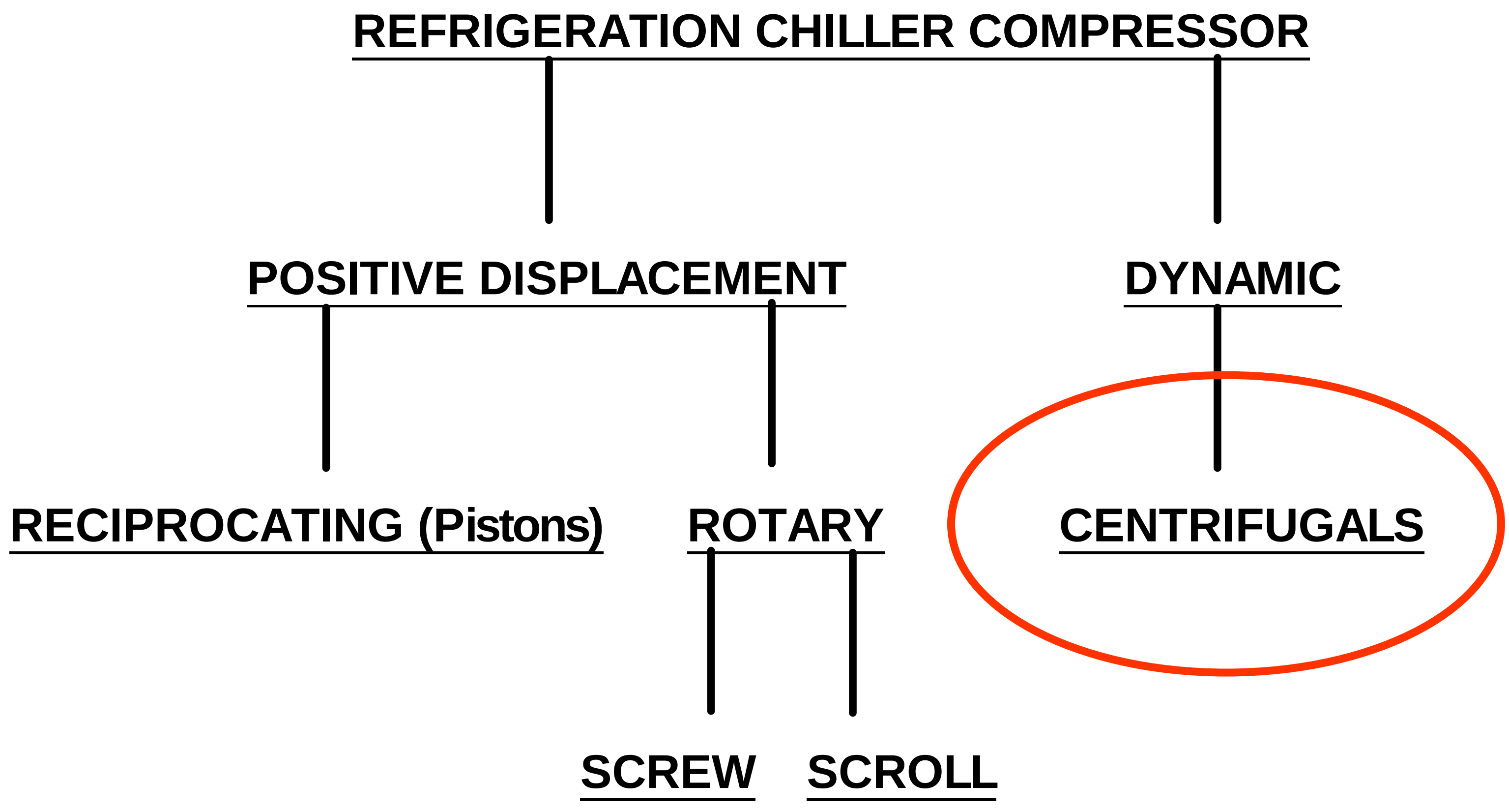
Centrifugal Chillers are mainly water cooled chillers

Refrigeration Compressors

There are two basic different compression technology:

- **Positive Displacement** (or **Volumetric**): pressure is increased directly by reducing the volume where gas is contained.
- **Dynamic**: gas velocity is increased and the velocity energy is then converted in pressure energy.

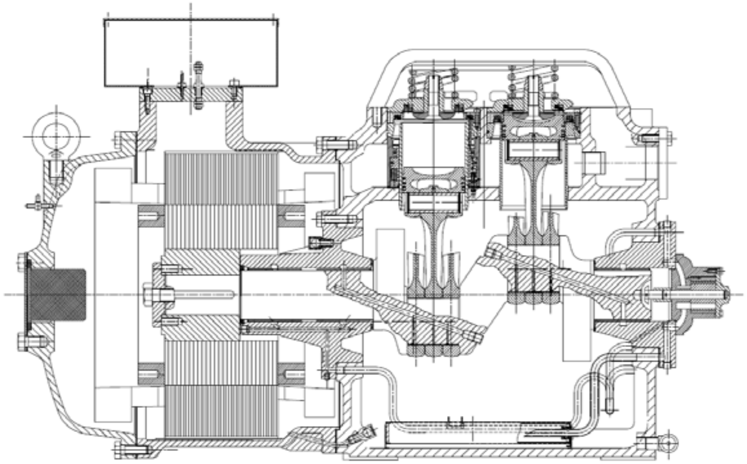
Refrigeration Compressors

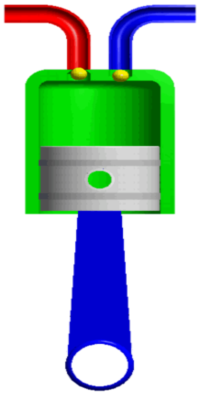


Positive Displacement (Volumetric) Compressors

Compressors used in HVAC industry are most commonly **Volumetric compressors**:

1) Reciprocating: the volume is reduced by a reciprocating movement of a piston inside cylinder





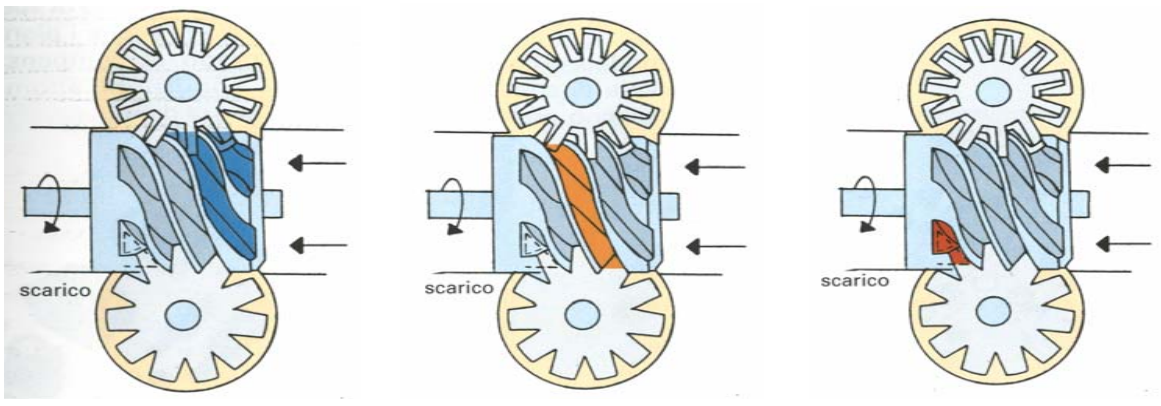
Positive Displacement (Volumetric) Compressors

2) Rotary: the volume is reduced by the rotation of two or more parts without reciprocating movement. Rotary compressors used in chiller industry are mainly:

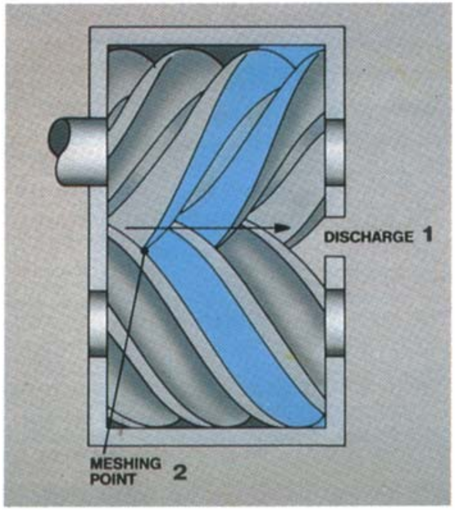
a) Scroll: two interleaved spiral-like vanes to compress gas; usually one of the scrolls is fixed, while the other orbits eccentrically without rotating, thereby compressing pockets of fluid between the scrolls.

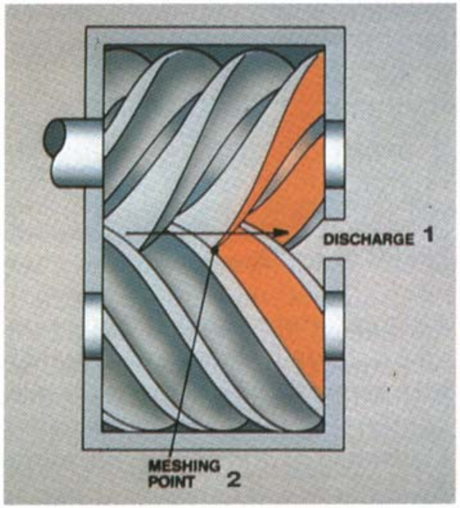
Positive Displacement (Volumetric) Compressors

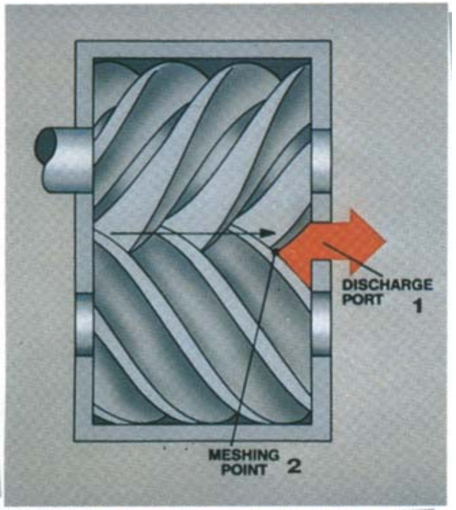
b) Screw: either a single screw element or two counter rotating intermeshed helical screw elements rotate within a specially shaped chamber. As the mechanism rotates, the rotation of the two helical rotors produces a series of volume-reducing cavities, thus increasing the pressure of the gas contained into the cavities.

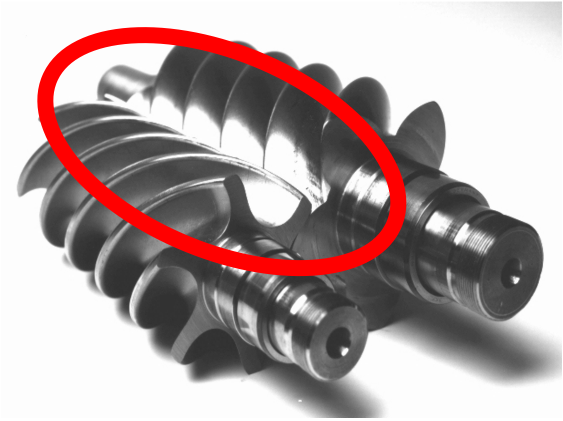


Positive Displacement (Volumetric) Compressors



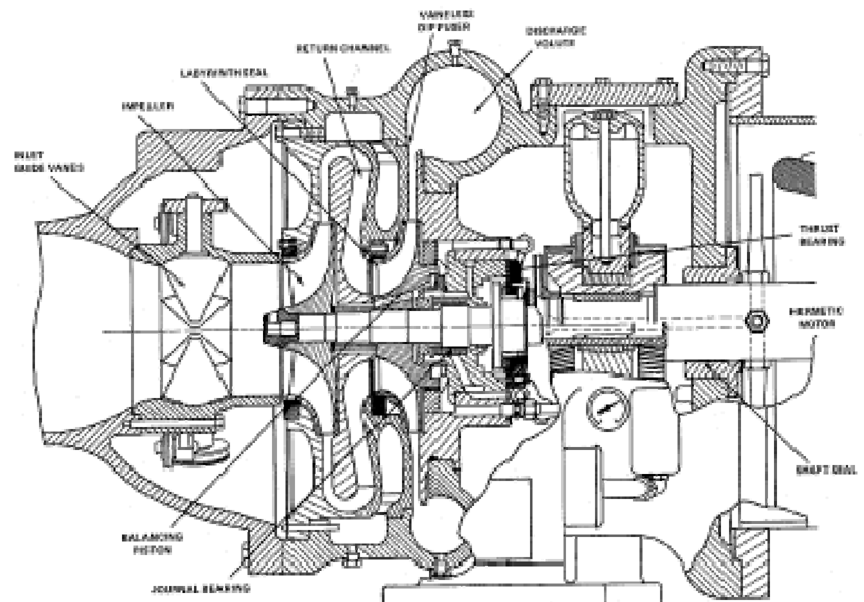


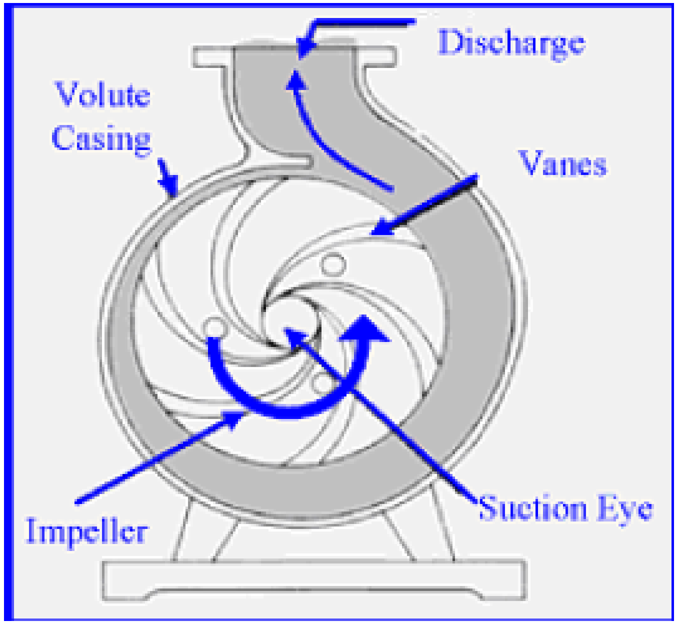




Dynamic Compressors - Centrifugal compressors

Centrifugal compressors use an impeller (similar to the centrifugal water pump) which rotates at very high speed into a volute casing (diffuser)





Dynamic Compressors - Centrifugal compressors

How a centrifugal compressor works?

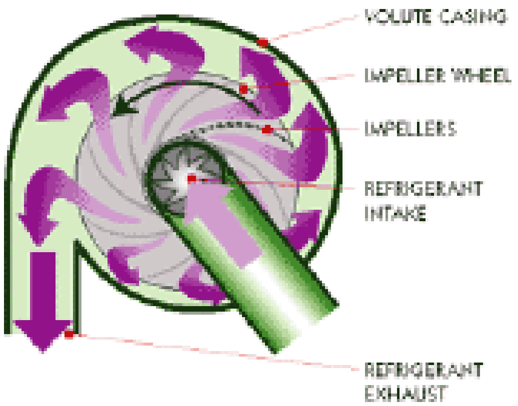
Centrifugal compressors use an impeller (a vaned rotating disk) in a shaped housing to force the gas to the exit of the impeller, increasing the velocity of the gas. A diffuser (divergent duct) section converts the velocity energy to pressure energy.

Like in rotary volumetric compressor, the movement is only rotary.

Dynamic Compressors - Centrifugal compressors

How a centrifugal compressor works?

In order to pass from the low pressure in impeller to the higher pressure of the diffuser, the refrigerant necessarily needs high velocity. In absence of sufficient velocity, the refrigerant will stuck in the impeller and the compressor will **stall**.

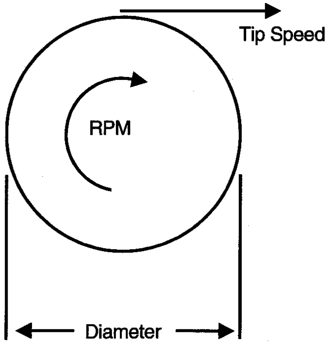


Dynamic Compressors - Centrifugal compressors

How a centrifugal compressor works?

- Therefore one of the fundamental parameter of centrifugal compressors design is the "tip speed", which must be in the range of 204 to 213 m/sec.
- This parameter determines the speed and the dimension of the impeller:

$$RPM = [TipSpeed(m/s) x 1910] / Diameter(cm.)$$

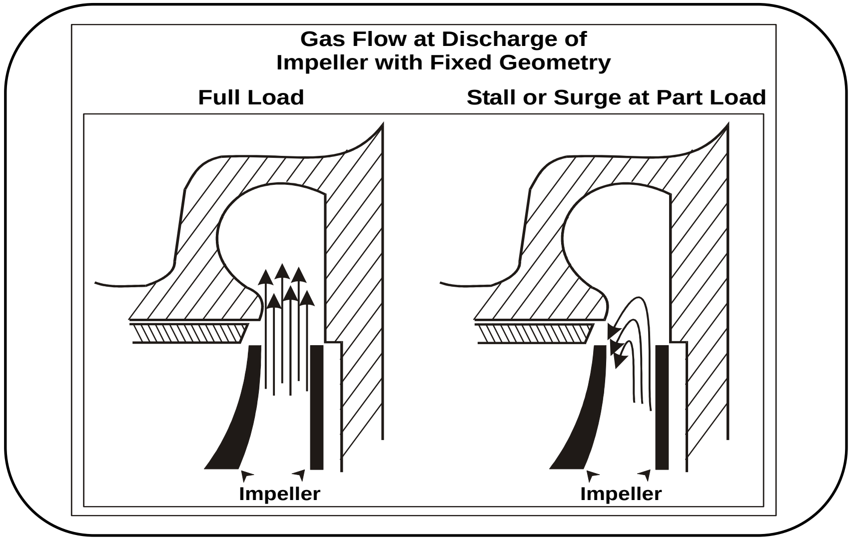


- A centrifugal compressor must be specifically designed for the right pressure difference we want to achieve.

Centrifugal compressor features

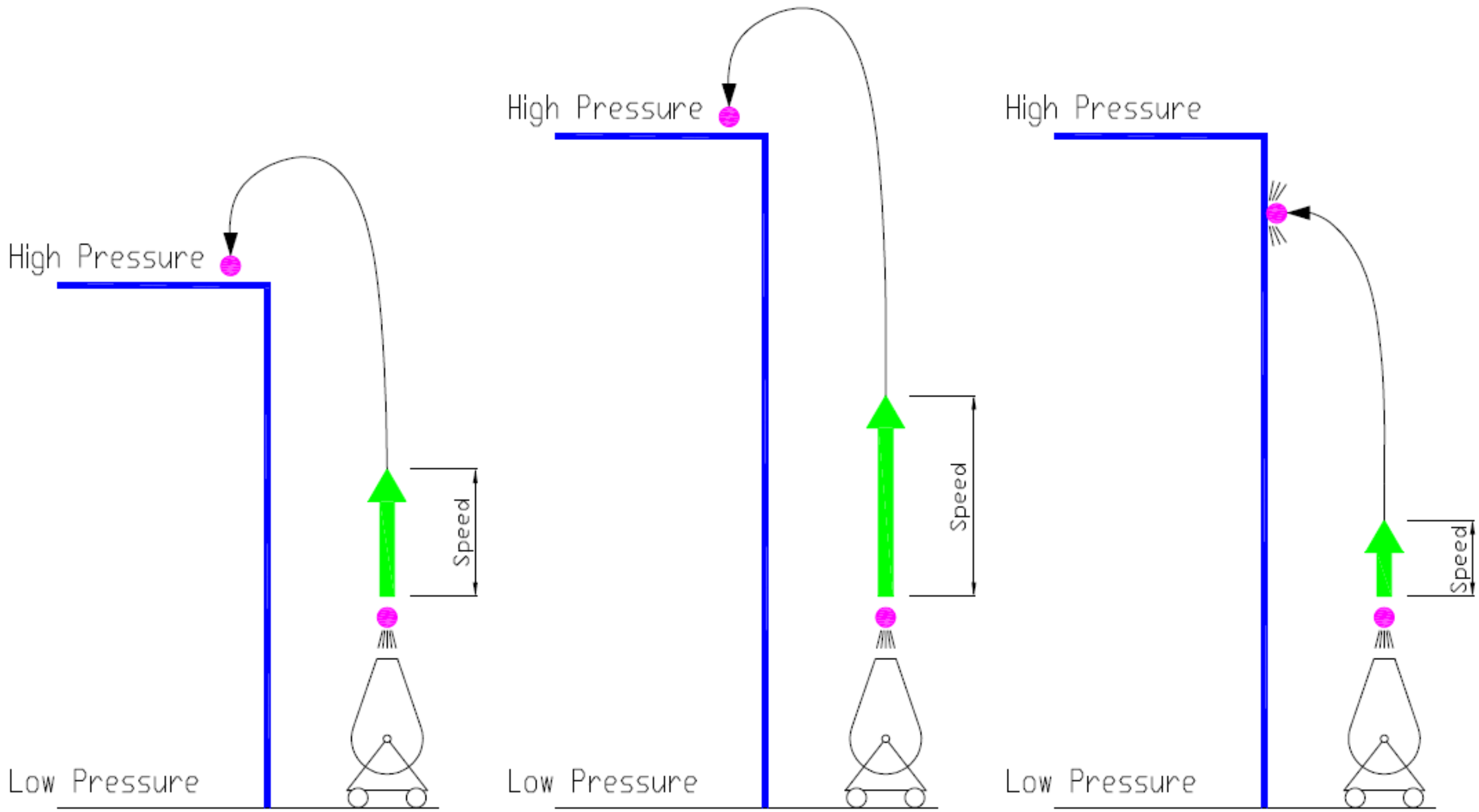
Part load conditions are the most critical for centrifugal compressors

Gas speed is even more critical in unloaded condition, when the gas flow decreases and therefore could not be able to overpass differential pressure to the diffuser. If this happens, the flow can go back into the impeller bringing compressor to stall



Part Load conditions for Centrifugal compressor

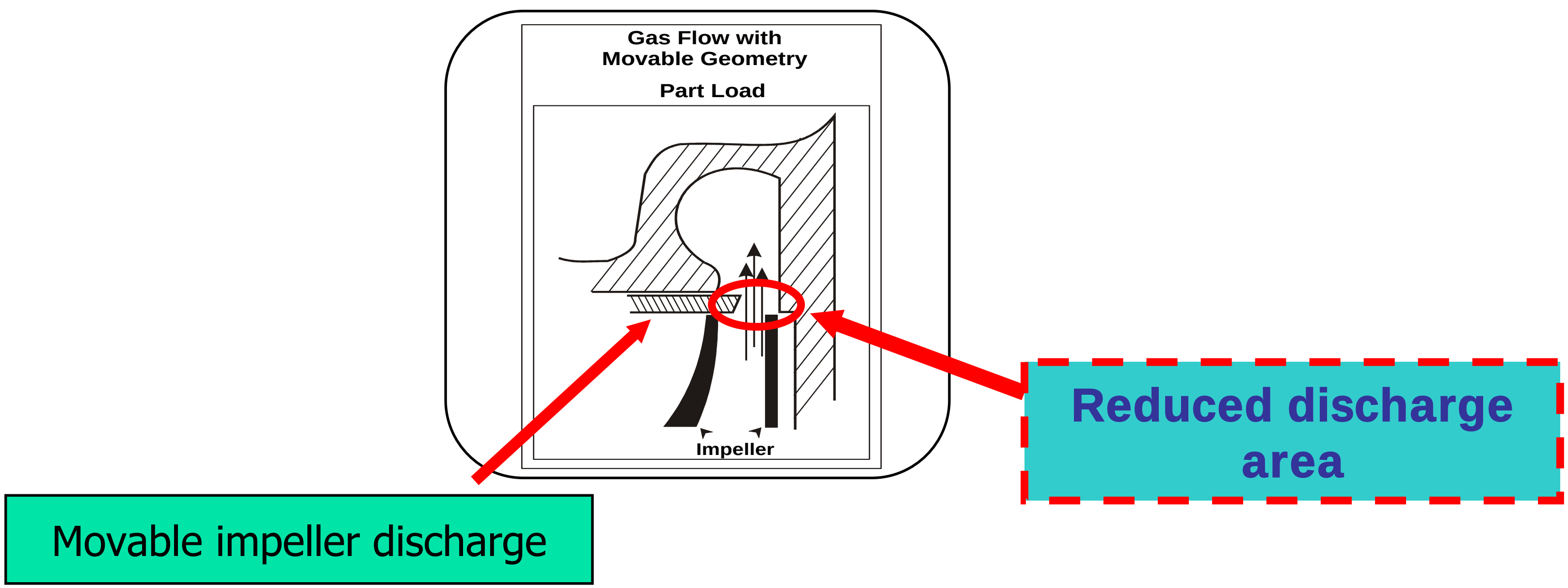
Why when gas velocity decrease, the compressor may stall (surge)?



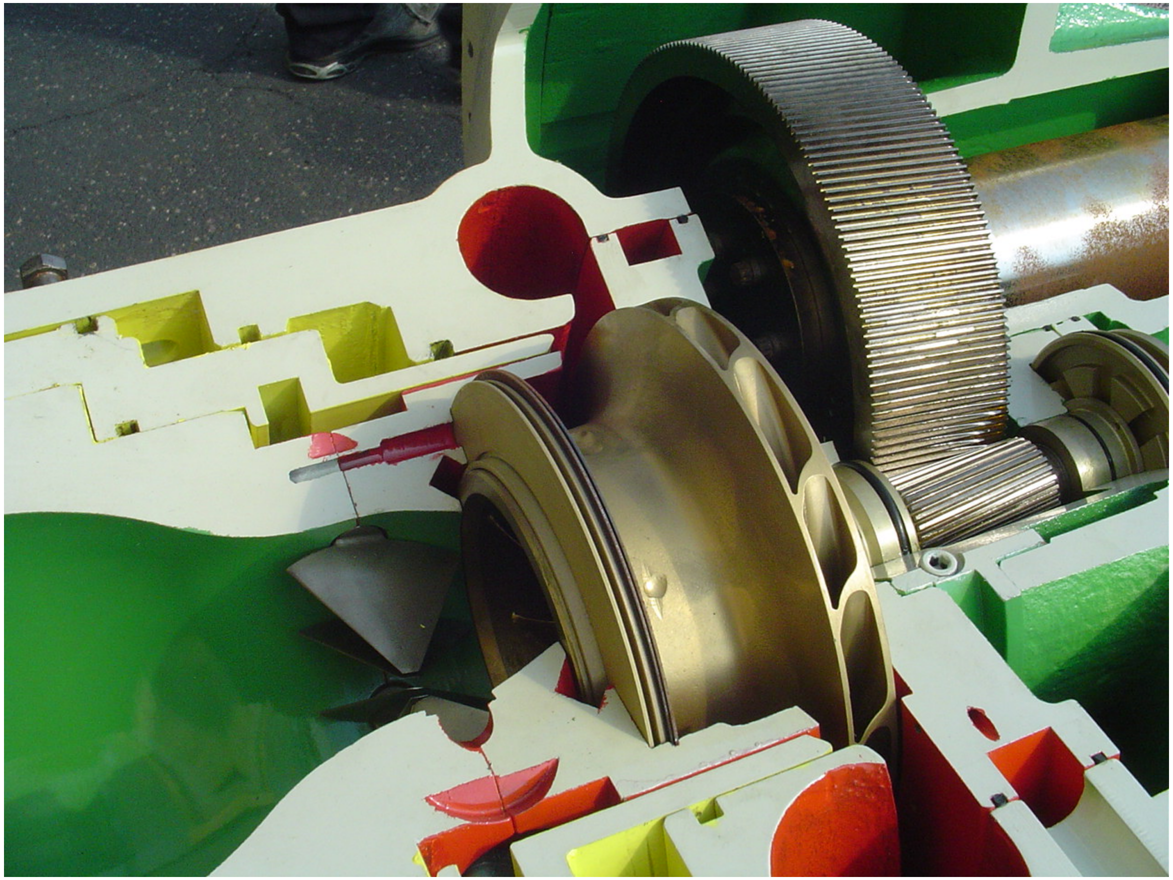
Part Load conditions for Centrifugal compressor

One of the most innovative technologies which allows to keep sufficient gas speed also in strongly unloaded conditions and extends unit working range, is the **movable impeller discharge technology**.

Compressor can work down to 10%, and dual compressors units down to 5%. In this way use of hot-gas bypass to unload capacity to low levels (energy waste), is eliminated.



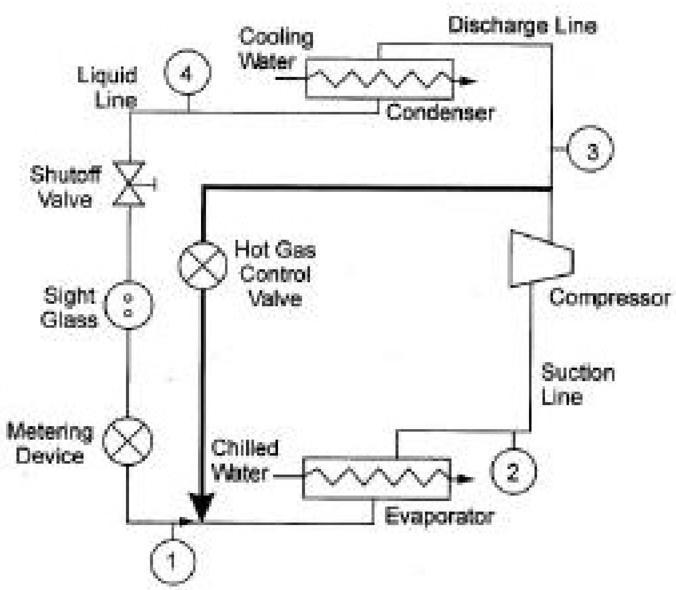
Part Load conditions for Centrifugal compressor



Capacity Control

Capacity Control

Hot Gas Bypass



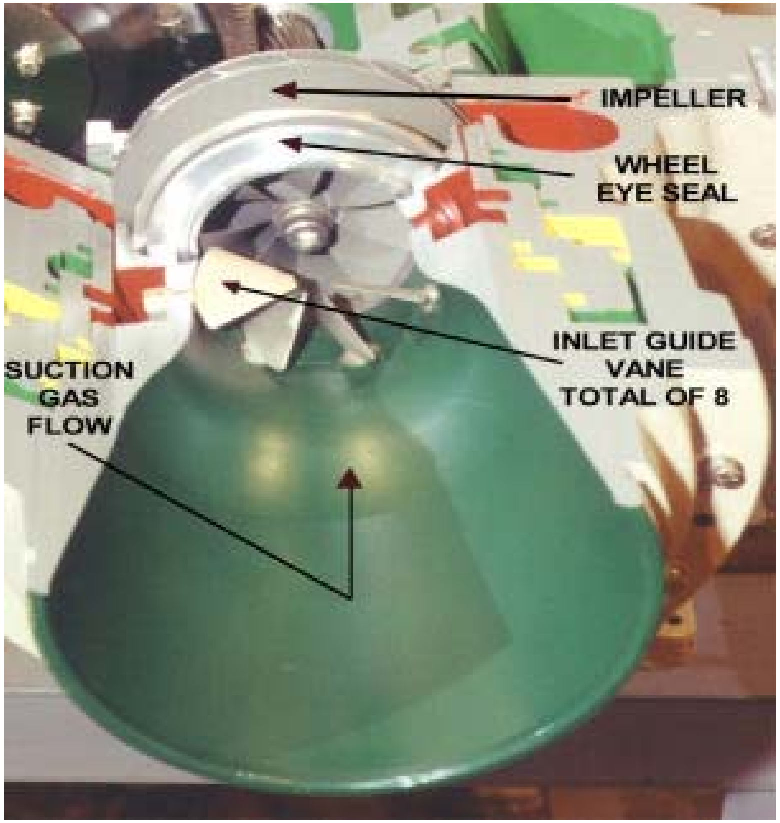
Hot gas bypass is a means of recirculating hot discharge refrigerant back into the evaporator applied at strongly unloaded conditions (below 20%). A disadvantage is that the work of compression on the recirculated refrigerant does not generate any refrigeration effect.

Careful selection of equipment size and using compressor that unload to a very low percentage of full load capacity (10%), can avoid the need for hot gas bypass in most HVAC applications.

Capacity Control

Inlet Guide Vanes

Inlet guide vanes are used to control the capacity of the compressor. As the inlet guide vanes start to close, they change the gas entry angle to the impeller and reduce gas flow and compressor capacity.



Capacity Control

Variable Frequency Drive

Changing the compressor speed can also control compressor capacity. Induction motors require a Variable Frequency Drive (VFD) to change their speed.

VFD – How does it work ??

From 100% down to 70 % VFD slow down the impeller speed.

Below 70% impeller speed, the inlet guide vanes (traditional unloading way on centrifugal) will be used together with VFD.

The controller processes the operating conditions and evaluates whether to use inlet guide vanes or the VFD.

This method is more efficient than guide vane by themselves !!!

Benefits of VFD application

What running conditions are the best for VFD applications ?

- Biggest part of chillers spend most of their operating time at part load

- Chillers operating during the winter in temperate climates, because of winter hours with lower condenser water temperature

Benefits of VFD application

Variable frequency drive offers ***outstanding part load*** *performance opportunities for centrifugal chillers!!*

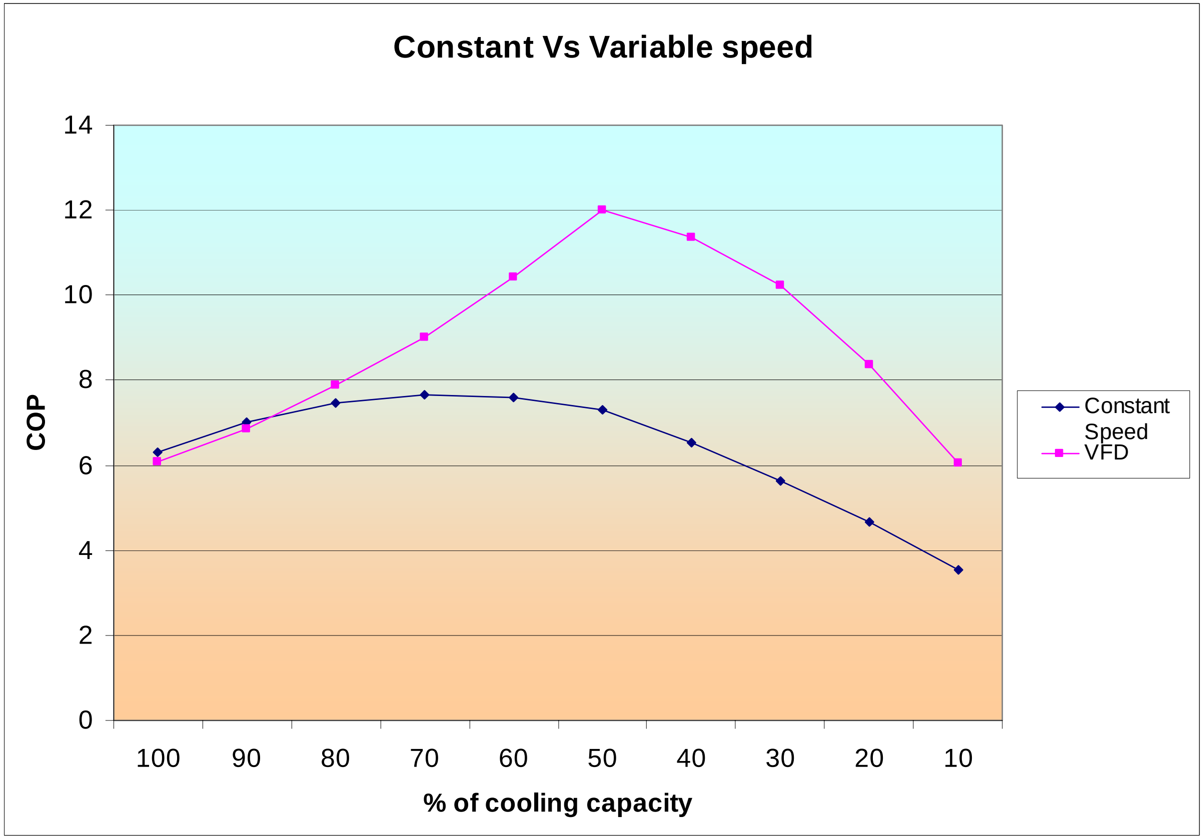
Variable Frequency Drive allows an annual energy saving up to 35 % compared to a fixed speed chiller . For some particular part loads point energy saving can be up to 75% !!

The application of VFD can offset its cost in a couple of years !!

Benefits of VFD application

Variable Frequency Drive

- 2000 kW Unit
- ARI partial load conditions



Benefits of VFD application

IPLV Defined

Part load performance can be presented in terms of Integrated Part Load Value (IPLV), which is based on ARI standard rating conditions. IPLV is based on the following equation from ARI 550/590.

IPLV = 0.01*A + 0.42*B + 0.45*C + 0.12*D

Where: A = COP at 100%

B = COP at 75%

C = COP at 50%

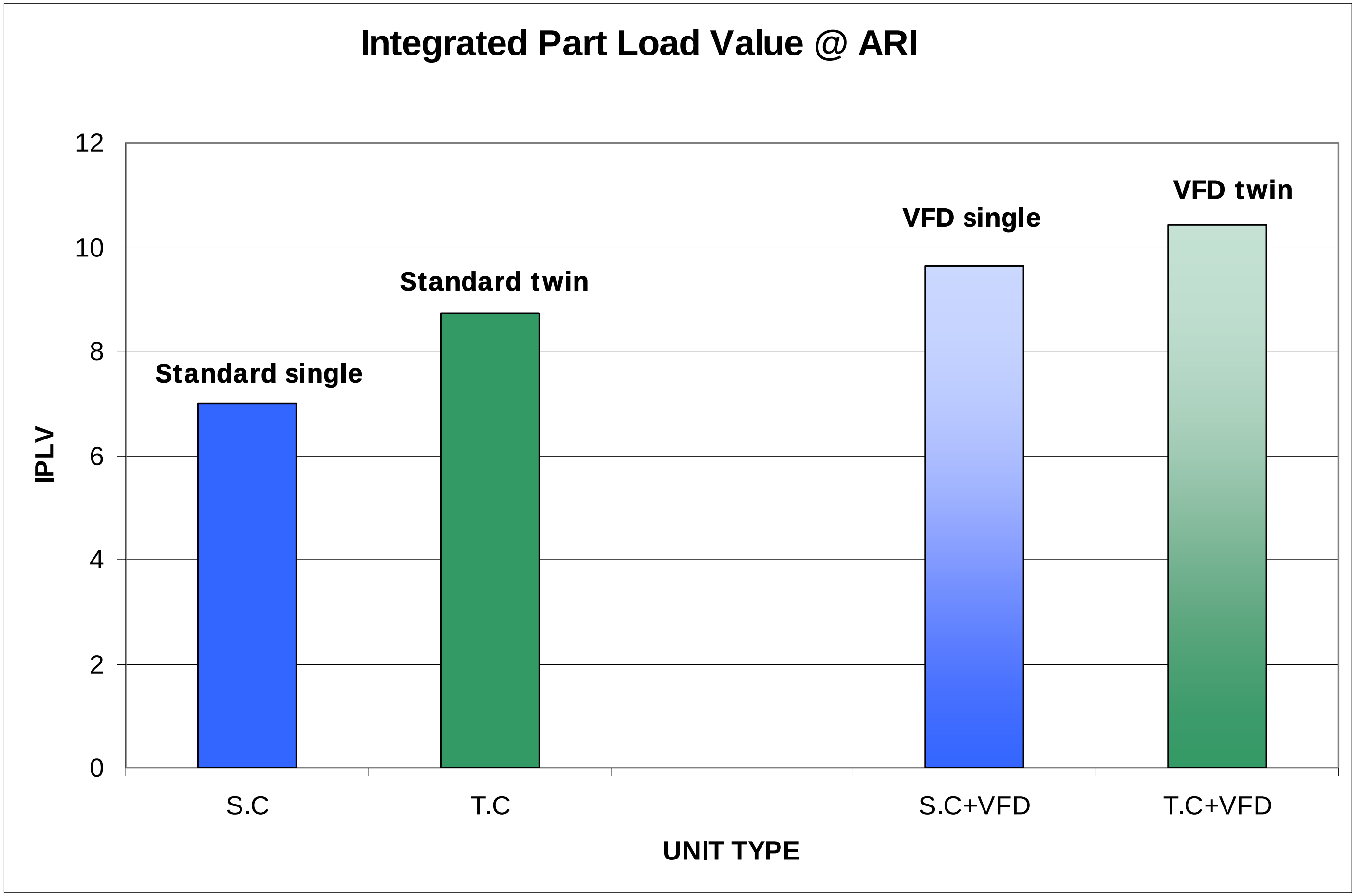
D = COP at 25%

Weighting

The percent of annual hours of operation at the four load points are as follows:

100% Load at 1%, 75% Load at 42%, 50% Load at 45%, 25% Load at 12%

Benefits of VFD application



Example of VFD Application

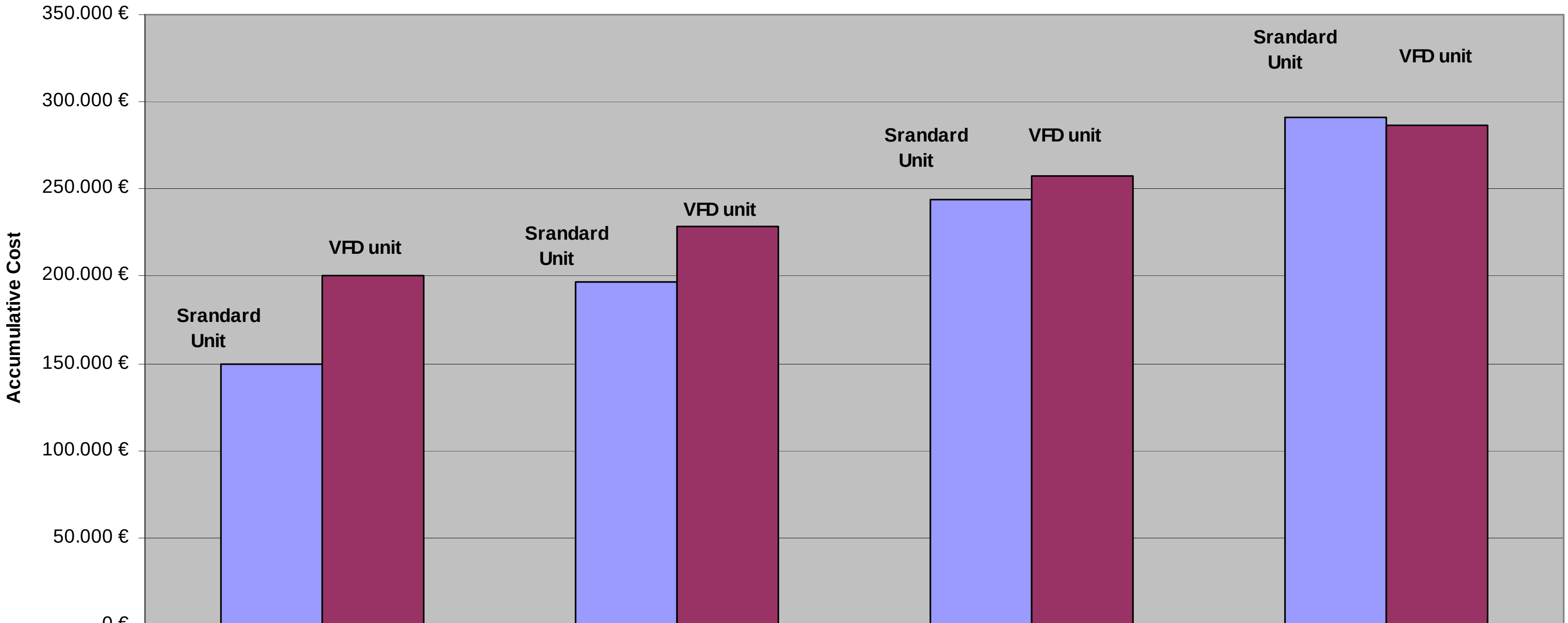
TOTAL CONSUMPTION CALCULATION (KWh)									
Load	**KW**	**Hour**	**COP1**	**COP2**		**IPLV1**	**IPLV2**	**KWh 1**	**KWh 2**
25%	762,5	216	3,8	9,17	0,12	0,46	1,10	43342	17960,7
50%	1525	810	6	12	0,45	2,70	5,40	205875	102938
75%	2287,5	756	6,18	8,6	0,42	2,60	3,61	279830	201087
100%	3050	18	4,8	6	0,01	0,05	0,06	11438	9150
		1800				**5,80**	**10,17**	**540485**	**331135**

Example of VFD Application

RETURN OF INVESTMENT PERIOD			
Type of centrifugal chiller		**VFD**	**Standard**
Hours of operation	h	1800	1800
Cost of electricity	€/kWh	0,08715	0,08715
Capacity	kW	3050	3050
IPLV		10,17	5,8
Consumption	kWh	331.135	540.485
Operational Cost	€	28.858	47.103
Operational Cost Difference	**€**		**18.245**
Purchase cost of one unit	€	200.000	150.000
Initial cost difference	**€**		**50.000**
Payback period	**years**		**2,74**

Example of VFD Application
Total Expenditure Comparison

Total Expenditure Comparison

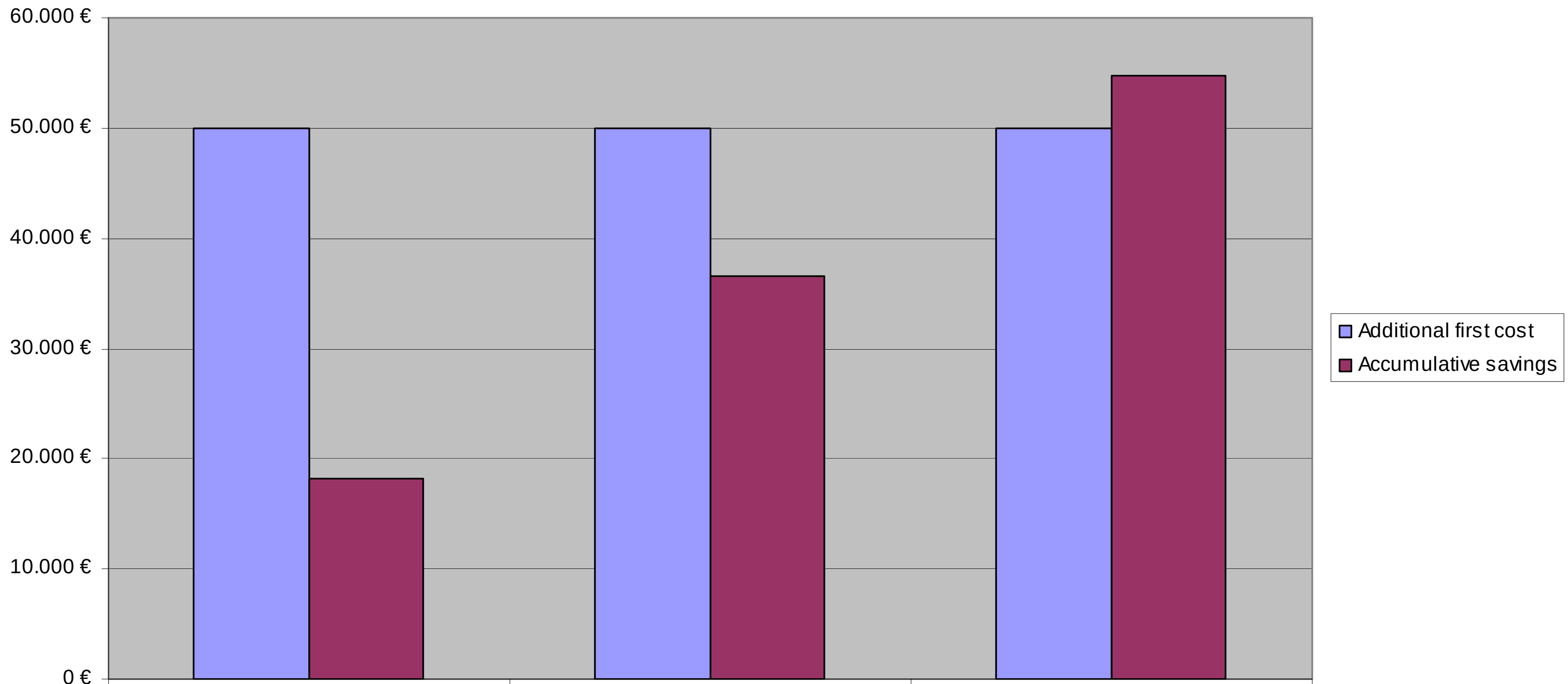


	Purchase of chiller	End of 1st Year	End of 2nd Year	End of 3rd Year
Standard	150.000 €	197.103 €	244.206 €	291.309 €
VFD	200.000 €	228.858 €	257.716 €	286.574 €

Standard VFD

Example of VFD Application
Additional initial cost / Accumulative Savings

VFD Application
Additional initial cost / Accumulative Savings



	End of 1st Year	End of 2nd Year	End of 3rd Year
Additional first cost	50.000 €	50.000 €	50.000 €
Accumulative savings	18.245 €	36.490 €	54.735 €

Other benefits of VFD application

VFD also works as a "soft starter"

- Reduced starting current :Inrush amps = RLA
- Reduced torque = Less stress and longer motor life
- Higher Power factor = Reduced nominal current
- Lower quantity of electrical parts = Less maintenance

=

Improved Performances and reliability !!

Other benefits of VFD application

<u>Lower sound pressure levels</u>

- Centrifugal compressor noise is largely dependent on the impeller tip speed.

VFD reduces tip speed at part load and,of consequence, noise level decreases of about <u>5 dBA</u> compared to traditional unloading method.

<u>Results:Saved money for noise reduction equipment !!</u>

END OF PRESENTATION

THANK YOU