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"Injection Pump for CCS"

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Abstract

In this paper, key point for design of CO_2 injection pump is explained. Material selection guide line is explained firstly both for main parts and wearing parts. Consideration of corrosion and low viscosity is important. Next, pump structure is explained. Design of thrust balancing device is very important because density of CO_2 will vary from inlet to outlet. Critical design point is explained, when inlet condition is close to border between liquid and vapour zone. Then, influence of temperature fluctuation is explained.
Next, seal and seal system suitable for CO_2 injection pump is explained.
Supply experience of acid gas injection pump is introduced.
Finally, optimum selection of turbo machines for CO_2 pressurizing is reported.

Keywords: Multi Stage Pump;Super Critical;Viscosity,Density;NPSH;Gas Seal, Power Consumption

1. Introduction

High pressure pump is required at the final stage of the CO_2 compression process for CCS.
In there CO_2 must be injected into reservoir in supercritical phase. In order to handle super critical CO_2, pump is thought to be suitable than compressor. Pumps are normally used in liquid phase of the fluid and compressibility is not taken in design. Therefore there are some points to be considered for design of supercritical CO_2 injection pump. Special care shall be taken for corrosion, low viscosity and density variation. In this paper, key points for design of CO_2 injection pump and its shaft sealing are explained.

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2. Material

2.1 Pump Main Parts

In case of pumping pure CO_2, there is no problem of corrosion, therefore carbon steel or 13Cr steel will be suitable for the wetted parts of the pump. However, in case H_2O or H_2S is included, special care must be taken for material selection, because corrosion will be a problem. When water density exceed 650 ppm, care for carbonate corrosion will be necessary [1]. In sour environment, where, total pressure is more than 0.4MPa and H2S partial pressure is more than 0.0003Mpa, material resistant to sulphide stress corrosion cracking, complying with NACE 0175[2] standard ,will be required.

2.2 Wearing parts

Since viscosity of supercritical CO_2 is very low and self lubricating property cannot be expected, special care must be taken for design of wearing parts e.g. surface hardness, running clearance and shape of the wearing surface.

In case of pure CO_2, 13Cr steel can be applied and it is possible to increase hardness by heat treatment, therefore it is no problem for material selection of wearing parts.

However, in corrosive environment that require use of material complying NACE 0175, special design for surface treatment is necessary to have anti galling property, because hardness of base metal complying NACE0175 is relatively low.

3. Pump structure

Horizontal double casing multi stage pump is normally required for CO_2 injection, because suction pressure is around 5 to 10MPa and required discharge pressure becomes around 15 to 25 MPa. Double casing structure is suitable for handling high pressure fluid. Typical structure of double casing multi stage pump is shown in Fig.1and 2. Both ring section type and back to back arrangement type can be applicable for the inner casing of double casing pump for CO_2injection service.

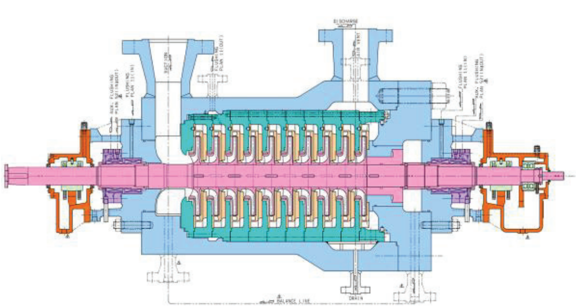

Fig.1 Ring section Type

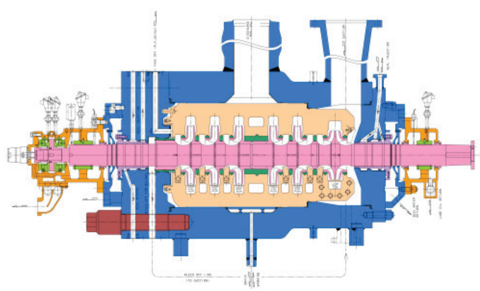

Fig.2 Back to back arrangement type

When using multistage pumps, density of CO_2 vary from inlet to outlet of the pump. Therefore, special care is required for impeller thrust balancing device. Thrust balancing mechanism is shown in Fig.3 and 4. In case of ring section type which is equipped with balance disk, Axial thrust can be balanced by balance disk function. In case of back to back arrangement, because generated pressure is different between front side and back side due to density variation, axial thrust balance must be achieved by adjustment of the balance sleeve diameter.

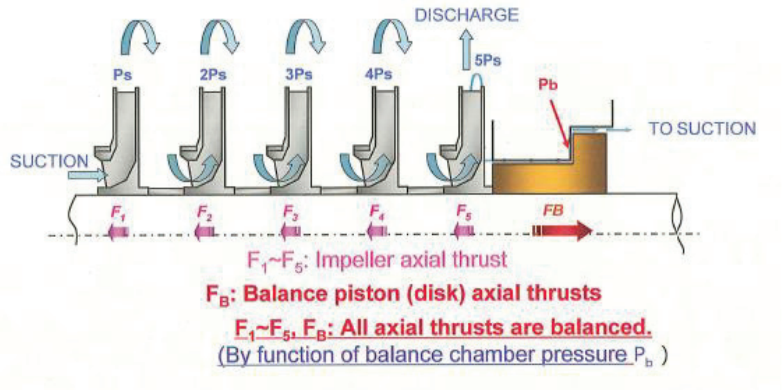

Fig. 3 Thrust balance mechanism of ring section type multi stage pump

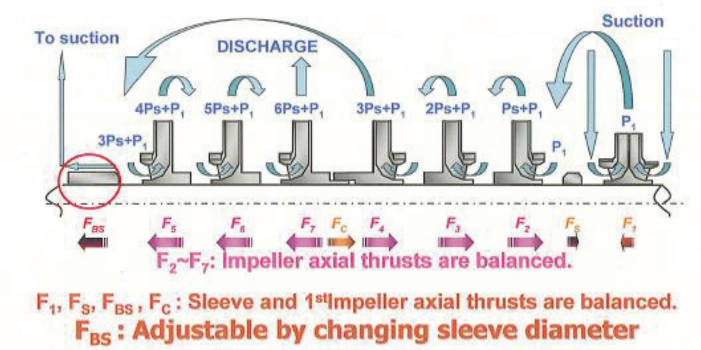

Fig.4 Thrust balance mechanism of back to back impeller arrangement multi stage pump

4. Balance pipe

Balance pipe is equipped for multi stage pump to achieve axial thrust balance.

Usually balance pipe is connected from down stream of the balance device to the pump suction.

By input power of the pump, CO_2 enthalpy increase in the pump from inlet (suction) to outlet (discharge) .On the other hand, adiabatic expansion is done through the balance devise and it is isenthalpic. Therefore CO_2 will vaporize at the outlet of the balance pipe when pump suction condition is near to the saturation liquid line as shown in Fig.5

In this case; balance pipe shall be connected to the intermediate stage of the multi stage pump to avoid vaporization. Fig.6 shows sample of this connection.

Inside of the pump, pump shaft power increase enthalpy of handling fluid.

Discharge point shifts by increased enthalpy delta h from suction condition as shown in P-h diagram.

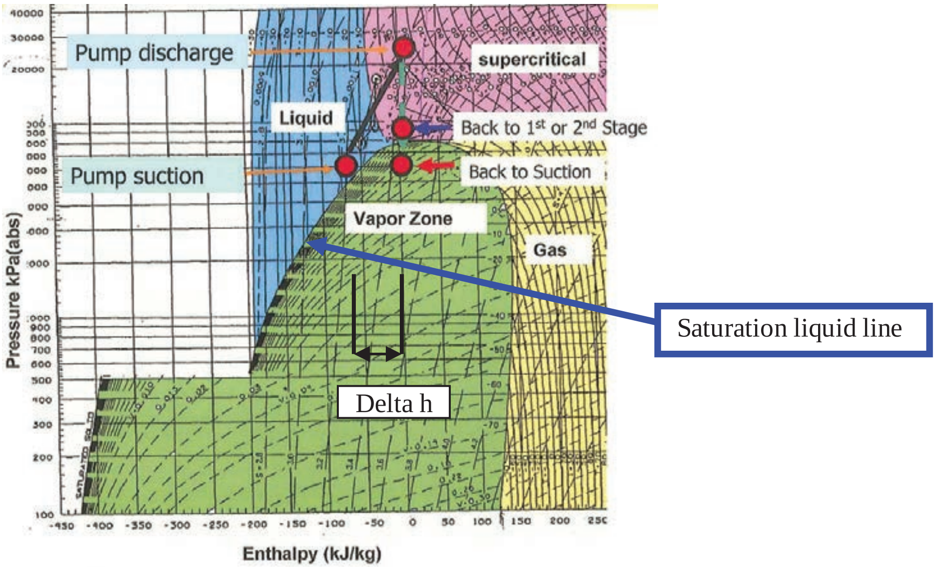

Fig.5 Balance pipe connecting point shown in P-h Diagram

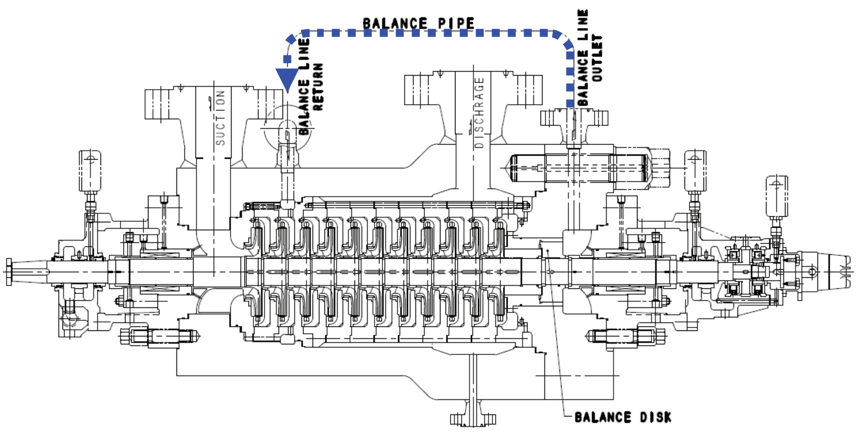

Fig.6 Sample of the balance pipe connection back to 2nd stage

5. NPSH and suction pressure, temperature

If fluid static pressure decreases below vapour pressure at inlet edge of pump impeller, fluid vaporize and pump operation become difficult, this phenomena is called cavitation.

There is required net positive suction head that fluid shall posses at inlet of the pump impeller to keep static pressure over vapour pressure. It is called required NPSH (NPSHR)

When suction condition is just on the saturated line (border between liquid and vapour), CO_2 will vaporize because of velocity increasing at inlet edge of the impeller and cavitation will occur.

In this case, if CO_2 temperature can be decreased to over cooled condition, there is NPSH margin. However refrigerator load increases, therefore it is no good from point of power saving. Refer to Fig.7

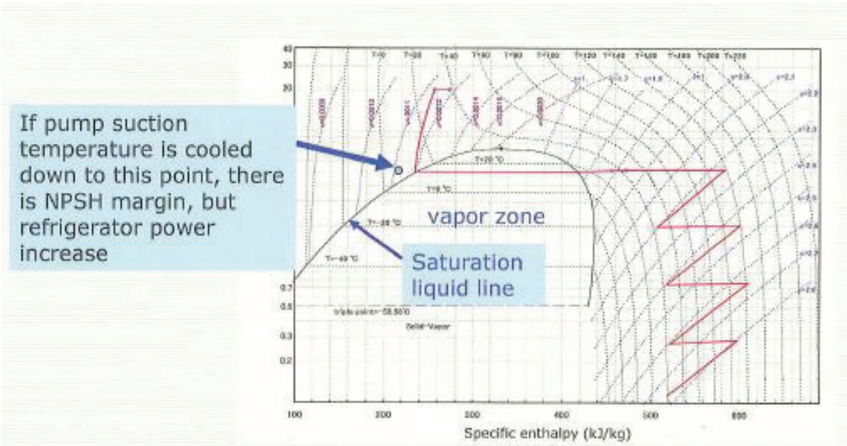

Fig.7. Relation of pressure and temperature, saturation liquid line

In order to give NPSHR to CO_2 Injection Pump, liquefied CO_2 reservoir which inside pressure is vapour pressure should be located over head of CO_2 pump higher than NPSHR as shown in Fig.8

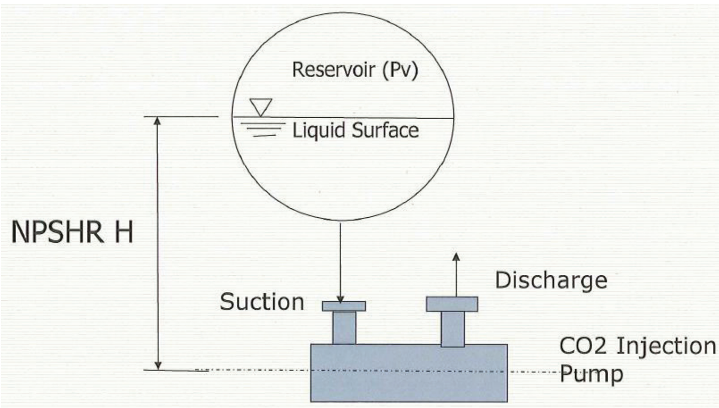

Fig.8 Location of CO_2 Injection Pump and liquid CO_2 reservoir

6. Influence of temperature fluctuation

Due to density variation pump volumetric flow change stage by stage and head generated by each stage become different. So, the diameter of pump impeller must be calculated so that it satisfies required discharge pressure when considering density change inside of the pump.

CO_2 pump impeller diameter will be calculated based on average density between suction and discharge. Pump head (H) generated by impeller is constant. However, differential pressure generated by pump is proportional to density. Therefore, in case pump inlet temperature fluctuation is large, inlet density also fluctuates largely and discharge pressure will be also influenced. That is, when inlet temperature decrease, then inlet density increase and discharge pressure will increases, on the contrary, when inlet temperature increases, discharge pressure will decrease. As shown in Fig. 9, if inlet temperature fluctuates by range of plus minus 10 deg C from rated condition, then density fluctuate more than 10% from average value calculated based on rated condition. Therefore, it is desirable to control pump inlet temperature fluctuation as minimum as possible. In case it is difficult to control inlet temperature constant, by adopting variable speed driver such as inverter motor, it is possible to adjust pump discharge pressure as per inlet temperature.

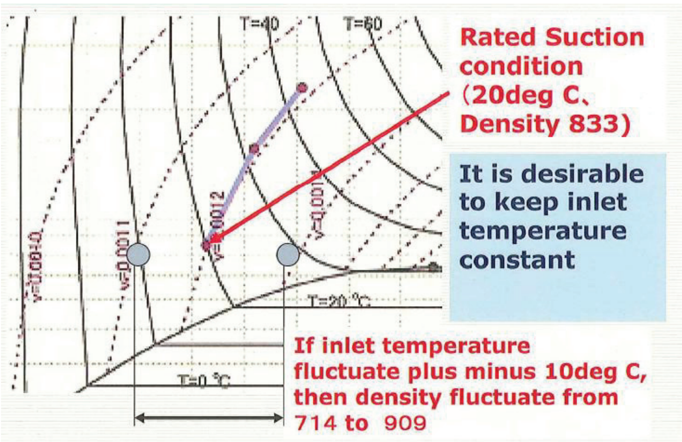

Fig. 9. Influence of inlet temperature fluctuation

7. Shaft sealing

7.1 Gas Seal

In case of pure CO2 which does not contain harmful ingredient like H2S, gas seal can be applied. However, dry gas seal is not applicable for horizontal pump, because it will be destroyed when starting in wet condition. Therefore it is necessary to adopt tandem seal , which is combination of vapour liquid seal for inside seal and dry gas seal for outside seal. Sample of this seal is shown in

Fig. 10. Example of seal system schematic is shown in Fig.11.

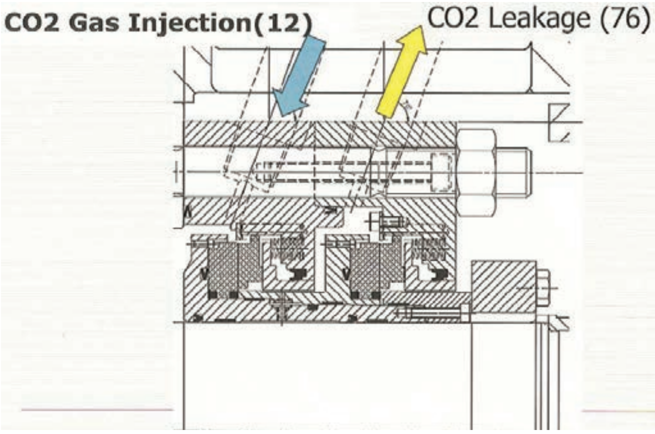

Fig.10 Tandem Gas Seal

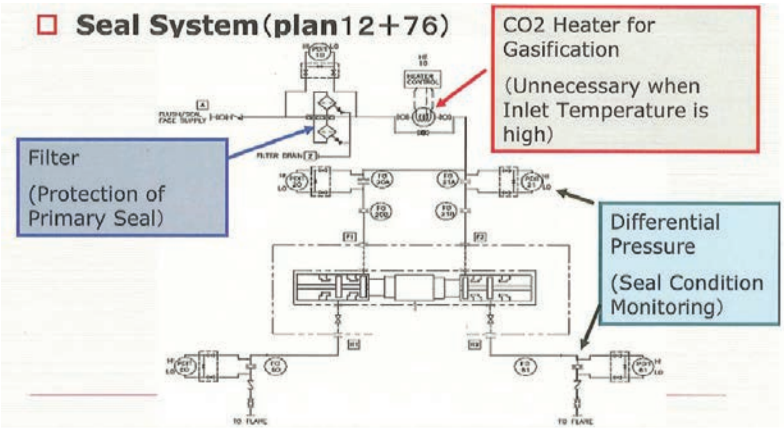

Fig.11 Sample of gas seal system

7.2. Wet seal

Since viscosity of CO2 is very low, self lubricating function is very poor. Therefore, in case wet seal is used, double or triple seal shall be adopted and sealing oil for barrier fluid shall be used.

8. Introduction of acid- gas injection pump[3]

EBARA supplied injection pump to the North America gas field in 2003.

The pump injects supercritical CO_2 & H_2S (ACID GAS) to the aquifer

- Pump Type: Double casing multi stage pump
  Volumetric Flow : 2.5 m^3/min
  Maximum suction pressure: 11MPaG
  Design discharge pressure: 32MPaG
- Pump material
  Austenite stainless steel complying with NACE MR0175 requirement.
- Wearing surface and thrust balance parts surface were hardened by special facing treatment
- Special design double mechanical seal and seal system were adopted in order to avoid leakage of H_2S. Mechanical seal is shown in Fig.14
  Mechanical seal specification
  *Special seal material (Anti corrosion)
  *Special seal oil (suitable for lubrication and cooling of wearing surface)
  *Soft start of main pump (To avoid transient load to the seal)
  *Control differential pressure for the seal constant from start to stop
  (To keep stable sealing condition)
  *Back up by accumulators (In case of emergency)

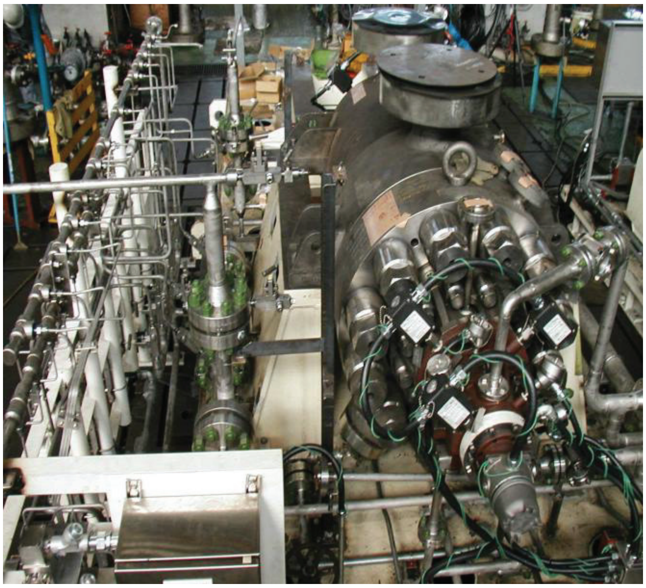

Fig.12 Acid gas pump during shop test

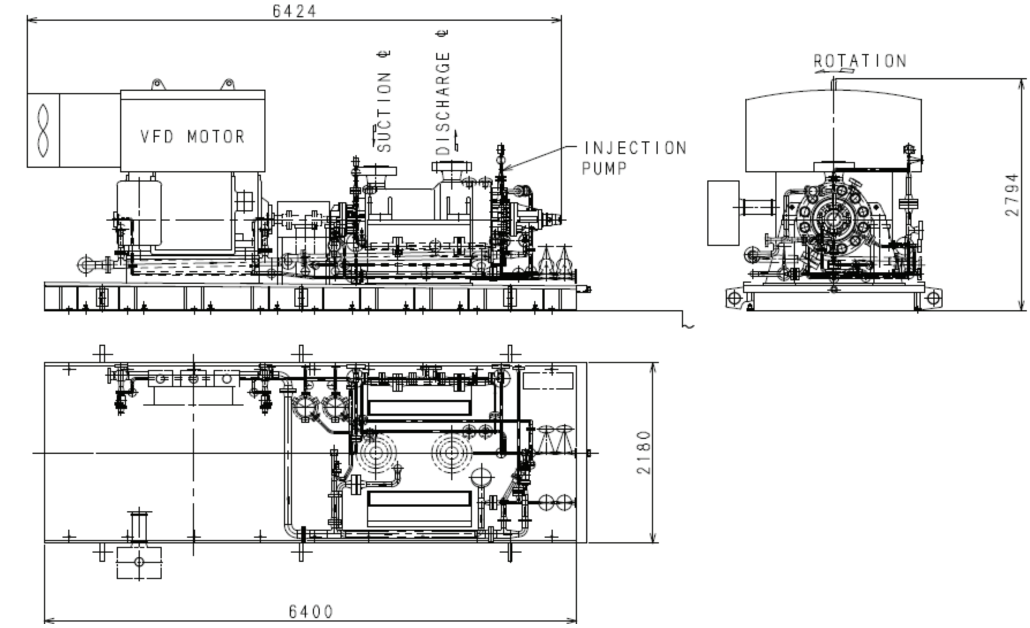

Fig.13 Acid gas pump layout drawing

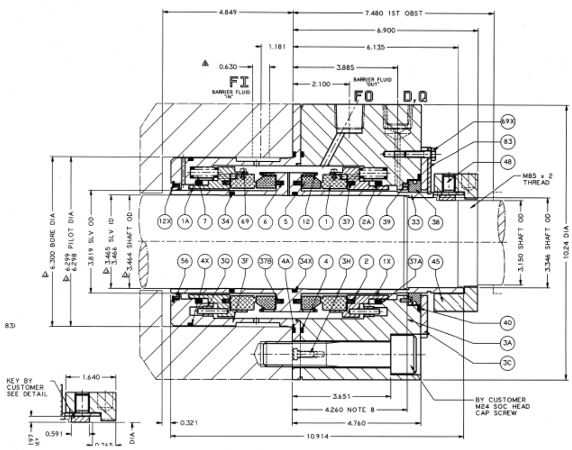

Fig.14. Double mechanical seal for acid gas pump

9. CO_2 pressurizing system[4]

In order to transport and storage CO2, it needs to pressurize CO_2 gas from atmospheric condition to the required pressure around 15 to 25 MPa. It is important to select layout of turbo machine to increase pressure so that total power consumption become minimum.

Fig. 15 shows step of pressure increasing on P-h diagram.

Supposing that handling amount of CO_2 to be 137 ton /hour, we have made comparison of total shaft power required by turbo machines. As shown in Fig. 15, total power consumption become minimum when liquefying CO_2 at pressure around 5MPa by using refrigerator with combination of five section compressors and injection pump as shown in Fig.16

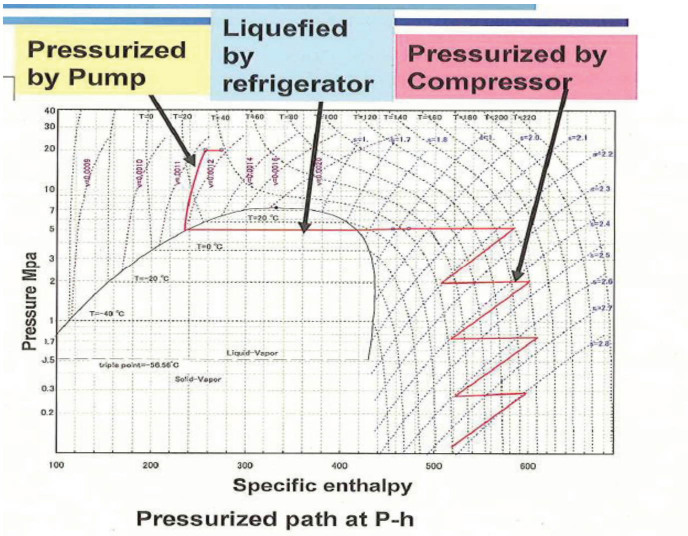

Fig. 15 CO_2 Pressurizing Process

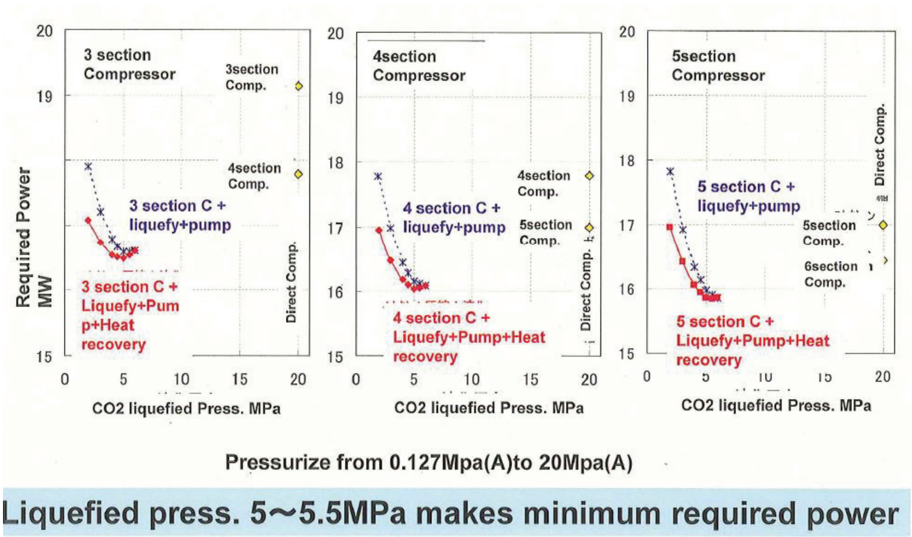

Fig.16 Comparison of Power Consumption by Turbo Machinery

10. Conclusion

In this paper, we explain about key point for design of CO_2 injection pump used for CCS.

Consideration for low viscosity and compressibility of CO_2 is very important.

We report optimum pressurization system by combination of several turbo machines from point of minimum power consumption.

We think that Injection Pump will be necessary to achieve best system of CO_2 storage.

We introduce supply experience of acid gas injection pump. Through successful experience of acid gas pump, we believe that Ebara can contribute to CCS by supplying reliable CO_2 injection pumps.

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