Design of cold box for air liquefaction with capacity of 10 ton/day

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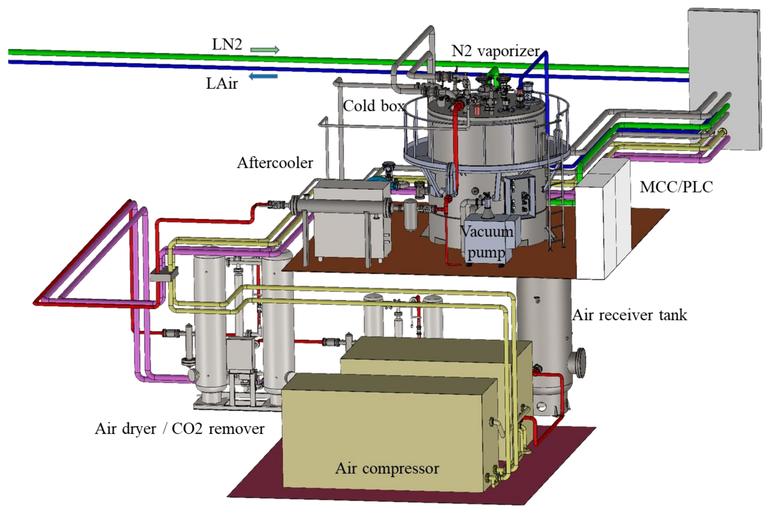
▣ Introduction

◈ The cold box for the cryogenic liquefaction process of the liquid air energy storage (LAES) device is a facility that produces cryogenic liquid air by introducing gas at high pressure/room temperature.

◈ Inside the cold box, various devices such as heat exchangers, cryogenic valves, filters, expansion turbines, and phase separators are installed, and each component must be optimally designed for high efficiency operation. Especially, expansion turbines are high speed rotating machines and require components such as filters and expansion joints to prevent mechanical damages.



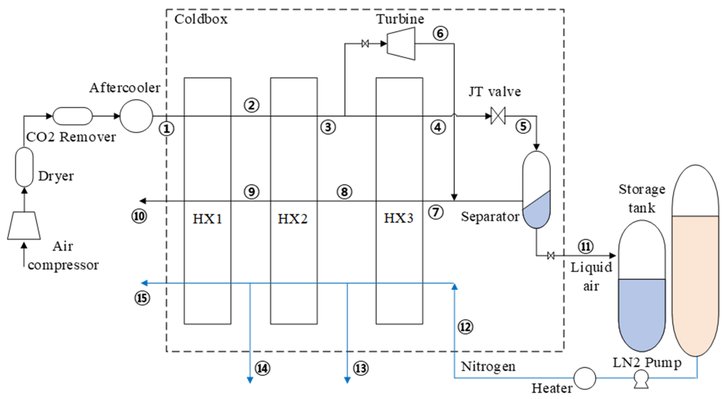
[Layout of liquefaction system]

▣ Design of cold box

◈ The various internal components of cold boxes are connected by process piping, and the cold box piping system must have sufficient structural strength to withstand high pressure and minimizes pressure loss of working fluid, as well as considering thermal deformation of the piping system due to cool-down operation.

[Specification of cold box of 10 tons/day]

Cold box	Specification	Remarks
Size (mm)	OD 2,500 x H 2,880	
Weight (kg)	Approx. 7,500	
Fluid	Air / Nitrogen	
Press. (MPaG)	4.5 / 0.5 / FV	
Temp. (DegC)	-196 ~ +40	
Test	Pressure & Tightness test	According KGS Code



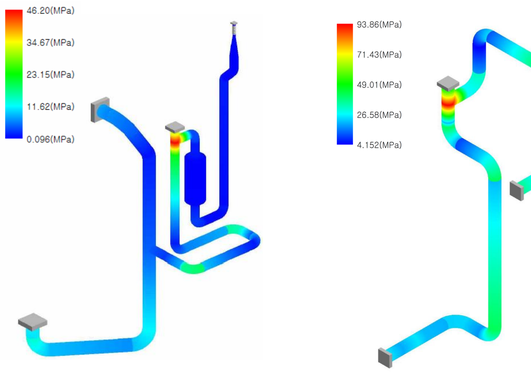
[Components of cold box]

Component	Quantity	Remarks
Heat exchanger	2	BAHX (3 stream)
Turbine filter	1	5 micron filter
Expansion turbine	1	3 stage
Phase separator	1	ID 497 x L1,510
Cryogenic valve	3	
Mass flow meter	2	
Safety valve	4	According KGS Code
Feedthrough	1	

◈ Thermal and structural analysis using CAEPIPE (ASME 31.2 “Processing Piping”) were performed to design a process piping system for the cold box. The structural robustness of the pipe as well as the force / moment acting on the nozzle of the heat exchanger and the pipe support were evaluated. And pressure losses in the pipe were evaluated.

[Design of process piping]

Str.	Designed Pipe		KGS FP112	
	Spec.	SCH / thickness (mm)	SCH Min. / thickness (mm)	Calculated Thickness (mm)
1	3”	40S / 5.49	5S / 1.65	1.483
3, 6	3”	10S / 3.05	5S / 2.11	1.575
4	2”	10S / 2.77	5S / 1.65	1.042
7	4”	10S / 3.05	5S / 2.11	0.225
9	4”	10S / 3.05	5S / 2.11	0.225
10	2”	10S / 2.77	5S / 1.65	0.114
11	4”	10S / 3.05	5S / 2.11	0.225
12	2”	10S / 2.77	5S / 1.65	0.114
13	3”	10S / 3.05	5S / 2.11	0.172
14	2” / 4”	10S / 2.77 10S / 3.05	5S / 1.65 5S / 2.11	0.114 0.225



[stream 3] [stream 4,5]

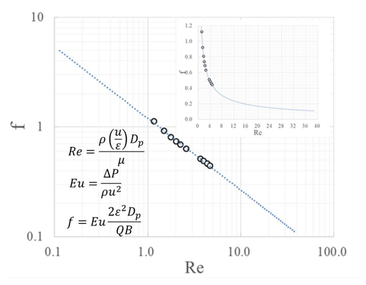
[Piping stress analysis]

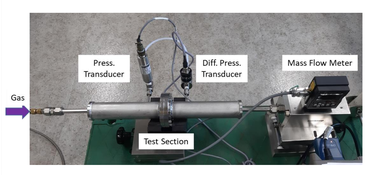
[Force and Moment acting on the nozzle]

Str.	Nozzle	Primary load			Secondary load		
		F(N)	M (N-m)	C	F(N)	M (N-m)	C
1	HX1	45.1	5.2	0.00	920.8	195.7	0.09
2 4	HX2 HX3	98.8 112.9	28.9 34.3	0.01 0.03	833.0 1016.5	370.7 314.7	0.13 0.25
3, 6	HX3	33.9	9.5	0.02	826.7	287.9	0.66
5, 7, 10	HX3	172.6	116.2	0.06	489.0	349.0	0.17
9	HX1	21.0	3.0	0.00	3778.5	1484.0	0.87
11	HX3	42.1	3.0	0.00	1361.7	637.0	0.42
12	HX2 HX3	119.5 38.1	24.8 6.7	0.02 0.01	1297.5 228.5	222.8 119.9	0.17 0.08
13	HX1 HX2	65.6 61.1	12.7 11.7	0.01 0.01	1219.8 2982.6	231.8 578.5	0.16 0.41
14	HX1	21.1	3.0	0.00	2310.7	146.0	0.19

[Pressure drop of process piping]

Stream	Fluid	Pressure drop (Pa)			
		Pipe	Minor	Valve, MFM	Total
1	HP Air	25.5	175.9	-	201.4
2	HP Air	30.1	80.1	-	110.2
3	HP Air	7.9	20.0	-	27.9
4	HP Air	712.8	304.7	20650.1	21667.6
5	LP Air	284.9	3822.6	-	4107.5
6	LP Air	213.7	1075.7	-	1289.4
7	LP Air	48.0	112.2	-	160.3
8	LP Air	60.8	263.2	-	324.0
9	LP Air	119.8	152.6	-	272.4
10	LAir	1.4	1.4	2659.2	2662.1
11	Nitrogen	59.5	92.9	-	152.3
12	Nitrogen	62.2	475.2	-	537.4
13	Nitrogen	92.7	685.3	-	778.1
14	Nitrogen	23.9	66.5	-	90.3





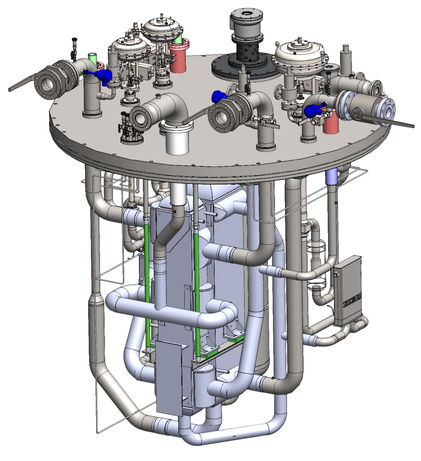
[Pressure drop of Turbine filter]

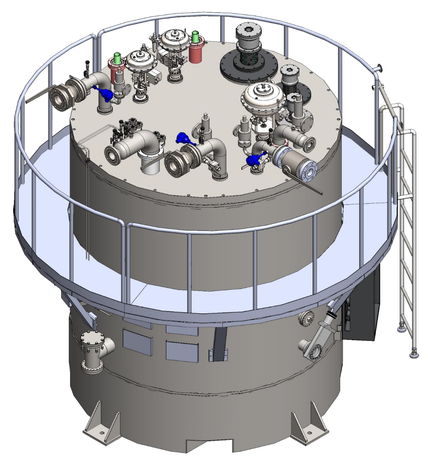
▣ Summary

◈ The detailed design of a cold box for the LAES

◈ Pressure vessel fabrication, inspection and testing

◈ Approval from KGS (Korea Gas Safety Corporation) for cold box





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