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Improvement Of Air Compressor Cooling With Intercooler Fine Pruning

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Abstract: A compressor is equipment that is used to rice the pressure of an air at specific volume. Compressors are commonly employed in in pneumatic air system, engines, oil extraction purpose and also domestic air cleaner. An intercooler is a mechanical system used to cool a liquid between multi-stage heat enabling factors, usually a heat exchanger in a gas compressor that removes excess heat. The compressor's efficiency is low due to varying variable that has been impacted as, without breathing machine, inappropriate intercooling, compressor rig terrible destination, and more dust absorption air. The reciprocating air compressor output overall is difficult. Increase performance through correct intercooling by intercooler in the two-stage reciprocating air compressor. Additionally, the amount of heat discharge drawn from the intercooler

Keywords: Reciprocating Air Compressor, Inter Cooler, Fin Length, Heat Transfer, Compressor efficiency, Heat enabling factor.

1. INTRODUCTION

The principle of heating and gas cooling in reciprocating compressors are natural activities correlated with compression and extension. This research is concerned with assessing the quality of reciprocating two-stage air compressor through offering a supply of water cooling, radiator coolant, and ethylene glycol. Experiments of an air-reciprocating two-cylinder piston system with Air and different inter-cooling agents were included. The equations describing the volumetric and isothermal performance have been solved and the expected findings compared to experimental evidence and water theoretical data, other cooling methods and showing strong compliance with air cooling. [1,3,6].

A successful phase comprises intercooling of the air compressors. A shell and tube model heat exchanger especially suitable as an intercooler between a compressor 's compression stages. The procedure for clarifying a design is a defining trait of pipe heat exchanger, Heat transfer region and pressure drops The purpose of his research paper is to include a simple and effective way of designing an intercooler air compressor. Methodology of design is focused on available research and the current industry norm given by TEMA [8,5].

This is designed based on the latest MATLAB ® application algorithm. Software specification codes are arranged to manually differentiate the parameters of the exchanger such as shell width, baffles timing, amount of tube-side passes to classify configurations matching the required heat transfer and pressure drops. [9, 14]

In fact, the purpose of compression is to a defined length, resulting in a rise in strain. He was talking specifically about the reciprocating compressor that is commonly used to compress air. Compression is achieved in more than one stage to increase performance, which is given in each stage of the intercooler. Intercooler increases air quality and lowers ambient temperatures at the inlet. [7,9,15]

Cooling system is an air-to - air or wind-to-liquid heat exchanger system that passes heat intake charge to an intermediate fluid that eventually refuses heat into the cold. A shell & tube style heat exchanger especially suitable as an air compressor intercooler between the compression stages. The process for defining a configuration, heat transfer region & pre is a feature of the heat exchanger system. [1,6,11, 17]

Therefore, certain thermodynamic and fluid dynamic parameters are included throughout the design phase so this state should accommodate and save time utilizing a machine. Rate a tube insert within the tube is given to improve tube side heat transfer. There are few drawbacks of software to remember. U Bend Exchangers are selected to reduce scale and expense of heat exchanger. Tubing systems are usually for a commonly used triangle design that requires more tubing to be found. Shell diameter limitation is within minimum 0.3 m and maximum 0.4 m. It is also presumed there's little benefit in varying less than the allowable pressure decrease, and that baffles are included the graphs represent the mean (one fifth of the shell diameter) and average (within the same variable and its effect on certain variables). Results obtained are contrasted with the current configuration outcome and the shell diameter is found. [1, 3,8,16]

2. METHODOLOGY

The testing was performed out in a two-stage reciprocating air compressor with two independent tubes, positioned in a V form with two separated cylinder.

The Compressor, manufactured by private company Coimbatore Compressor Engineering. (Model type ELT 600), can generate a maximum output pressure of about 13 kg / cm2 and 4.4 kg / cm2. The compressor was dynamic duo assembled, driving the second stage directly from the first stage 's rear. Inlet of compressor sucked the air from the atmosphere as required amount by using sensor. After the compression, compressed air is stored in the reservoir at bottom of the compressor setup. Pressure transducer is mounted on the air compressor and its indicate the pressure level in the tank.

Figure: 1 Photographic view of two stage reciprocating compressor

This is a two stage air compressor so, after the completion of first stage the compressed air passing through a intercooler, it is a device used to reduce the heat from the first stage compressed air. This heat reduction method is done by a different methods and all electric and electronic component are used to measure the data from the setup

Figure:2 Existing intercooler

Table 1. Parameter variation

Existing intercooler	**New intercooler**
Fins diameter – 73 mm Length – 152 mm Number of fins – 16	Fins diameter – 86 mm Length – 159 mm Number of fins - 21

Figure: 3. newly adapted intercooler

The different set of reading was taken in various condition of compressor. All the parameter changed compared with existing compressor rig to newly adapted one.

- Altitude increased into – 0.3 m
- Motor efficiency increased 0.6% to 0.8% .

Table 2. Two stage reciprocating air compressor specification

Compressor type	**Two stage, reciprocating, air cooled**
Number of cylinders	2

High pressure cylinder diameter	0.06 m
High pressure cylinder stroke	0.085 m
Low pressure cylinder diameter	0.1 m
Low pressure cylinder stroke	0.085 m
Gas constant	0.287 kJ/kg
Air density	1.17 kg/m^3
Water density	1000 kg/m^3
Motor efficiency	0.6 %

3. RESULT AND DISCUSSION

The reports of two-stage reciprocating compressor experimental set-up are discussed. Firstly, the working conditions in the background are investigated before the compressor begin.

The stable temperature dependent on the perform of the absorption chiller and on the air temperature placed in the intercooler from the first stage t2 t2 and t4.increase rapidly with time.

These are indicating the existing intercooler performance compressor rig. Inlet temperature (T_2) of intercooler is always higher then outlet temperature (T_3) of intercooler. Those parameters measured at normal condition. (Table 3)

Table 3. Existing intercooler

T_1 [K]	T_2 [K]	T_3 [K]	T_4 [K]	P_1 [kg/cm^2]	P_2 [kg/cm^2]	P_3 [kg/cm^2]	P_4 [kg/cm^2]	P [kW]	m [m^3/s]	N [rpm]
307.7	378.9	365.1	366.3	1	2.29	2.5	2.67	2.498	0.0063	1116
307.7	378.9	367.7	369.1	1	2.29	3.0	2.87	2.473	0.0065	1116
307.7	380.9	371.5	373.3	1	2.25	3.5	4.13	2.473	0.0065	1072
307.7	384.5	382.4	384.1	1	2.25	4.0	4.49	2.473	0.0065	1068
307.7	387.5	386.4	388.1	1	2.29	4.5	4.58	2.498	0.0065	1063
307.7	389.9	387.5	391.9	1	2.25	5.0	5.19	2.498	0.0068	1058
307.7	393.5	390.7	393.1	1	2.29	5.5	5.34	2.498	0.0066	1044
307.7	407.3	395.7	398.9	1	2.29	6.0	6.23	2.498	0.0067	1041
307.7	408.5	396.3	397.9	1	2.29	6.5	6.69	2.523	0.0065	1046
307.7	411.1	397.8	403.4	1	2.29	7.0	6.94	2.523	0.0065	1049

This parameter indicates the existing intercooler performance compressor rig. The altitude increased from sea level to 0.3 m. (Table 4)

Table 4. Observation table of existing intercooler with altitude variation

T_1	T_2	T_3	T_4	P_1	P_2	P_3	P_4	P	m	N
[K]	[K]	[K]	[K]	[kg/cm^2]	[kg/cm^2]	[kg/cm^2]	[kg/cm^2]	[kW]	[m^3/s]	[rpm]
310.6	378.4	365.6	366.6	1	1.55	2.5	2.62	2.243	0.0066	1117
310.6	378.5	367.3	369.6	1	1.55	3.0	2.83	2.269	0.0065	1114
310.6	380.4	371.1	379.3	1	1.59	3.5	4.24	2.243	0.0065	1074
310.6	384.7	382.4	384.4	1	1.59	4.0	4.5	2.269	0.0066	1064
310.6	387.3	383.4	385.6	1	1.59	4.5	4.59	2.294	0.0067	1068
310.6	389.9	387.9	392.0	1	1.55	5.0	5.13	2.294	0.0067	1058
310.6	393.1	390.4	397.6	1	1.63	6.5	5.37	2.269	0.0065	1044
310.6	396.3	395.6	403.3	1	1.51	7.0	6.26	2.269	0.0067	1041

This data clearly indicated the existing intercooler performance compressor rig. The motor efficiency increased from 0.6% to 0.8%.(Table 5)

Table 5. Existing intercooler with higher motor efficiency

T_1	T_2	T_3	T_4	P_1	P_2	P_3	P_4	P	m	N
[K]	[K]	[K]	[K]	[kg/cm^2]	[kg/cm^2]	[kg/cm^2]	[kg/cm^2]	[kW]	[m^3/s]	[rpm]
311.2	378.7	365.3	365.4	1	1.67	2.5	2.67	2.32	0.0065	1119
311.2	378.1	367.9	369.6	1	1.67	3.0	2.99	2.269	0.0064	1117
311.2	380.9	371.1	372.5	1	1.59	3.5	4.18	2.294	0.0068	1072
311.2	384.3	382.7	383.8	1	1.67	4.0	4.54	2.269	0.007	1068
311.2	387.5	381.4	384.2	1	1.63	4.5	4.68	2.269	0.0065	1064
311.2	389.8	386.5	392.4	1	1.67	5.0	5.16	2.243	0.0065	1051
311.2	393.6	390.9	396.4	1	1.67	5.5	5.37	2.269	0.0065	1049
311.2	396.2	395.1	398.4	1	1.67	6.0	6.21	2.294	0.0065	1041

311.2	395.3	396.3	396.7	1	1.67	6.5	6.67	2.294	0.0066	1046
311.2	399.4	399.6	404.1	1	1.63	7.0	7.03	2.269	0.0065	1043

These parameters indicate the newly adapted intercooler performance compressor rig. Inlet temperature (T2) of intercooler is always higher then outlet temperature (T3) of intercooler at normal condition. (Table 6)

Table 6. of newly adapted intercooler

T_1 [K]	T_2 [K]	T_3 [K]	T_4 [K]	P_1 [kg/cm^2]	P_2 [kg/cm^2]	P_3 [kg/cm^2]	P_4 [kg/cm^2]	P [kW]	m [m^3/s]	N [rpm]
308.3	378.7	365.4	365.7	1	2.37	2.5	2.69	2.677	0.0064	1116
308.3	378.9	367.9	369.1	1	2.22	3.0	2.81	2.702	0.0063	1119
308.3	380.9	371.1	374.1	1	2.33	3.5	4.17	2.702	0.0062	1072
308.3	384.1	382.5	384.7	1	2.37	4.0	4.35	2.702	0.0063	1069
308.3	387.8	386.4	385.6	1	2.37	4.5	4.71	2.677	0.0063	1063
308.3	389.3	387.6	392.4	1	2.25	5.0	5.78	2.702	0.0063	1058
308.3	393.2	389.7	392.5	1	2.29	5.5	5.44	2.702	0.0064	1044
308.3	396.3	395.2	397.1	1	2.41	6.0	6.75	2.702	0.0064	1041
308.3	395.5	396.1	396.5	1	2.29	6.5	6.32	2.702	0.0061	1047
308.3	399.9	399.4	402.4	1	2.25	7.0	6.87	2.702	0.0066	1050

These parameters indicate the newly adapted intercooler performance compressor rig. Inlet temperature (T2) of intercooler is always higher then outlet temperature (T3) of intercooler. With altitude vary from 0 to 0.3 m. (Table 7)

Table 7. Newly adapted intercooler with altitude variation

T_1 [K]	T_2 [K]	T_3 [K]	T_4 [K]	P_1 [kg/cm^2]	P_2 [kg/cm^2]	P_3 [kg/cm^2]	P_4 [kg/cm^2]	P [kW]	m [m^3/s]	N [rpm]
304.8	383.6	365.3	366.6	1	2.37	2.5	2.66	2.906	0.0058	1118
304.8	383.6	367.7	369.1	1	2.29	3.0	2.72	2.88	0.0061	1116

304.8	383.6	371.2	374.5	1	2.41	3.5	3.64	2.88	0.0059	1073
304.8	389.6	382.1	384.0	1	2.29	4.0	4.52	2.855	0.006	1068
304.8	397.8	386.3	386.4	1	2.33	4.5	4.61	2.88	0.0058	1067
304.8	399.3	387.9	391.4	1	2.37	5.0	5.17	2.88	0.0059	1056
304.8	399.2	390.4	393.6	1	2.29	5.5	5.47	2.88	0.0058	1044
304.8	399.3	395.3	397.8	1	2.45	6.0	6.13	2.906	0.0058	1041
304.8	398.5	396.4	398.0	1	2.37	6.5	6.42	2.906	0.0058	1046
304.8	405.4	399.8	402.5	1	2.33	7.0	6.73	2.855	0.0059	1046

These table parameters indicate the newly adapted intercooler performance compressor rig. Inlet temperature (T2) of intercooler is always higher then outlet temperature (T3) of intercooler. With higher motor efficiency. (Table 8)

Table: 8 Newly adapted intercooler with higher motor efficiency

T_1	T_2	T_3	T_4	P_1	P_2	P_3	P_4	P	m	N
[K]	[K]	[K]	[K]	[kg/cm^2]	[kg/cm^2]	[kg/cm^2]	[kg/cm^2]	[kW]	[m^3/s]	[rpm]
301.2	369.5	365.3	369.3	1	2.29	2.5	2.64	3.11	0.0066	1116
301.2	370.1	367.4	369.1	1	2.29	3.0	2.88	3.11	0.0067	1116
301.2	373	371.6	377.6	1	2.29	3.5	4.14	3.11	0.0065	1072
301.2	373	382.3	382.4	1	2.29	4.0	4.39	3.11	0.0065	1068
301.2	387.8	386.2	387.0	1	2.29	4.5	4.5	3.11	0.0067	1063
301.2	389.3	387.9	394.7	1	2.29	5.0	5.15	3.11	0.0067	1058
301.2	393.2	390.1	394.1	1	2.29	5.5	5.16	3.11	0.0067	1041
301.2	396.3	395.3	398.4	1	2.33	6.0	6.43	3.161	0.0065	1041
301.2	398.5	396.4	397.1	1	2.33	6.5	6.48	3.161	0.0065	1046
301.2	399.9	393.9	403.6	1	2.33	7.0	6.87	3.161	0.0065	1048

4. CALCULATION

1) Swept volume is defined as Volume displaced by each piston moving from bottom dead center to top dead center

Swept volume = $\frac{\pi \text{ x D2x Lx N}}{4 \text{ x } 60}$

Where

D = Bore diameter

L = Stroke length

N = Number of revolution ric

2) Volumetric efficiency is the ratio between the actual volume to swept volume of the compressor

Volumetric Efficiency = $\frac{\text{Actual volume}}{\text{Swept volume}}$

3) Isothermal Work done is when no heat flows into or out of the gas because its container is at the same temperature, then there is no work done

Isothermal Work done = P_1 x Q_{actual} x ln $\frac{P3}{p1}$

Where

P_1 = Inlet pressure

P_3 = Delivery pressure

4) Shaft power = Motor power x Motor efficiency

5) $Re_d = \frac{4 \text{ x m}}{\pi \text{ x D x } \mu}$

Where

Re_d = Reynolds number

m = Mass flow rate

μ = Absolute viscosity

6) Nu = 0.023 x Re d^n x Pr^n r(or)

Nu =$\frac{\text{h x D}}{\text{k}}$

Where

Nu = Nusselt number

Pr = Prandtl number

7) Q = h x A x ΔT

Where

h = Heat transfer coefficient

A = Fins Area

ΔT = Temperature difference

Calculation table of existing intercooler

To find the volumetric efficiency, isothermal efficiency, and the amount of heat rejection values from existing intercooler with normal condition.

Table: 9 Existing intercooler

S. No	Delivery Pressure	Actual Volume	Swept Volume	Volumetric Efficiency	Isothermal Work done	Shaft Power	Isothermal Efficiency	Heat Rejection
	[kg/cm^2]	[m^3/s]	[m^3]	[%]	[kW]	[kW]	[%]	[kJ/kg]

1	3	0.0063	$4.55X10^{-3}$	76.7	0.594	1.99	30.1	33.2
2	4	0.0064	$4.53X10^{-3}$	77.78	0.602	1.98	30.4	33.93
3	5	0.0065	$4.55X10^{-3}$	79.14	0.652	1.97	33.09	35.82
4	6	0.0068	$4.55X10^{-3}$	82.8	0.68	2.01	33.83	37.89
5	7	0.0069	$4.56X10^{-3}$	83.2	0.682	2.08	32.78	38.25

Calculation table of existing intercooler with altitude variation

To find the volumetric efficiency, isothermal efficiency, and the amount of heat rejection values from existing intercooler with varying altitude.

Table: 10 Existing intercoolers with altitude variation

S. No	Delivery Pressure	Actual Volume	Swept Volume	Volumetric Efficiency	Isothermal Work done	Shaft Power	Isothermal Efficiency	Heat Rejection
	[kg/cm^2]	[m^3/s]	[m^3/s]	[%]	[kW]	[kW]	[%]	[kJ/kg]
1	3	0.0065	$4.5X10^{-3}$	82.8	0.669	1.36	49.19	40.22
2	4	0.0066	$4.31X10^{-3}$	84.9	0.698	1.34	52.08	42.37
3	5	0.0066	$4.42X10^{-3}$	84.7	0.699	1.35	51.77	44.32
4	6	0.0067	$4.43X10^{-3}$	83.9	0.727	1.37	53.06	43.5
5	7	0.0067	$4.44X10^{-3}$	84.3	0.731	1.38	52.97	45.47

Calculation table of existing intercooler with higher motor efficiency

To find the volumetric efficiency, isothermal efficiency, and the amount of heat rejection values from existing intercooler with higher motor efficiency condition.

Table: 11 Existing intercoolers with higher motor efficiency

S. No	Delivery Pressure	Actual Volume	Swept Volume	Volumetric Efficiency	Isothermal Work done	Shaft Power	Isothermal Efficiency	Heat Rejection
	[kg/cm^2]	[m^3/s]	[m^3/s]	[%]	[kW]	[kW]	[%]	[kJ/kg]
1	3	0.0066	$4.23X10^{-3}$	86.59	0.716	1.83	39.12	45.89
2	4	0.0065	$4.21X10^{-3}$	85.97	0.727	1.82	39.94	47.47
3	5	0.0065	$4.2X10^{-3}$	85.44	0.739	1.81	40.82	50.76
4	6	0.0066	4.27X1	84.81	0.741	1.83	40.49	51.35

			0-3					
5	7	0.0065	4.25X10-3	84.72	0.756	1.81	41.76	52.11

Calculation table of newly adopted intercooler

To find the volumetric efficiency, isothermal efficiency, and the amount of heat rejection values from newly adapted intercooler with normal condition.

Table: 12 newly adopted intercooler

S. No	Delivery Pressure	Actual Volume	Swept Volume	Volumetric Efficiency	Isothermal Work done	Shaft Power	Isothermal Efficiency	Heat Rejection
	[kg/cm^2]	[m^3/s]	[m^3/s]	[%]	[kW]	[kW]	[%]	[kJ/kg]
1	3	0.0063	4.39X10^{-3}	79.64	0.844	1.62	52	52.78
2	4	0.0064	4.38X10^{-3}	79.72	0.86	1.61	52.72	53.23
3	5	0.0063	4.39X10^{-3}	79.64	0.87	1.6	54.39	54.88
4	6	0.0064	4.38X10^{-3}	80.03	0.901	1.62	55.4	54.12
5	7	0.0066	4.37X10^{-3}	83.82	0.924	1.62	57.25	58.34

Calculation table of newly adopted intercooler with altitude variation

To find the volumetric efficiency, isothermal efficiency, and the amount of heat rejection values from newly adapted intercooler with altitude varying condition.

Table: 13 newly adopted intercooler with altitude variation

S. No	Delivery Pressure	Actual Volume	Swept Volume	Volumetric Efficiency	Isothermal Work done	Shaft Power	Isothermal Efficiency	Heat Rejection
	[kg/cm^2]	[m^3/s]	[m^3/s]	[%]	[kW]	[kW]	[%]	[kJ/kg]
1	3	0.0058	4.08X10^{-3}	78.71	0.924	1.743	53.42	56.98
2	4	0.0058	4.09X10^{-3}	78.52	0.931	1.738	53.98	58.7
3	5	0.0057	4.1X10^{-3}	78.4	0.949	1.743	54.41	57.63
4	6	0.0058	4.07X10^{-3}	79.34	0.957	1.727	55.74	59.61
5	7	0.0059	4.06X10^{-3}	80.46	0.968	1.713	56.5	61.21

Calculation table of newly adopted intercooler with higher motor efficiency

To find the volumetric efficiency, isothermal efficiency, and the amount of heat rejection values from newly adapted intercooler with higher motor efficiency condition.

Table: 14 newly adopted intercooler with higher motor efficiency

S. No	Delivery Pressure	Actual Volume	Swept Volume	Volumetric Efficiency	Isothermal Work done	Shaft Power	Isothermal Efficiency	Heat Rejection
	[kg/cm^2]	[m^3/s]	[m^3/s]	[%]	[kW]	[kW]	[%]	[kJ/kg]
1	3	0.0066	4.2X10^{-3}	87.17	1.2	1.866	64.3	61.14
2	4	0.0065	4.18X10^{-3}	86.34	1.22	1.862	65.52	62.34
3	5	0.0065	4.19X10^{-3}	87.23	1.25	1.88	66.48	63.2
4	6	0.0065	4.18X10^{-3}	86.26	1.25	1.866	66.98	62.29
5	7	0.0067	4.2X10^{-3}	88.49	1.3	1.896	68.56	63.39

GRAPHS

All the graphs are draw between delivery pressure to volumetric efficiency, isothermal efficiency, and amount of heat rejection.

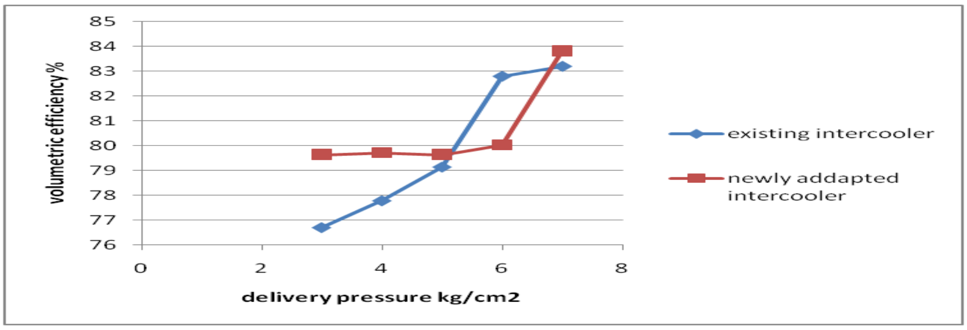

Figure:4 Volumetric efficiency of normal condition

Newly adapted intercooler 84% volumetric efficiency has more volumetric efficiency compare to existing one 83%.

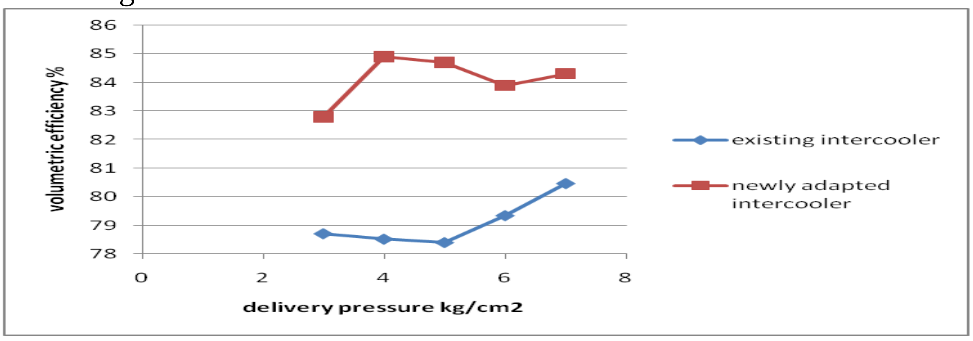

Figure: 5 volumetric efficiency of altitude variation

The volumetric efficiency has higher (85%) in newly adapted intercooler in altitude varying condition. Volumetric efficiency of the older type has lesser efficiency 80.5 %

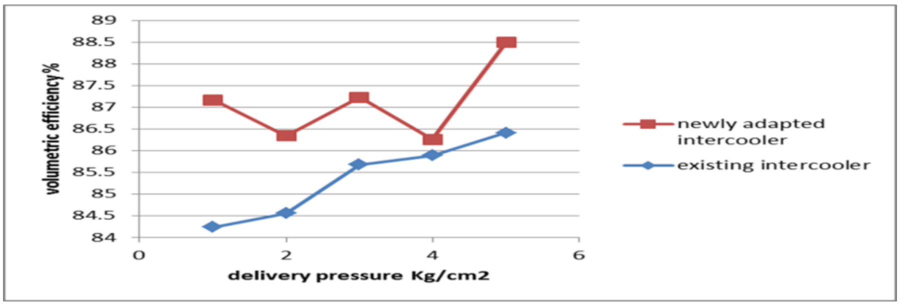

Figure: 6 volumetric efficiency of higher motor efficiency

Isothermal efficiency of the new and old type compared new one got higher efficiency.

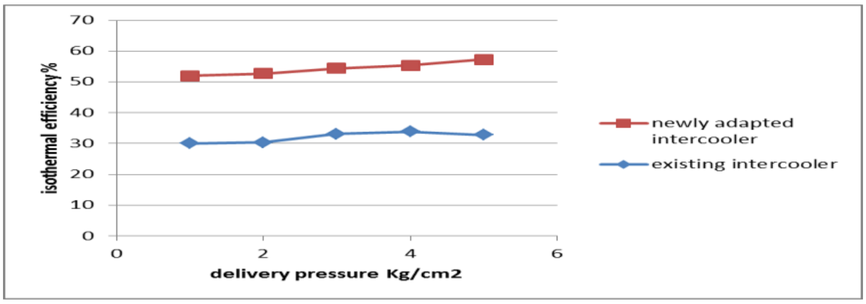

Figure:7 Isothermal efficiency of normal condition

Isothermal efficiency of the new and old type compared new one got higher efficiency (56.5%).

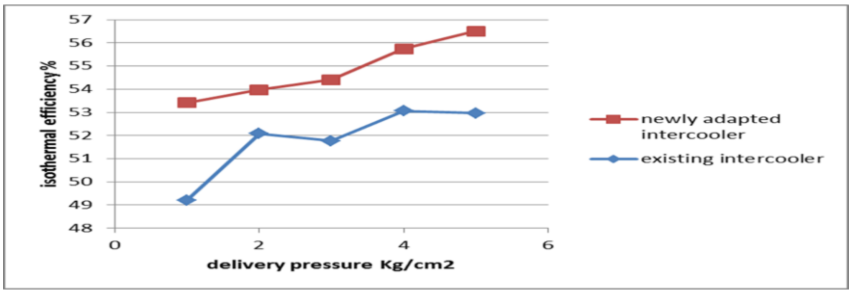

Figure: 8 Isothermal efficiency of altitude variation

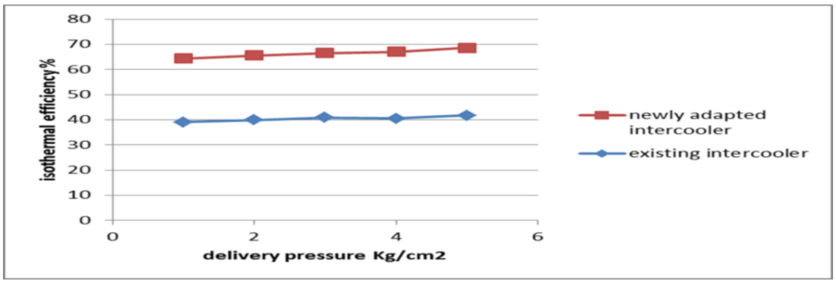

Figure: 9 Isothermal efficiency of higher motor efficiency

Heat rejection of the new and old type compared new one got higher diameter, this cause increase heat transfer rate.

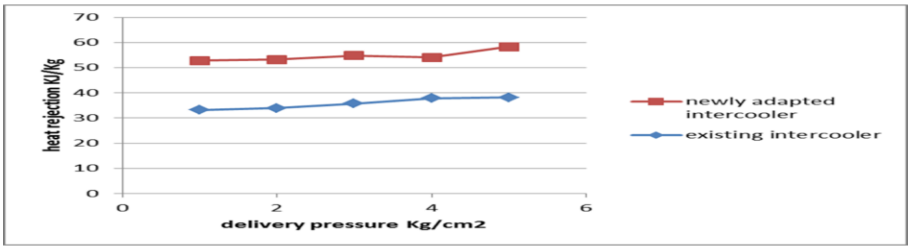

Figure:10 Heat rejection of normal condition

Heat rejection has higher (61%) in newly adapted intercooler in higher altitude heat rejection of the older type has lesser efficiency 57 %.

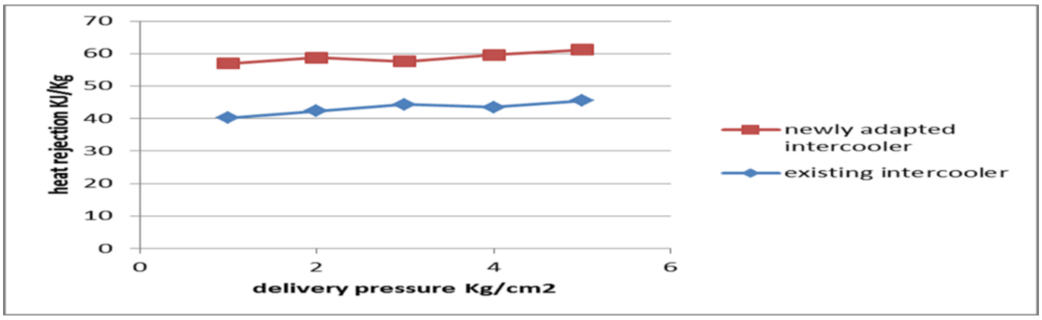

Figure:11 Heat rejection of altitude variation

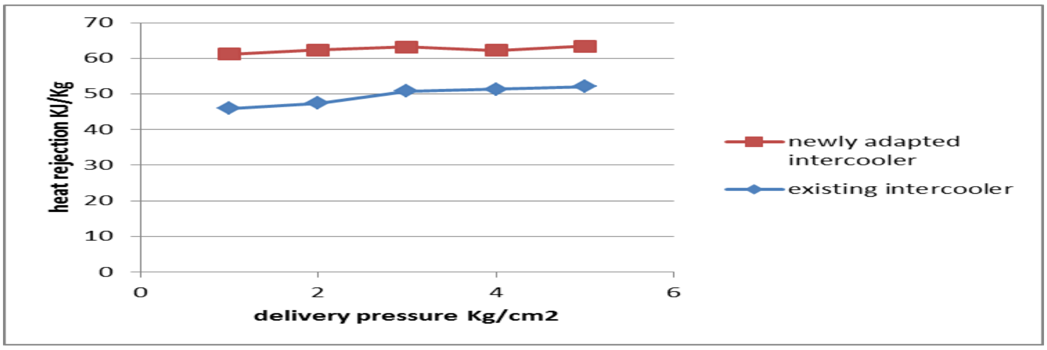

Figure:12 Heat rejection of higher motor efficiency

Heat rejection has higher (65%) in newly adapted Intercooler in higher motor efficiency heat rejection of the older type has lesser efficiency 53.5 %

5. CONCLUSION

Thus by modified intercooler to an existing two stage compressor, various performance is improved. The changes to the intercooler were in the terms of widened fin diameter and increased number of fins for the given length. These modifications resulted in the improvement of the Volumetric Efficacy, isothermal efficiency and heat rejection of the compressor.

Also the altitude of the entire experimental setup was increased and this gave room for further improvement in the performance which could be inferred from the values found in the tabulations which draw comparisons between the old and the retrofitted system. In addition to the above said changes, the retrofitted setup was run with an improvement in the motor efficiency and as a consequence, the results indicated further improvements in the performance.

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