

## INDUSTRIAL AIR COMPRESSOR(TYPE: VT4) DESIGN, MODIFICATION, AND ANALYSIS

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**Abstract**—*This essay demonstrates how crucial air compressor intercooling is to a productive procedure. Compressing air means to decrease a certain volume while raising pressure. Compression is carried out in stages, with intercoolers placed between each stage, to increase the system's efficiency. In the final stage, the intercooler lowers the temperature of the incoming air while also enhancing air quality. The air is cooled by the intercooler as it exits the low-pressure cylinder and enters the high-pressure cylinder. This increases the compressor's effectiveness and guarantees that the air receiver exit valves are at the ideal temperature for the tools attached to the compressor to operate at their best. Either a tubular core or sheet metal plate components make up the intercooler. Two-cylinder, two-stage reciprocating air compressors of type VT4 are most frequently employed for industrial and underground mining purposes. This study demonstrates that increasing the size of the intercooler improves the compressor's efficiency and prevents heating in high-pressure cylinders.*

**Keywords**—*Air Compressor, High-Pressure Cylinder, Intercooler, Low-Pressure Cylinder, Shell and Tube.*

### I. INTRODUCTION

By compressing air and raising its pressure, a VT4 compressor (Two Cylinder, Two Stage Reciprocating Air Compressor) transforms power (often from an electric motor, a diesel engine, or a gasoline engine) into potential energy. When the air is still under pressure, the energy in the form of compressed air can be stored in the tank. Using the kinetic energy of the air when it is depressurized is one of the many uses for these energies[8].

Till date, heat transfer in reciprocating compressors has played a back burner role. Energy consciousness recently has shown interest and generated considerable debate, contradictory opinions about the extent of influence of heat transfer on compressor performance. The performance of the compressor is

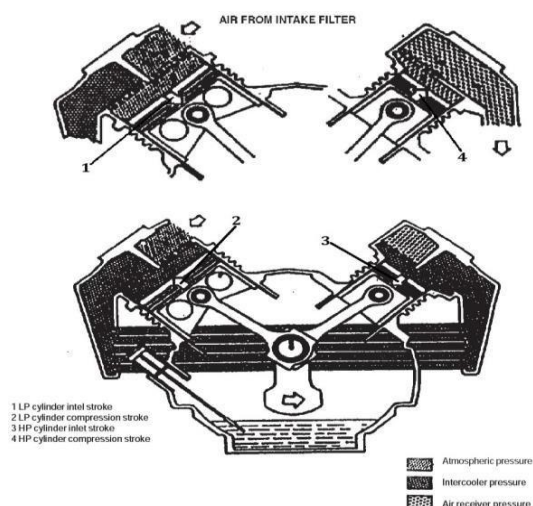
They are affected by not only heat transfer but also the design, operation and reliability. Compressed air units ranging from power values of 5 HP to over 50,000 HP is used in industrial plants throughout production and maintenance operations. Cost of a compressor is much lower than compared with its running cost, which is worth nothing. For improving efficiency, compression is done in more than one stage (in this case 2 Stage), and between each stage, an intercooler is provided.

The primary drawback in the Industrial Air Compressor (Type VT4 design)'s is the greater air temperature at the High-Pressure Cylinder's inlet port, which causes a high discharge temperature. High-Pressure Cylinder of the Compressor Unit is becoming heated due to high discharge temperature, which can be seen with the naked eye, and the hose connecting the

discharge pipe and air receiver tank is frequently damaged. Multi staging is necessary whenever temperature becomes a determining factor in the operation of an air compressor, and the intercooler is essential in boosting the system's efficiency. In many cases, the operational pressure ratio needs to be limited depending upon the inlet temperature, to keep the discharge temperature within the limits of the working environment and to handle air temperature.

The material properties are affected by temperature, in addition to dimensional stability and integrity of the component itself. It is the matter of concern that the outlet valves which are located above the High- Pressure Cylinder become faulty. The faulty valve must be attended immediately. Serious damage can result if a compressor is operated with a broken valve or valve plate. In the Air Compressor (Type VT4), Low-Pressure Cylinder has two inlet or suction valves and two outlet or delivery valves. At the same time, High-Pressure Cylinder has one input or suction valve and one output or delivery valve. All valves are located in the respective Low Pressure and High-Pressure Cylinder Heads.

Designers have started searching for energy savings at whatever cost, since the efficiency of the compressor is approaching their limits and energy deficiencies have started looming on the horizon<sup>[2]</sup>. This is driving researchers to take another look at the effect of heat transfer on the performance and efficiency of compressors. The early stages of such effort were clouded with conflicts of opinion between different groups, and it is only since 1980's, that the importance of the influence of heat transfer on compressor performance has been recognized<sup>[2]</sup>.



**Fig.1: Front View of Compressor Element.**

Larger Two-Stage Reciprocating Compressors up to 1,000 HP are commonly found in large Industrial and Underground Mining operation applications. Discharge pressures achieved from air compression can range from low pressure, i.e. 1 kg/cm<sup>2</sup> to very high pressure, i.e. 10 kg/cm<sup>2</sup> which are used for various applications, multi-stage double-acting compressors are said to be the most efficient compressors available, and are typically larger, and more costly than rotary units. Another famous type of Reciprocating Compressor is the swash plate compressor, which uses washplate on which pistons are mounted on a shaft. Most multi-stage compressors use intercoolers in between each stage, which are heat exchangers that remove the heat of compression between the stages of each compression. Inter cooling of pressurized air affects the overall efficiency of the machine<sup>[2]</sup>.

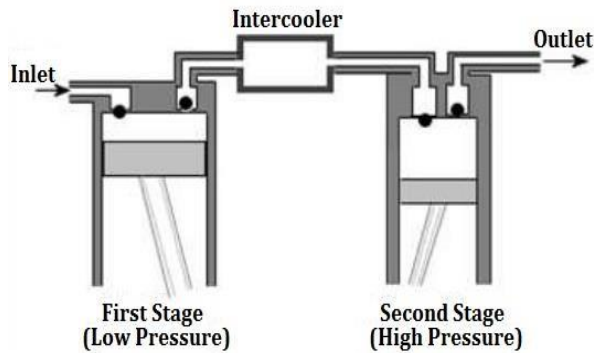


Fig.2: Example of an intercooler on a two-stage reciprocating air compressor.

## II. LITERATURE SURVEY

1. Shashank Gurnule, Ritesh Banpurkar, "Design, Modification & Analysis of Industrial Air Compressor (Type – VT4) – A Review", Seventh Sense Research Group – International Journal of Mechanical Engineering, Volume: 4, Issue: 12, Page Nos. 3 – 7.

This paper presents a review of how important the intercooling of the air compressor is necessary for an efficient process. The meaning of air compression is to reduce a specified volume, increasing pressure. For improving the efficiency of the system, compression is done in more than one stage, and intercooler is provided between each stage. Intercooler improves the quality of air and reduces inlet air temperature in the last stage. The function of the intercooler is to cool the air as it leaves the Low-Pressure cylinder and before it enters the High-Pressure cylinder. This improves the efficiency of the compressor and ensures that the temperature of the air receiver outlet valves is just right for optimum operation of the tools connected to the compressor. The intercooler is composed of sheet metal plate elements or tabular core. Type VT4 compressor is a Two Cylinder, Two Stage Reciprocating Air Compressor which is most widely used for Industrial and Underground Mining Purpose. This paper highlights the various efforts of various researchers. Based on various researches, it is proposed that the change in the size of intercooler will avoid heating in High-Pressure Cylinder during long run<sup>[1]</sup>.

2. Kanwar J.S Gill, Surinder Pal Singh, Gurpreet Singh & Malinder Singh, "Designing and Fabrication of Intercooler and Control of Three- Phase Digitalized Reciprocating Air Compressor Test Rig with Automatic Control Drive Unit", International Conference of Advance Research and Innovation (ICARI-2015).

The Air Compressor Test Rig is designed to study the characteristics of a Two-Stage Reciprocating Air Compressor and the compressed airflow through flow arrangement. This unit is self-contained and fully instrumented with mild steel frame-mounted on a raised foundation, with intercooler, Air stabilizing tank and air receivers. An AC Motor drives the compressor. To provide adequate cooling to the system, the function of the intercooler is supplied with Pressure and Temperature measuring instruments at the inlet and outlet. With the introduction of an intercooler, the volumetric efficiency has been increased to 100 %. To measure the airflow rate air stabilizing tank should stabilize the flow of air, which is mandatory in this work. The actual volume of free air delivered by this compressor is 0.020 m<sup>3</sup>/sec with a work done of 77 N-m was the result obtained during the test. Moreover, it was also found that the capacity to deliver air is about 1.02 kg/minute of the compressor when the isothermal efficiency of the compressor is 45 %. If an intercooler is specially designed, it has a capacity of 2.049 kilojoules/kg of heat rejection<sup>[2]</sup>.

3. Vijaykumar F Pipalia, Dipesh D. Shukla and Niraj C. Mehta, "Investigation on Reciprocating Air Compressors - A Review", International Journal of

Recent Scientific Research Vol. 6, Issue, 12, pp. 7735-7739, December 2015.

Heating is an undesirable effect of the compression process at least as far as compressors are concerned and heat transfer is nature's way of driving systems towards stability. This has not only provided food for thought for researchers trying to understand its influence and quantify its effects but also challenged designers to mitigate its impact and develop safe and efficient designs. Also, this investigation is concerned with improving the efficiency of Two- Stage Reciprocating Air Compressor by providing water cooling source, radiator coolant and ethylene glycol. The experiments with air, water and different inter coolants are performed on a Two-Stage Double Cylinder Reciprocating Compressor System<sup>[3]</sup>.

4. Suprasanna Rao Ravur, Subbareddy. E. V, "*Experimental Investigation to Increase the Efficiency of the Air Compressor by Changing the Coolants in Inter Cooler*", International Journal for Research in Applied Science & Engineering Technology Volume 3 Issue IX, September 2015.

The compressed air usage is increasing quickly nowadays. But the efficiency of the compressor is low due to many reasons like location, elevation, length of pipelines, intercooler performance, even atmospheric conditions also affects the efficiency of the compressor, which increases the power consumption of the compressor. Inter cooling is the best method to reduce coolant. In this study, we are extending the investigating by changing the temperature of the water and the mixing of different types of coolants in the water at different proportions. The selection of the coolants depends upon their properties like miscibility, self- ignition temperature, boiling point and exploding range. For this investigation ethylene glycol and glycerol as coolants and a two-stage reciprocating air compressor fitted with shell and tube type heat exchanger is selected. This investigation shows the good arguments between the water, glycerol and ethylene glycol<sup>[4]</sup>.

5. Kuldeep Tyagi & Er. Sanjeev Kumar, "*Improved Air Compression System*", International Journal of Scientific Engineering and Applied Science, Volume 1, Issue 5, August 2015.

Intercooling of Air Compressors is necessary for increasing its efficiency. A shell and tube type of heat exchanger is particularly suitable as an intercooler between two compression stages of a compressor. A characteristic of heat exchanger design is the

procedure of specifying a design, heat transfer area, pressure drops and checking whether the assumed design satisfies all requirements or not. The purpose of this research paper is to provide an easy and efficient way to design an intercooler for air compressor. This paper describes the modelling of the heat exchanger, which is based on the minimization of heat transfer area and a flow chart is provided showing the designing procedure involved<sup>[45]</sup>.

6. Wadbudhe R. C., Akshay Diware, Praful kale, "*A Research Paper on Improving Performance and Development of Two-Stage Reciprocating Air Compressor*", International Journal of Research In Science & Engineering, Volume: 3 Issue: 2 March- April 2017.

The Two-Stage Reciprocating Air Compressors is the most used type of compressor found in many industrial applications such as crucial machine in gas transmission pipelines, petrochemical plants, refineries, etc. Since there is a requirement of high- pressure ratio, a reciprocating air compressor is commonly used in locomotives. After a certain period, unexpected failures of internal components due to miscellaneous reasons occur, which inversely affects the performance of the operating system. It is essential to establish the recommended clearances mentioned for the various parts of the compressor. Compressor parts selection between repair and replacement is done based on Dimensional Measurement, which leads to easy maintenance in an economical point of view<sup>[6]</sup>.

7. Pawan Kumar Gupta<sup>1</sup>, S.P. Asthana<sup>2</sup>, Neha Gupta, "*A Study Based on Design of Air Compressor Intercooler*", International Journal of Research in aeronautical and Mechanical

Engineering, Vol.1 Issue.7, November 2013, Pages: 186-203 ISSN (ONLINE): 2321-3051.

This paper presents a study on which the main objective is intercooling of air compressor, which is necessary for an efficient process. Increase in pressure is a result of the reduction of a specified volume which is also known as compression. This paper mainly discusses the reciprocating compressor, which is widely used for air compression. Compression is done in more than one stage, and between each stage, the intercooler is provided to improve the efficiency of the system<sup>[7]</sup>.

8. Vishal P. Patil, Shridhar S. Jadhav, Nilesh D. Dhas, "*Performance and Analysis of Single Stage Reciprocating Air Compressor Test Rig*", SSRG International Journal of Mechanical Engineering, Volume 2, Issue 5, May 2015, ISSN: 2348 – 8360.

An experimental test rig has been built to test reciprocating compressors of different size and capacity. The compressors were tested with the help of air as a working fluid. The paper provides us with much-needed information regarding the efficiency of the compressors operating under the same conditions with the same system parameters. This paper also highlights reports on the investigation carried out on the effect of pressure ratio on indicated power, isothermal efficiency of both compressors. The result shows that the indicated power is increasing as the discharge pressure increases, but the isothermal efficiency of both the compressor is decreasing with increase in pressure ratio. Both compressor types exhibit the same general characteristics concerning system parameters. When the experiment was carried out for the constant angular speed of the compressor, no change in volumetric efficiency is observed. Besides, a comparative study was carried out for two compressors, and their differences were analyzed. To verify the model's goodness to predict the compressor performance, the study seems to be useful<sup>[8]</sup>.

### III. PROBLEM DEFINITION

The system under study is Industrial Air Compressor (Type: VT4). To investigate the applicability of the proposed compressor, the image of the Air Compressor (Type: VT4) is shown in the figure below:



Fig. 3: Air Compressor (Type VT4).

The figure shows Air Compressor Type VT4 is a Two Cylinder, Two Stage Reciprocating Air Compressor. The High-Pressure Cylinder is getting heated up and can be viewed with the naked eye that the High-Pressure Cylinder is becoming red when it is made to run for a longer period.

### IV. DESIGN CALCULATIONS AND ANALYSIS

The High-Pressure Cylinder is getting heated up due to improper working of the intercooler. Hence, the Temperature of the Intercooler is to be decreased.



By Gay-Lussac's Law which is also known as The Pressure Temperature Law states that "The Pressure of a given amount of gas held constant volume is directly proportional to the Kelvin Temperature." As the pressure goes up, the temperature goes up and vice versa.

$$\text{i.e. } P \propto T \text{ or } T \propto P$$

Hence, to decrease the Temperature of the Intercooler, its pressure is to be decreased.

As the formula of pressure says:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

To decrease the pressure, either force should be decreased, or area should be increased.

Let us consider the first case, i.e., force should be decreased.

To decrease the Force, Volume of Air should be decreased, and the Volume of Air can be decreased by reducing either Low-Pressure Cylinder Bore or Stroke of Piston.

1. To reduce the size of the Low-Pressure Cylinder Bore, the cylinder is to be replaced due to which the crankcase of the compressor needs to be modified. ... (a)
2. To reduce the Piston Stroke, the size of the connecting rod needs to be changed, which in turn results in changing of Crankshaft of the Compressor. ... (b)

Let us consider the second case, i.e., the area should be increased.

To increase the area on which the force is acting, the following parameters can be changed:

1. The diameter of tubes of intercooler can be increased, which in turn makes the existing Intercooler tubes waste for us. ... (c)
2. Length of Intercooler tubes can be increased, which in turn will result in a change of complete fitting of the intercooler. ... (d)
3. The number of tubes of the intercooler can be increased, which can be done easily by keeping the other parameters of compressor same. ... (e)

From Statements (a), (b), (c), (d) & (e), we can conclude that Statement (e) is the most cost-effective way to achieve the objective.

Hence, the objective of this dissertation is to modify the Intercooler "Shell and Tube" type for heat transfer between two stages of compression. Therefore, let us increase 2 Nos. of Tubes in each row.

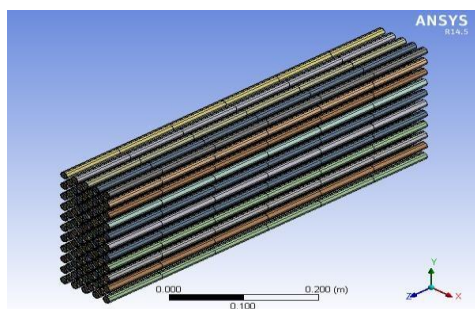
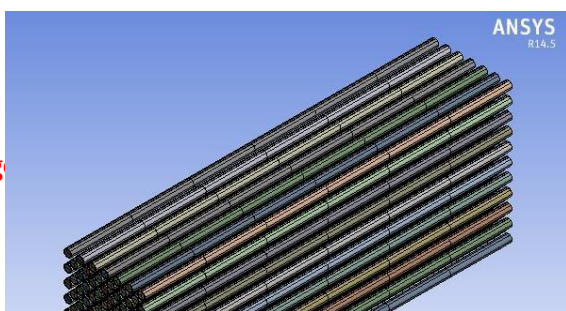


Fig. 4: Meshed Geometry of Existing Intercooler (Isometric View).



7. ID of Intercooler Tube,  $d_2 = 10.7 \text{ mm} = 0.0107 \text{ m}$

8.

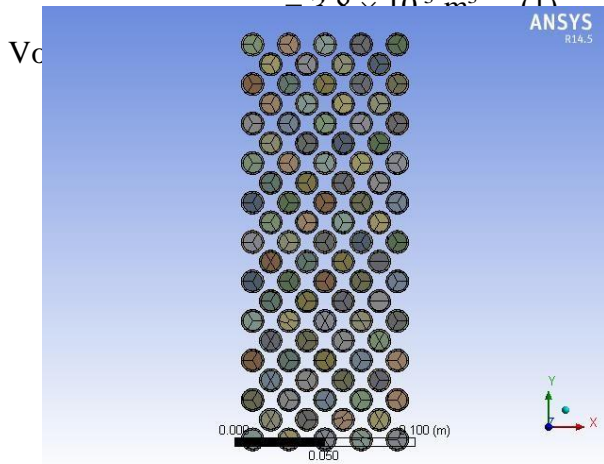
- Length of Each Tube,  $l = 600 \text{ mm} = 0.6 \text{ m}$
- 9. No. of Tubes in Existing Intercooler,  $N_e = 86 \text{ Nos.}$
- 10. No. of Tubes in Modified Intercooler,  $N_m = 124 \text{ Nos.}$
- 11. Inlet Temperature of Intercooler,  $T_I = 150^\circ\text{C} = 423 \text{ K}$ .  $T_{1e} = T_{1m} = T_I = 423 \text{ K}$

Now,  
Inlet Volume of Intercooler = Volume of LP Cylinder  
 $\therefore$  The Volume of LP Cylinder  $= \pi \times D^2 \times L$

Fig. 5: Meshed Geometry of Modified Intercooler(Isometric View).

Where,  $D =$  Cylinder bore  
 $L =$  Piston Stroke

$\therefore$  The Volume of LP Cylinder  $= \pi \times 0.22^2 \times 0.1$   
 $= 3.8 \times 10^{-3} \text{ m}^3$



nder

The volume of LP Cylinder for 1 sec = Volume of LP Cylinder  $\times$  No. of Strokes per sec  
 $= 3.8 \times 10^{-3} \text{ m}^3 \times 24.33$   
 $\therefore$  Volume of LP Cylinder for 1 sec  $= 92.45 \times 10^{-3} \text{ m}^3$  Now,

Fig. 6: Meshed Geometry of Existing Intercooler.

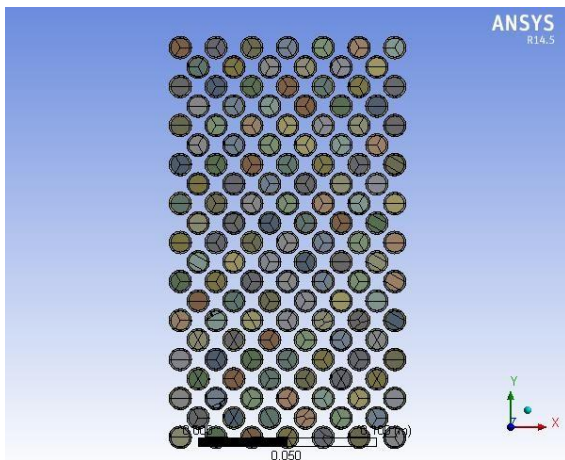


Fig. 7: Meshed Geometry of Modified Intercooler. Basic Data required for calculation are as follows:

1. Cylinder Bore LP,  $D_1 = 220 \text{ mm} = 0.22 \text{ m}$
2. Cylinder Bore HP,  $D_2 = 130 \text{ mm} = 0.13 \text{ m}$
3. Piston Stroke,  $L = 100 \text{ mm} = 0.1 \text{ m}$
4. No. of Strokes,  $N = 1460 \text{ per min} = 24.33 \text{ per sec}$
5. Density of Air,  $\rho_{air} = 1.225 \text{ kg/m}^3$

$$\text{Mass of Air} = \text{Volume of LP Cylinder for 1 sec} \times \text{Density of Air } (\rho_{air})$$

$$= 92.45 \times 10^{-3} \text{ m}^3 \times 1.225 \text{ kg/m}^3$$

$$\therefore \text{Mass of Air} = 0.1133 \text{ kg}$$

Now,

$$\text{The force of air} = \text{Mass of Air} \times \text{Gravity } (g)$$

$$= 0.1133 \times 9.81$$

$$\therefore \text{Force of Air} = 1.1115 \text{ N} \quad \dots(2)$$

Now,

$$\text{Surface Area of Existing} = \pi \times d_2 \times l \times N_e$$

Intercooler

$$= \pi \times 0.0107 \text{ m} \times 0.6 \text{ m} \times 86$$

$$\therefore \text{Surface Area of Existing Intercooler} = 1.74 \text{ m}^2 \dots(3)$$

Also,

$$\text{Surface Area of Modified} = \pi \times d_2 \times l \times N_m$$

Intercooler

$$= \pi \times 0.0107 \text{ m} \times 0.6 \text{ m} \times 124$$

$$\therefore \text{Surface Area of Modified Intercooler} = 2.5 \text{ m}^2 \dots(4)$$

Pressure in Existing Intercooler,  $P_e$

$$= \frac{\text{Force of Air}}{\text{Surface Area of Existing Intercooler}}$$

From Equation (2) & (3),

$$P_e = \frac{1.1115 \text{ N}}{1.74 \text{ m}^2}$$

$$6. \text{ OD of Intercooler Tube, } d_l = 12.7 \text{ mm} = 0.0127 \text{ m}$$

$$\therefore \text{Pressure in Existing Intercooler, } P_e = 0.64 \text{ N/m}^2 \dots(5)$$

Also,

$$\text{Pressure in Modified Intercooler, } P_m = \frac{\text{Force of Air}}{\text{Surface Area of Modified Intercooler}}$$

From Equation (5),  $P_{2e} = P_e = 0.64 \text{ N/m}^2$  The General Gas Equation becomes,

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{P_e V_e}{T_e} = \frac{P_m V_m}{T_m}$$

From Equation (2) & (4),

$$= \frac{1.1115 \text{ N}}{2.5 \text{ m}^2}$$

$$T_{2e} = 408.75 \text{ K} \quad \dots(12)$$

For Modified Intercooler, the General Gas Equation

$$\therefore \text{Pressure in Modified Intercooler, } P_m = 0.45 \text{ N/m}^2 \dots(6)$$

Here,

From Equation (5) & (6),

will be,

$$P_1 m = P_2 m$$



$$T_{1m} \quad T_{2m}$$

$$\text{Percentage of Decrease in Pressure} = \frac{P_e - P_m}{P_e} \times 100$$

$$= \frac{0.64 - 0.45}{0.64} \times 100$$

From Equation (6),  $P_2 = P_m = 0.45 \text{ N/m}^2$  The General Gas Equation becomes,

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$= 0.64$$

$$\therefore \text{Percentage of Decrease in Pressure} = 29.69 \% \quad \dots(7)$$

$$T_{2m} = 287.41 \text{ K} \quad \dots(13)$$

We know that the General Gas Equation is as follows:

$$\text{From Equation (12) \& (13),} \quad \text{Percentage of Decrease in Temperature} = \frac{T_2 - T_{2m}}{T_2} \times 100$$

$$= \frac{408.75 - 287.41}{408.75} \times 100$$

Let us consider the Gas for One Stroke of Piston by  
 $= 408.75 - 287.41$

keeping the volume constant, i.e.  $V_1 = V_2$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Hence, the above equation becomes,

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\therefore \text{Percentage of Decrease in Temperature} = 29.69 \% \quad \dots(14)$$

Let,  $P_1$  = Pressure in LP Cylinder  
 $T_1$  = Temperature in LP Cylinder

From Equation (7) & (14),

$$\text{Percentage of Decrease in Pressure} = \text{Percentage of Decrease in Temperature}$$

$T_2$  = Temperature in Intercooler  
 in pressure  
 in temperature

From Equation (1), For One Stroke of Piston Volume of LP Cylinder =  $3.8 \times 10^{-3} \text{ m}^3$

Mass of Air = Volume of LP Cylinder for One sec  $\times$  Density of Air ( $\rho_{air}$ )

$$= 3.8 \times 10^{-3} \text{ m}^3 \times 1.225 \text{ kg/m}^3$$

$$\therefore \text{Mass of Air} = 4.655 \times 10^{-3} \text{ kg}$$

$$\dots(8)$$

Now,

Force of Air = Mass of Air  $\times$  Gravity ( $g$ )

$$= 4.655 \times 10^{-3} \times 9.81$$

$$\therefore \text{Force of Air} = 0.0457 \text{ N}$$

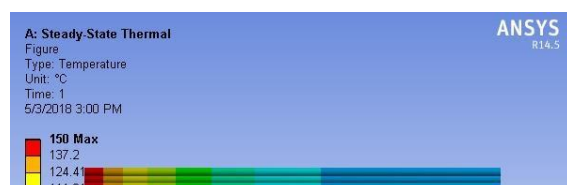
$$\dots(9)$$

Hence, Gay-Lussac's Law is proved which is also known as The Pressure Temperature Law, which states that "The Pressure of a given amount of gas held constant volume is directly proportional to the Kelvin Temperature." As the pressure goes up, the temperature goes up and vice versa.

$$\text{i.e. } P \propto T \text{ or } T \propto P$$

In this case, When the Pressure of Intercooler is decreased; the temperature of the intercooler is decreased.

Now, let us have a look at the Analysis part of dissertation:



Now,  
Surface Area of LP Cylinder =  $\pi \times D_l \times L$   
 $= \pi \times 0.22 \text{ m} \times 0.1 \text{ m}$   
 $\therefore$  Surface Area of LP Cylinder =  $0.069 \text{ m}^2$   
 ... (10)

Now,  
Pressure in LP Cylinder =  $\frac{\text{Force of Air}}{\text{Surface Area of LP Cylinder}}$   
 $= \frac{0.0457}{0.069}$

$\therefore$  Pressure in LP Cylinder =  $0.6623 \text{ N/m}^2$   
 $\therefore P_{1e}$   
 $= P_{1m}$   
 $= 0.6623 \text{ N/m}^2$   
 ... (11)

For Existing Intercooler, the General Gas Equation will be,

$$P_{1e} = P_{2e}$$

Fig.8: Temperature Distribution Result in Existing Intercooler  
 $T_{1e}$   $T_{2e}$

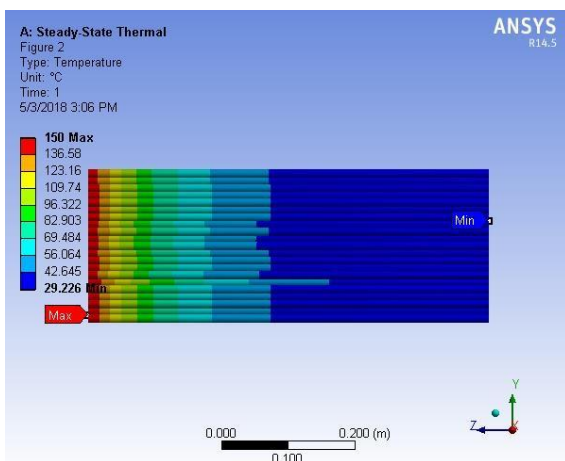


Fig. 9: Temperature Distribution Result in Modified Intercooler

Here,

From Figure 8 & 9,

Percentage of Decrease in Temperature =  $\frac{T_e - T_m}{T_m} \times 100$   
 $= \frac{34.84 - 29.226}{29.226} \times 100$

$T_e$   
34.84

$\therefore$  Percentage of Decrease in Temperature = 16 %  
 ... (15)

From Equation (7), (14) & (15),

When the Pressure of Intercooler is decreased by 29.69%, the temperature is decreased by 16%. The change in temperature values is due to actual ambient conditions.

## V. CONCLUSION

Several intercooling procedures are used in a two-stage reciprocating air compressor, and it can be inferred that the more the intercooling surface area, the greater the air temperature drop, which directly increases the air compressor's efficiency. A conclusion that can be drawn from all the intercooling process data is that radiator intercooling with a larger intercooler produces better volumetric efficiency than another type of intercooling. When prices for various factors are taken into account during the operation of a two-stage reciprocating air compressor, it's probable that the approach we utilised will help to increase overall efficiency.

In this essay, we investigated the two stage reciprocating air compressor and intercooler, one of its key parts employed in an air compression system. Also, we used very straightforward and quick techniques to construct the intercooler for the air compressor.

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