Design and Analysis of Ejector for ERS

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Abstract— In conventional refrigeration system we use compressor for compressing the refrigerant gas coming out of evaporator by using the electric energy. But due to Increase in pressure and Temperature it may cause compressor to overheat and fail. Also, the electrical failure includes imbalances in the voltage or current, results in overheating and failure of Compressor. Also, the compressor produces a hissing or creaming noise. So here introduces an Ejector Refrigeration system which uses the ejector in place of compressor. Ejector is main part of ERS which use to increase pressure without any moving part. So, the improved system performance will reduce energy consumption. Refrigerant for the ERS is the first selection criteria. The ejector is most important part of Ejector Refrigeration system .so designing of Ejector is the main work in Ejector refrigeration System.

Keywords: Design of Ejector, Analysis of ejector, ERS, Ejector refrigeration

I. Introduction

Ejector Refrigeration System as name indicated that it uses the ejector as the main replacement for the compressor refers to conventional refrigeration systems. Ejector Refrigeration system is heated driven process, it use low grade heat as power source for refrigeration systems. Waste process heat and waste steam is common in industry and it is used for heating, cleaning and absorption cooling cycles along with other uses. Ejector is the critical component of the Ejector Refrigeration Systems. So Design of ejector play an important role in ERS. Ejector has less moving parts compare to the compressor. An ejector is a device in which a high-velocity jet of fluid mixes with a second fluid stream. The mixture is discharged into a region at a pressure higher than the source of the second fluid .So there will less wear of components. ERS help in reduction in Global warming and Greenhouse Effect Emission., So now days we using Natural Refrigerant such as carbon dioxide, air, water and ammonia, have been used as Refrigerants in cooling systems.

II. Problem statement

In conventional refrigeration system we use compressor for compressing the refrigerant gas coming out of evaporator by using the electric energy.

But due to Increase in pressure and Temperature it may cause compressor to overheat and fail. Also the electrical failure includes imbalances in the voltage or current, results in overheating and failure of Compressor. Also the compressor produces a hissing or screaming noise.

III. Objective

So to overcome these problems of compressor in conventional refrigerators, here introduces an Ejector Refrigeration system, which uses the ejector in place of Compressor. Ejector is main component of ERS which use to increase pressure without any moving part. Their greatest advantage is their capability to produce refrigeration using waste heat, so the improved system performance will reduce energy consumption as well as reduce CO2 emissions.

Initially it's needed to select the refrigerator for the ERS based on the selection criteria's. The ejector is most important part of ERS. so designing of Ejector is the main work of our project. After designing geometry of ejector, the next work is to design condenser, evaporator, expansion valve, and boiler/generator

IV. Methodology

For ERS which will be readily available in market. After designing all this parts next work is to design the piping system to transport refrigerant through various parts of ERS. After that have to assemble all the parts in a proper sequence. And also we are going to do the CFD analysis of it. After completion we have to do testing of it. so as to achieve the required result.

V. Working of ejector refrigeration system.

A. Refrigerant

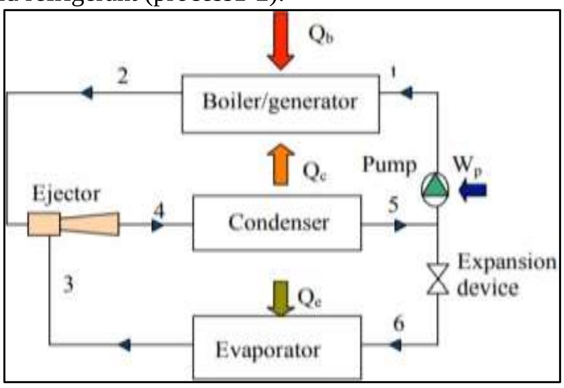
In Refrigeration Systems fluid use for cooling the cabinet or room is Refrigerant. Refrigerant is the main criteria to design the ejectors, On the basis of refrigerant the pressure, temperature are selected for design of ejector.

Here are some of Natural Refrigerant listed below.

1) Ammonia NH3 R-717:–It is highly toxic refrigerant, It use for home refrigerant.
2) Carbon Dioxide CO2 R-744:– Mainly used in the automotive industry
3) Propane CH3CH2CH3 R-290:-It is Highly Flammable Hydrocarbon.
4) Isobutene 3CH (CH3) CH3:- It is also Flammable Hydrocarbon.

B. Working of ERS

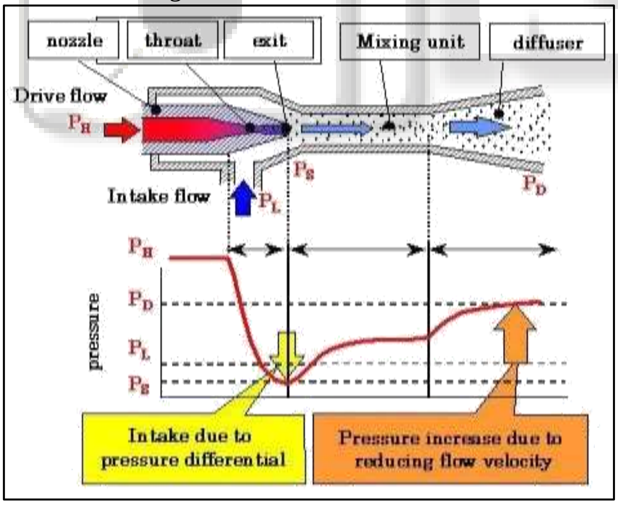
Given above the schematic diagram of the basic ejector refrigeration cycle in Figure 1, the system is divided in the two loops; the first loop is power loop and second is the refrigeration loop. As the power loop is, low-grade heat, Qb, is used in a boiler or generator to evaporate high pressure liquid refrigerant (process1-2).



The high pressure vapour is formed in boiler or generator, known as the primary fluid, flows through the ejector where it accelerates through the nozzle. In nozzles reduction in pressure and increase in velocity & there is small amount of temperature drop that occurs induces vapor from the evaporator, known as the secondary fluid, at point 3. This two fluids mix in the mixing chamber , In mixing there is large amount of temperature drop occur and pressure is regain again before entering the diffuser section where the flow decelerates and pressure recovery occurs to condenser pressure. The mixed fluid is further flows to the condenser section where it is condensed rejecting heat to the environment, Qc. A portion of the liquid exiting the condenser at point 5 is then pumped to the boiler for the completion of the power cycle. The remainder of the liquid is expanded through an expansion device where it drop the pressure to evaporator level and enters the evaporator of the refrigeration loop at point 6 as a mixture of liquid and vapor. The refrigerant evaporates in the evaporator producing a refrigeration effect, Qe, and the resulting vapor is then drawn into the ejector at point 3. The refrigerant (secondary fluid) mixes with the primary fluid in the ejector and is compressed in the diffuser section before entering the condenser at point 4.The mixed fluid condenses in the condenser and exits at point 5 And thus repetition of the refrigeration cycle goon.

C. Ejectors

An ejector may be used as a fluid-driven compressor in a refrigeration system. The motive fluid can be heated up in a generator, where it boils at constant pressure. The entrained fluid is vaporized at low pressure in an evaporator, in order to extract the cooling load from a cold source.



As Shown in diagram Ejector is has following parts.

1) Nozzles
2) Suction Head
3) Converging Part
4) Throat or mixing Chamber
5) Diverging Part

VI. Computational Fluid Dynamics (CFD)

It is the analysis of systems involving fluid flow, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation. The technique is very powerful and spans a wide range of industrial and non-industrial application areas.

CFD codes are structured around the numerical algorithms that can tackle fluid flow problems. In order to provide easy access to their solving power all commercial CFD packages include sophisticated user interfaces to input problem parameters and to examine the results. Hence all codes contain three main elements:

– a pre-processor,
– a solver and
– a post-processor.

VII. Problem Solving with CFD

In solving fluid flow problems we need to be aware that the underlying physics is complex and the results generated by a CFD code are at best as good as the physics (and chemistry) embedded in it and at worst as good assist operator. Elaborating on the latter issue first, the user of a code must have skills in a number of areas. Prior to setting up and running a CFD simulation there is a stage of identification and formulation of the flow problem inters of the physical and chemical phenomena that need to be considered. Typical decisions that might be needed are whether to model a problem in two or three dimensions, to exclude the effects of ambient temperature or pressure variations on the density of an air flow, to choose to solve the turbulent flow equations or to neglect the effects of small air bubbles dissolved in tap water. To make the right choices requires good modelling skills, because in all but the simplest problems we need to make assumptions to reduce the complexity to a manageable level whilst preserving the salient features of the problem at hand.

Overall conservation of the flow properties – are very small. Progress towards converged solution can be greatly assisted by careful selection of the settings of various relaxation factors and acceleration devices.

Every numerical algorithm has its own characteristic error patterns. Well known CFD euphemisms for the word ‘error’ are terms such as numerical diffusion, false diffusion or even numerical flow.

Validation of a CFD code requires highly detailed information concerning the boundary conditions of a problem, and generates a large volume of results.

CFD computation involves the creation of a set of numbers that (hopefully) constitutes a realistic approximation of a real-life system. One of the advantages of CFD is that the user has an almost unlimited choice of the level of detail of the results, but in the prescient words of C.

VIII. Implementation of Boundary Conditions

All CFD problems are defined in terms of initial and boundary conditions. It is important that the user specifies these correctly and understands their role in the numerical algorithm. In transient problems the initial values of all the flow variables need to be specified at all solution points in the flow domain. Since this involves no special measures other than initializing the appropriate data arrays in the CFD code, we do not need to discuss this topic further.

IX. Design of ERS

A. Material Selection

1) Basically for maximum heat transfer two, Copper is more effective than other material because of its Strength and High heat capability.
2) Thickness of hot fluid having more temperature and pressure so decide it's the thickness (tw) from standard valve

B. Design of Nozzle

- First of all we have to decide approx. Pressure for our system.
- So let us consider
- Evaporator Pressure- 4Bar
- Boiler Pressure– 35Bar
- Evaporator Temperature- 10℃
- Boiler Temperature– 95℃

1) *Throat Design*

- Gamma ("γ")=Cp/Cv=1.94
- Cp = 2.74 & Cy=1.41 for Ammonia
- Throat Area
- $A_t = W_t / P_t * \sqrt{RTt/\gamma gc}$
- Wt = flow rate through boiler to entry nozzles is 0.01030kg/s
- Pt = Pressure at throat , so we have to match the primary vapor pressure with secondary pressure ,i.ept=1bar
- T_t –Temperature of throat is given by Formula
- $T_t = T_c * [\frac{1}{1+\frac{\gamma-1}{2}}]$
- Tt=54°C from above Formula
- After Calculation At=83.667mm2.
- Diameter of Throat dt = (4*At/π) ^1/2.
- Diameter of Throat By calculation-10mm

2) *Inlet Design*

- From the study it is found that the inlet diameter of nozzles should be 3-5 Times of Nozzle Throat, so the ejector will have usable face.
- Dc=Inlet Diameter of nozzle.=3*Dt
- Dc=30mm.
- Area Ac=π*dc^2/4
- Ac=706.85mm^2.

3) *Exit Design*

- Me-Mass flow rate at Exit is given below Formula $(M_e)^2 = \frac{2}{\gamma-1} * [(\frac{Pc}{Patm})^{\frac{\gamma-1}{\gamma}} - 1]$
- $(M_e)^2$ =7.99kg/s therefore Me=2.82
- Ae=Area Exit of Nozzle is given Below Formula $A_e = \frac{At}{Me} * [\frac{1+\frac{\gamma-1}{2}*(Me)^2}{(\gamma+1)/2}]^{\frac{\gamma+1}{2(\gamma-1)}}$
- A_e=186.054mm^2.
- So Now we find the diameter of Exit part, Formula is
- De= (4*Ae/π)^1/2.
- De=16mm.

4) *Angle and Length.*

- Alpha (α) =The Nozzle angle Divergence half angle is α<15degree.
- Beta (β) = The Nozzle convergence half angle is β=60degree.
- V_c=volume of inlet Chamber=1.1*Ac*l_c
- V_c=38876.75mm^3
- L_c=50mm

5) *Efficient of working of nozzle.*

- There are Some Parameter Has to be followed to increase the efficiency of Systems
- Suction Head Should be mounted on the Top Part.
- Pressure at Primary Nozzle exit should be less than the Evaporator Pressure.
- Reduced the Back pressure of vapor.

6) *Dimension of Nozzle*

- Dc=Inlet Diameter of Nozzle=10mm
- Dt=Throat Diameter =2.4mm.De=Exit
- Diameter of Nozzle=4mm.
- Alpha (α) <10degree.
- Beta (β) = 60degree.

C. Design of Ejector:

1) *Throat Design*

- Gamma ("γ")=Cp/Cv=1.94
- Cp=2.74 & Cv=1.41 for Ammonia
- Throat Area
- $A_t = W_t / P_t * \sqrt{RTt/\gamma gc}$
- Wt=flow rate through boiler to entry of Ejector which combination of primary and secondary flow
- is 0.01030kg/s
- Pt=Pressure at throat , so we have to match the primary vapor pressure with secondary pressure ,i.e. Pt=pt + ps=1.5 bar
- Tt –Temperature of throat is given by Formula
- $T_t = T_c * [\frac{1}{1+\frac{\gamma-1}{2}}]$
- Tt=54 ℃ from above Formula
- After Calculation At=254.46 mm^2.
- Diameter of Throat dt = (4*At/π)^1/2.
- Diameter of Throat By calculation-18 mm.

2) *Converging Part Design*

- From the study it is found that the inlet diameter of Ejector should be 2.5-5 Times of Ejector Throat.
- Di=Inlet Diameter of Ejector.=2.5*Dt
- Di=45mm.
- Area Ai=π*di^2/4
- Ai=1590.4312 mm^2.

3) *Diffuser Design*

- Me-Mass flow rate at Exit is given below Formula
- $(M_e)^2 = \frac{2}{\gamma-1} * [(\frac{Pc}{Patm})^{\frac{\gamma-1}{\gamma}} - 1]$
- Me^2=7.99kg/s therefore Me=2.82
- Ae=Area Exit of Nozzle is given Below Formula
- $A_e = \frac{At}{Me} * [\frac{1+\frac{\gamma-1}{2}*(Me)^2}{(\gamma+1)/2}]^{\frac{\gamma+1}{2(\gamma-1)}}$
- Ae=Ad=1590.4321mm^2.
- So Now we find the diameter of diffuser part ,Formula is
- De= (4*Ad/π)^1/2.
- Dd= 45mm.

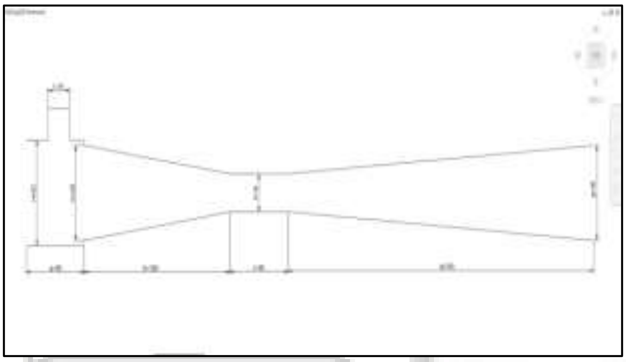
D. Main Head Diameter

- The main Diameter is where the primary nozzle and secondary flow is present
- The Main Diameter of Ejector Dm= 50 mm
- Area of Main Head Am=1963.49 mm^2.

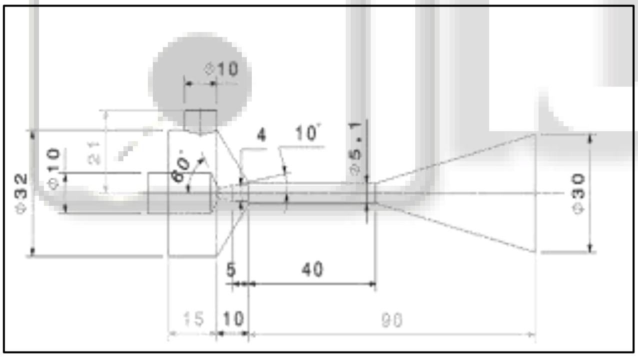
E. Secondary Inlet Port Diameter.

- The Secondary inlet diameter is which come from the Evaporator.
- So the diameter of the secondary inlet port is equal to pipe diameter
- Therefore Ds=15 mm.
- Area of Secondary port As=176.71 mm^2.

X. DESIGN MODEL OF EJECTOR ON CAD

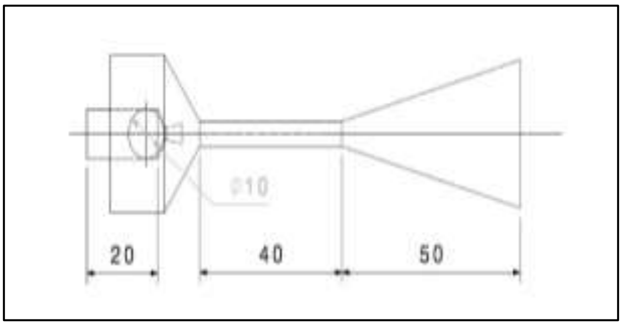


A. Optimum Design of Ejector Model CAD Diagram.

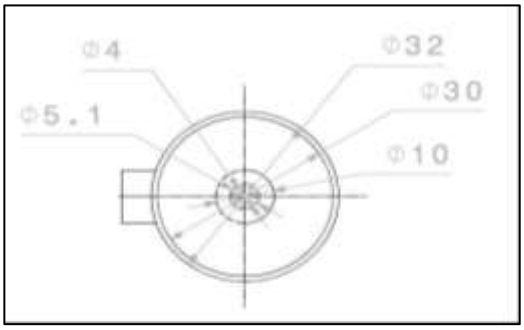


- Di =Inlet Diameter of Ejector =32mm, Length is Li= 20mm
- Dt=Throat Diameter =5.1mm, Length is Lt=40 mm.
- Dd=Exit Diameter of Ejector =30mm, Length is LD=50mm.
- Secondary Inlet Port Diameter Ds= 10mm.

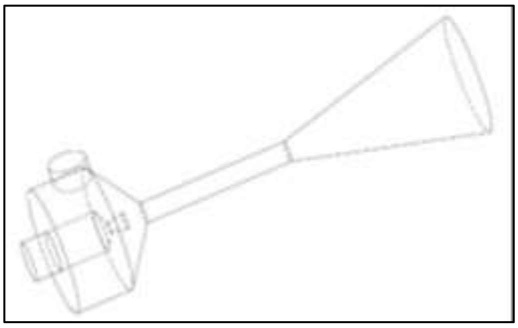
B. CAD Drawing Top View.



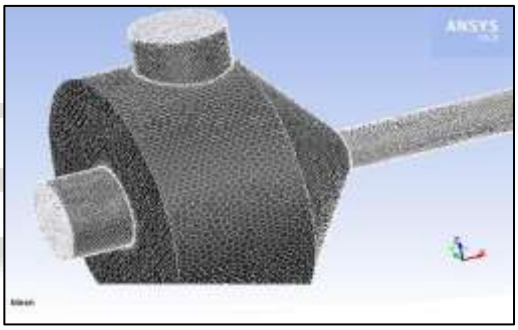
C. Side View of Model



D. Isometric View of model.



E. Meshing



1) Boundary Condition For Model:

- Pressure

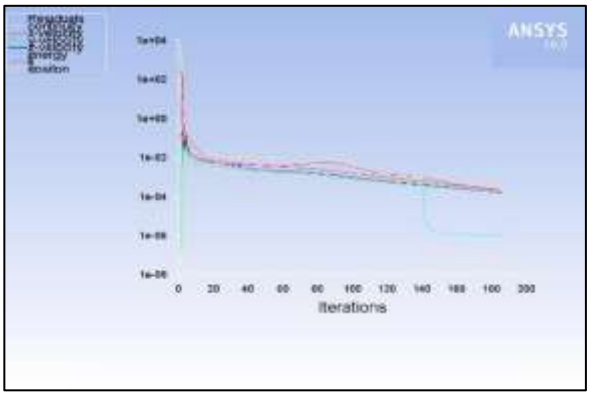
1) Inlet 2- 35 Bar.
2) Inlet 1- 4 Bar.

- Temperature

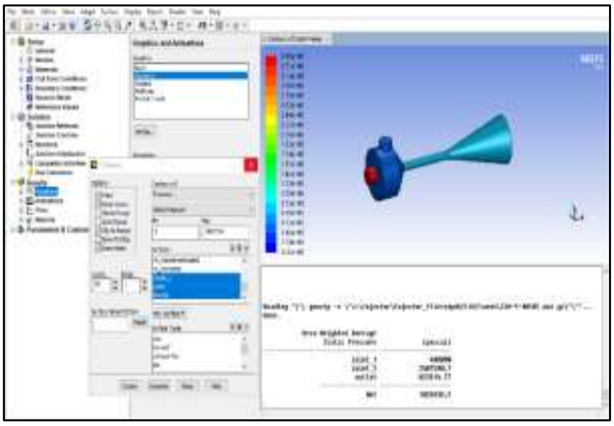
1) Inlet 1- 10℃.
2) Inlet 2- 95℃.

XI. RESULTS

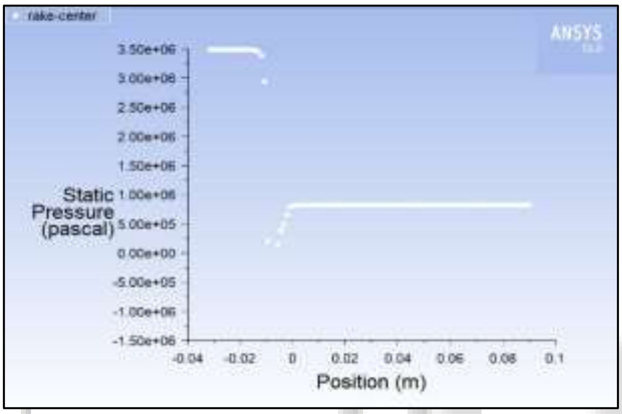
A. Iteration Graph



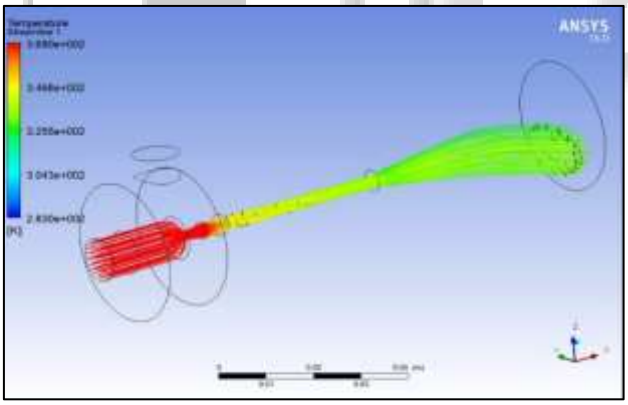
B. Pressure Static Report



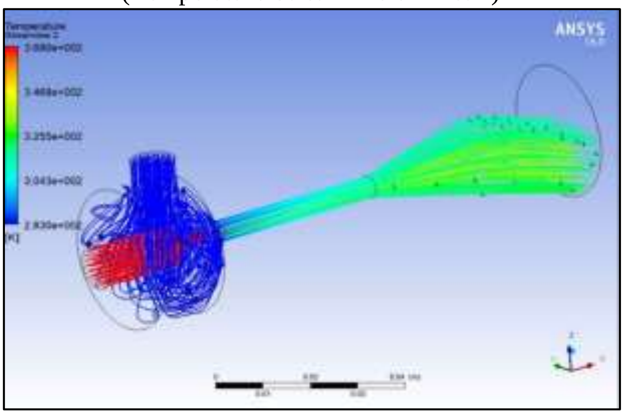
C. Pressure Graph with Rake Center



D. Temperature Results

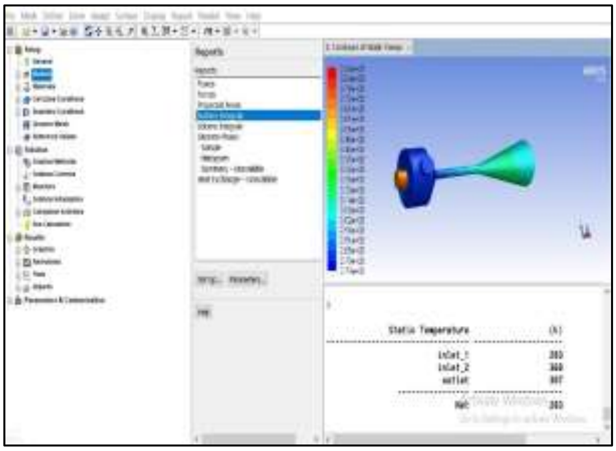


(Temperature Streamline of inlet 2)

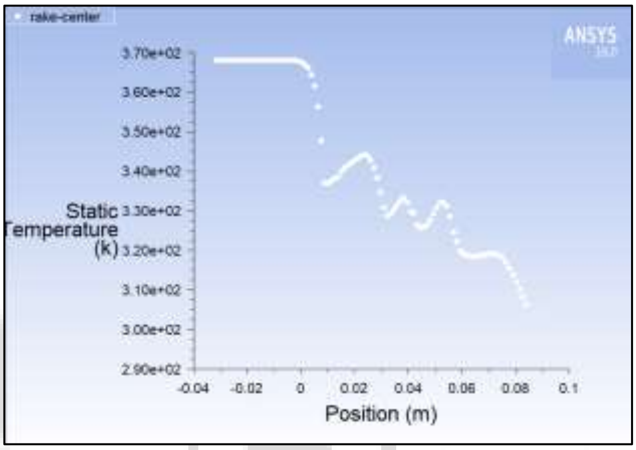


(Temperature Streamline of Both combined inlet.)

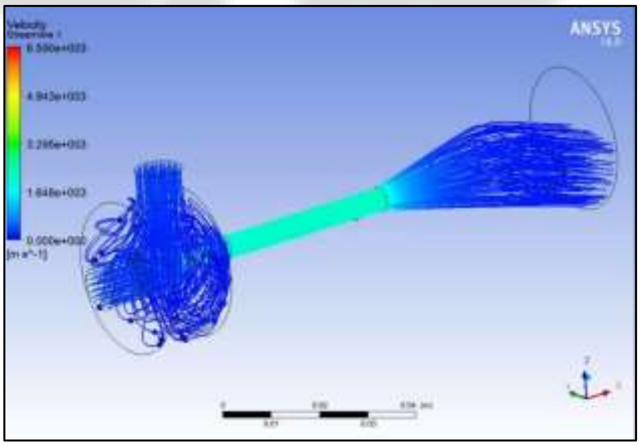
E. Temperature Surface Integral Report



F. Temperature Graph using Rake Line in Center



G. Velocity Results



XII. CONCLUSION

ERS is a promising technology for producing a cooling effect by using low-grade energy sources with different working fluids. Ejector technology, refrigerant properties and their influence over the ejector performance, the main jet refrigeration cycles.

Environmental friendly halocarbons, hydrocarbons, natural refrigerants (R717, R744) and HFC/HFO mixtures will be increasingly employed for their low ODP and GWP values. As the most economically and environmental friendly

The geometry of the ejector plays a vital role in improving the COP of the refrigeration system. Depending on the application, there exists an optimum mixing chamber length and convergence angle. Critical back pressure can be varied by adjusting primary and secondary fluid pressure as well as nozzle size. Increase in generator and condenser temperature increases entrainment ratio. Optimizing nozzle geometry (throat diameter) strongly influences the ejector performance.

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