XVII International Conference on Recent"Trends in Engineering, Applied Science and Management"

(IETE) Institution of Electronics and Telecommunication Engineers,Chandigarh TEAM-18

24th June 2018 www.conferenceworld.in ISBN: 978-93-87793-31-6

A Study and Analysis of an Ejector in Steam Power Plant

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ABSTRACT

Now a day's Energy consumption is very important for our future. This paper discusses about the use of Ejector in steam power plant to save the heat. The effect of process parameter on vacuum is calculated. From this investigation it is found that the vacuum continue produces to easily maintainedS. It was observed that the water is smoothly flow in pipe line to followed the path.

Keyword- Ejector, Nozzle, Steam, Vacuum

1. INTRODUCTION

Two important area of application of thermodynamics are power generation and refrigeration. Both power generation and refrigeration are usually accomplished by a system that operates on a thermodynamics cycle.

Thermodynamics cycles can be divided into two generation categories:

- Power Cycles
- Refrigeration Cycles

The devices or systems used to produce a net power output are often called engines and the thermodynamics cycles they operate on are called power cycle.

The devices or systems use to produce refrigeration are called refrigerator, air conditioners or heat pumps and the cycles they operates on are called refrigeration cycles.

Thermodynamic cycles can be categorized as :

(a) Power cycles or Refrigeration cycles.

(b) **Gas Cycles or Vaporr Cycles :** In gas cycles, the working fluid remains in the gaseous phase throughout the entire cycle, whereas in vapor cycles the working fluid exists in the vapor phase during one part of the cycle and in the liquid phase during another part.

Closed Cycles or Open Cycles : In closed cycles, the working fluid is returned to the initial state at the end of the cycle and is re-circulated. In open cycle, the

1.1 Ejector

Steam-Jet Ejectors are pumping devices used in general to evacuate fluids from one process step and deliver them to another. A simple example is the removal of air from a closed vessel and discharging it to the atmosphere. The theory behind the Steam Jet Ejector involves converting high-pressure motive steam into a high velocity jet in a converging diverging nozzle. Steam jet Ejectors are based on the ejector-venturi principal and operate by passing motive steam through an expanding nozzle. The nozzle provides controlled expansion of the motive steam to convert pressure in to velocity which creates a vacuum with in the body chamber to draw in and entrain gases or vapours. The motive steam and suction gas are then completely mixed and then passed through the diffuser or tail, where the gases velocity is converted in to sufficient pressure to meet the predetermined discharge pressure. Gas and vapour molecules surrounding the high velocity jet are entrained, or swept up, under the principle of viscous drag. The continuous entrainment of molecules near jet, and the jet itself drives the pumping effect and creates the vacuum. Further down past the nozzle tip the two constituents (motive steam and suction load) are mixed violently in the converging section of the venture and recompressed in the straight and diverging section. Upon discharge the stream is at an intermediate pressure higher than the inlet 'suction' pressure but lower than the motive steam pressure and traveling at a velocity much lower than that of the jet. In order to obtain lower absolute pressure for a given load, higher jet velocities (meaning more steam and thus large components) are required. Eventually, as the required vacuum level deepens, the single stage Ejector becomes too large and uses too much steam to be economically attractive. For this reason, Ejector Systems are split into stages (Y & Z) and combined with inter and after condensers, with each Ejector Stage covering a given range of pressures and the Interco denser reducing the load to the next Ejector. The ultimate objective is to pump a given load from the required suction pressure to the required discharge pressure using. Two ejector Stages are normally required where the absolute pressure to be maintained is less than 75 torr (75mm Hg (abs)) and above 15 torr. The stages are designated as Y & Z with the Z discharging to the highest pressure, usually to atmosphere through after condenser. The surface condensers drain the condensate either through barometric drain legs of sufficient height to overcome atmospheric pressure or through properly sized steam powered condensate pumps.

Normally, in case of condensing Turbine Application, condensate of the Inter condenser and after condenser is sent back to Turbine condenser hot well via U Loop or through vacuum condensate trap.

Vacuum Ejectors are used in a variety of applications in the process, food, steel and petrochemical industries. Typical duties involve filtration, distillation, absorption, mixing, vacuum packaging, freeze drying, dehydrating and degassing. Ejectors will handle both condensable and none condensable gas loads as well as small amounts of solids or liquids, however accidental entrainment of liquids can cause a momentary interruption in vacuum but this will not cause damage to the ejector.

Type of Ejectors

2.1 On basis of the motive fluid:

2.1.1 Liquid Jet Ejectors

In a liquid Jet Ejector, the motive fluid is a non-compressible liquid (generally water) with no heat energy hence with a single stage centrifugal pump we cannot increase its pressure much.

As a result motive fluid velocity at the nozzle tip is very less and it affects its non-condensable load handling capacity drastically

2.1.2 Steam Jet Ejectors

In a steam jet Ejector, the motive fluid is a jet of high pressure and low velocity compressible steam which exists from the nozzle at the designed suction pressure and supersonic velocity thus entraining the vapor in to the suction chamber. Due to the supersonic velocity of the steam at the tip of the nozzle, its non-condensable load handling capacity is much higher than liquid jet ejectors from the nozzle at the designed suction pressure and supersonic velocity thus entraining the vapour in to the suction chamber. Due to the supersonic velocity of the steam at the tip of the nozzle, its non-condensable load handling capacity is much higher than liquid jet ejectors

2.1.3 Combination of Both

In this type of ejector system, both Liquid jet and Steam jet Ejectors are employed simultaneously to produce low absolute pressure. The suction of Liquid Jet Ejector is connected to the discharge of last stage of the steam jet ejector.

2.2 On basis of number of nozzles

Single Nozzle Ejector:

The uniqueness of Shail Vac's multiple nozzle ejector is in its design and performance. A multiple nozzle ejector usually has one nozzle on centre while remaining of the nozzles equally spaced peripherally around it. In most of the cases, multi nozzle ejectors designed for the same conditions usually reduce steam consumption by 10% to 15% as compared to Single Nozzle Ejector.

- The advantage of multiple nozzle ejectors is its much higher efficiency compared to single nozzle ejectors.It is also considerably shorter in length than an equally rated single nozzle ejector.

2.2.2 Steam Jet Vacuum Systems:

Ejectors range from Single upto Six Stage units, and can be either Condensing or Non-Condensing types. The number of Ejector stages required are usually determined by the economy of the ejectors and the level of vacuum required. The operating range for each stage of Vacuum Ejector can be seen below, also for reference 1 BarA = 760 mm HgA.

1st Stage : 10mm HgA - 30mm HgA
2nd Stage : 130mm HgA - 3 mm HgA
3rd Stage : 25mm HgA - 0.8mm HgA
4th Stage : 4mm HgA - 75 microns HgA
5th Stage : 0.4mm HgA - 10 microns HgA
6th Stage : 0.1mm HgA - 3 microns HgA

ISBN: 978-93-87793-31-6

4.1 Identified Problem

If the desired vacuum is not obtained, it is probably due to one of the following causes:

4.1.1 Low Steam Pressure: - An Ejector will operate with a higher than specified steam pressure but not with a lower pressure. Therefore, never operate the system below the minimum motive steam pressure specified in the data sheet / P & ID. Excessive superheat will have save effect as low pressure.

4.1.2 High Back Pressure: - If a stage has a higher back pressure than it was designed for (see the system data sheet), aq loss in vacuum will result. Check for restrictions or obstructions in the exhaust lines, such as accumulate condensate. Also check water flow and temperatures.

4.1.3 Excessive Air Leakage: - Inspect the assembly for opening split pipes, missing gaskets, leaky valves, etc. Hydro-test with water to locate leaks, Make sure that the drain lines are sealed in the condensate loop. An air leak will tend to overload the inter and after Condensers creating a high back pressure condition.

4.1.4 Malfunctioning of condensate traps: Confirm that the condensate trap provided at the bottom of the after condenser is functioning properly. Please ensure that the traps are designed to operate under vacuum and preferably of Thermodynamic type.

4.1.5 Air Blockage: Remove air from the channel shell of inter and after condensers by crack opening the valves provided on top of channel shell.

4.1.6 Clogged Steam Nozzles: - Clogged steam nozzles with a new installation, pipe scale or dirt from the steam lines can clog the EVACUATOR steam nozzles, even when a strainer is use. Remove the nozzles for inspection and clean thoroughly with emery cloth, particularly the orifices. Note that additives to the boiler water have been known to clog nozzles. The deposits collect on the nozzle walls, and can be easily missed during inspection.

4.2 Maintenance:

Vacuum equipment maintenance is relatively straight forward, but can vastly improve reliability and performance if approached systematically. Some users get by with swapping out parts in periods of dire emergency: performance slowly erodes over a period of time and nothing is done until the unit ceases to effectively operate altogether. At that point spare parts are installed to correct the problem, (if the problem is in fact known and the correct spare parts are in the plan’s inventory), and the unit is returned to service. The period of degraded performance leading up to failure and the downtime itself, however, can result in higher operating costs from longer cycle times, increased steam usage and production outages. For this reason, a systematic preventative maintenance (PM) program is highly recommended.

An effective PM program begins with documentation. Serial numbers, parts lists, performance curves, operating histories and maintenance procedures should be kept up to date by the maintenance or engineering departments for quick reference.

An effective PM program also included periodic inspection and tests, yearly shut downs are perfect opportunities to perform such tests, but an Ejector or barometric Condenser can be disassembled in minutes for a thorough visual inspection. A typical PM procedure should include the following:

- Disassemble and inspect gaskets for evidence of leaks.
- Check for and document regions of corrosion and wear.
- Check nozzle bores and throat diameters against original specifications.
- Clean all internal surfaces (nozzles, heads, throats, diffusers) thoroughly.
- Reassemble with new gaskets and required spare parts, avoiding misalignment of the components.
- Blow down steam strainers and inspect traps.
- Record what spare parts were taken from inventory and order replacements.
- Inspect the condensers for evidence of fouling and corrosion and clean thoroughly.
- Calibrate the vacuum, pressure and temperature gauges and replace if necessary.
- Test the unit in-line against the performance curve with either a blanked suction or Piccolo Tube.
- Always use calibrated vacuum gauges or mercury manometers and use the correction factor for the barometric pressure prevailing at site.

A properly stocked inventory of spare parts in necessary regardless of the extent of the PM program. At least on nozzle for each ejector stage should be kept in stock.

5. Experimental

Steam-jet vacuum systems combine ejectors, condensers and interconnecting piping to provide relatively low-cost and low-maintenance vacuum pumping. These systems operate on the ejector-venturi principle, which relies on the momentum of a high-velocity jet of steam to move air and other gases from a connecting pipe or vessel.

During system design, critical decisions must be made regarding process conditions, component orientation and layout. A reliable source of steam and cooling water must be available, and provisions must be made to carry out condensate removal under vacuum. Finally, the appropriate monitoring and control instrumentation must be specified. Specific guidelines should be followed during equipment layout and installation, to optimize system performance.

5.4 CONTROL AND INSTRUMENTATION

Basic steam-jet vacuum systems require nothing more than an on off valve to control the steam and water lines. Additional valves and instrumentation can be added for increased vacuum control, ease of troubleshooting and system optimization.

5.4.1 Suction control: A given steam-jet system has a fixed performance curve of capacity (lb/h) vs. absolute suction pressure (mm or in. Hg absolute). Therefore, a given capacity can be obtained by controlling the suction pressure. Several methods are described below.

Using a control valve, an artificial load can be taken from the discharge of any one of the ejectors in the system to produce a recycle control loop. To avoid vacuum leaks, care should be taken. in both the sizing and the installation of this control valve (between two levels of vacuum).

The load could also be taken from an external source, such as an atmospheric air bleed, steam bleed from the utility steam, or other process fluids. Condensable vapours are preferred, as their load on subsequent ejector stages can be minimized in the first Inter-condenser. In a competing method, a valve can be used in the suction line to create an artificial pressure drop across the ejector. This scheme works well when flow through the suction line is sufficient to cause a pressure drop across the valve's restricted flow area. When actual flow through the suction line is at least 50% of the design flow, such an artificial pressure drop can usually be induced. The addition of a valve in the suction line is also useful to isolate the vacuum system during startup, shutdown, and troubleshooting. In the event of a vacuum system failure, such a valve can also protect a water-sensitive process, by preventing steam or condensate from flowing back into the suction line. The performance curve of a multistage ejector system varies according to the number of operating stages, and will therefore produce different levels of vacuum with on-off control of select ejector stages. To control suction, successive stages may only be turned off, starting in succession from the first stage (that which is nearest the process) to the last one (that which discharges to the atmosphere). A single stage operating alone will produce pressures in the range of about 50 mm Hg absolute up to atmospheric pressure. Two stages will produce pressures between 10 mm and 100 mm, while three stages will produce between 1 mm and 25 mm. Finally, suction pressure can be controlled by bringing the whole system in parallel on or off line, or by turning on and off individual ejector elements that have been installed in parallel to the primary stage and use the same interconnections. To isolate individual elements from the process, a valve must be installed in the steam line to that jet, and in the suction line. A discharge valve may also be added to allow the element to be completely isolated from the system and to be removed for servicing According to HEI Standards (Paragraph 4.2.2.4.1), the design pressure of the suction chamber and diffuser must be no more than 15 psi (internal), and the unit should be able to withstand full vacuum, unless otherwise specified. During operation, care must be taken when using a discharge valve to avoid pressurizing the ejector bodies with mainline steam pressure. To ensure that this does not happen, the suction valve should be closed first, followed by the steam valve, and then the discharge valve (use the opposite sequence when turning the system on). If this procedure cannot be guaranteed, then a pressure-relief valve should be used. It should be sized for the steam consumption of the ejector, plus an additional 40%. According to HEI standards (Paragraph 4.1.7.2), the valves should be set to relieve the pressure when it exceeds 15 psi.

5.7 TROUBLESHOOTING TIPS

There are two basic types of malfunction in an ejector system: those caused by external influences or equipment, and those caused by the ejectors or condensers themselves. It is important that only qualified personnel, using proper equipment, perform testing. External problems To locate the source:

• Determine whether any changes have been made to the process served by the steam-jet vacuum system

• Determine whether the pressure and temperature of the steam or the condensing water have changed with respect to system specifications

• Determine whether any recent process changes have been made, which may have altered the feed rate of the vapour stream evacuated from the process vessel. • Determine whether the problem developed gradually or suddenly. As a general rule, a gradual loss of vacuum is due to changes or the deterioration of the vacuum system, while a sudden loss of vacuum usually is due to a change in utilities, increase in back pressure, or system leak

• Review the unit's recent maintenance history, and make note of any recent modifications

• Review any records of previous problems Once these steps have been followed, and it has been determined that the correct flow, steam pressure and cooling water temperature are in use, and that the pressure at the discharge of the final-stage ejector is not excessive, the next step is to determine whether the operational problem resides within the ejector system itself. Internal problems. To pinpoint malfunctions, a step-by-step procedure should be followed to assess each component. First, the ejector should be isolated by means of "blank off" plate at the suction inlet of the first-stage ejector. With all units operating while the plate is in place, the ejector will evacuate the first-stage suction chamber to the minimum pressure that the ejector is capable of producing.

The following shut-off pressure can be expected (each is approximate, and will vary with the system):

• Single-stage ejector 50 mm Hg absolute (A)

• Two-stage ejector 4-10 mm HgA

• Three-stage ejector 0.8-1.55 mm HgA

• Four-stage ejector 0.1-0.2 mm HgA

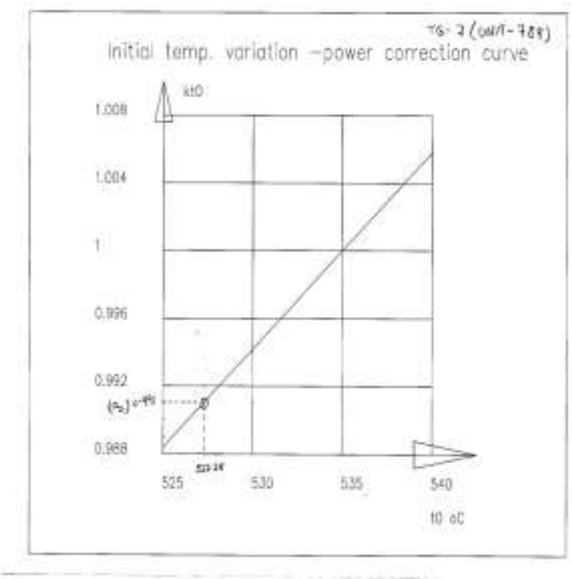
• Five-stage ejector 0.01-0.02 mm HgA

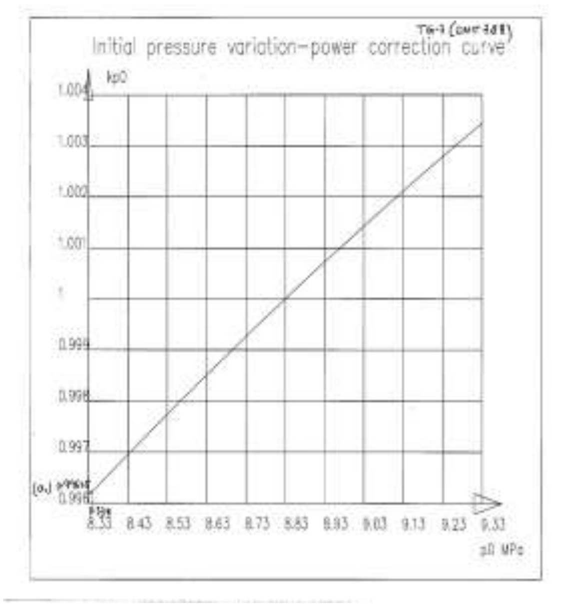
• Six-stage ejector 0.001-0.003 mm HgA

If this test indicates that the ejector is operating at its approximate shut-off pressure, then it can be assumed that the ejector will operate satisfactorily along its entire performance curve.

Further troubleshooting would then be required on the vacuum system upstream to the ejector. However, if the expected shut-off pressure is not obtained or is unstable, then the troubleshooting should be confined to the ejector system. A hydrostatic test is recommended to check for air leakage. Caution should be exercised: Before carrying out such a test, determine whether the system is designed to carry the extra pressure and weight of the water required to perform the hydro test. If a hydro test cannot be used, a low-pressure air test, using air pressurized to roughly 5 psig, can determine if the ejector system has a leak. Once again, system specifications should be checked to ensure that the unit will tolerate such pressure. During the test, a soap solution or spray should be applied to all joints, valve packing and other potential leak sites. If an air leak is present, the soap solution will form a bubble over the leak. For systems operating under vacuum, ordinary shaving cream is another inexpensive indicator. When applied to all joints and potential leak joints, the cream will be sucked into the opening, and the leakage source will be easily observed. If the hydro, air, or vacuum tests have not indicated any leakage, the next step is to check the internals of each component for damage or wear. Dismantle the ejector and check for deposits, scaling of internal parts, and wear in the nozzle and diffuser. If the system uses multistage ejectors, begin with the final-stage unit. Check the threads of the nozzle for telltale white or tan streaks, which indicate a steam leak through the threaded connection. Remove deposits from the suction chamber and make sure it is not cracked, rusted, or corroded. Shine a small light through the diffuser to make sure it is completely free from scale and is not pitted, grooved, or cut. After all stages and inter condensers have been cleaned; the throat diameters or the nozzles and diffusers should be measured as accurately as possible. Compare these with the original dimensions of the throat diameters, supplied by the manufacturer, to determine wear. If either diameter is larger than the original equipment specifications, calculate both original and present throat areas, and determine the percentage increase in areas. If the percentage increase is greater than 7%, the nozzle or diffuser will have to be replaced before satisfactory operation can be expected.

Even if the percentage increase in area is only 5%, replacement nozzles or diffusers should be ordered, prepare for an inevitable upgrade.





CALCULATION:

3. Procedure for applying the correction on measured steam flow value

Since heat rate is guaranteed, measured steam flow and power output shall be corrected as follows

Flow measurement:

Main steam flow as per site (Q1) = 208.01

1. Correction factor of inlet steam pressure = a1 (read from curve)=0.99625

2. Correction factor of inlet steam temperature = a2 (read from curve)=0.991

Corrected steam flow (Q'1) = Q1 X a1 X a2= 208.01 X 0.99625 X 0.991= **205.36**

Measured Power Output (P) = 47.14

H1=Enthalpy at Steam turbine Inlet = 827.86078

H2= Enthalpy of feed water at HP heater outlet = 238.77482

Q2= feed water flow is assumed at least 1% (for ejector, Blow down, etc.) more than the turbine steam flow =1.01 x 205.36 = 207.418

Corrected Heat rate = (Q'1X H1 - Q2 X H2)/P

= (205.36X 827.86078– 207.418 X 238.77482)/47.14

= (170009.489-49526.3249)/47.14

= 120488.16/47.14

Corrected Heat rate (Achieved without applying exhaust correction curve) = 2555.96

Design Heat Rate = 2296

Legend:

Q1= Turbine steam flow as measured

Q2= Feed water flow at the outlet of HP heater (only assumed at least 1% additional for the ejector, Blow down and other)

H1=Enthalpy at steam turbine inlet

H2= Enthalpy of feed water at HP heater outlet

Q'1=Corrected turbine steam flow

P=Measured power output

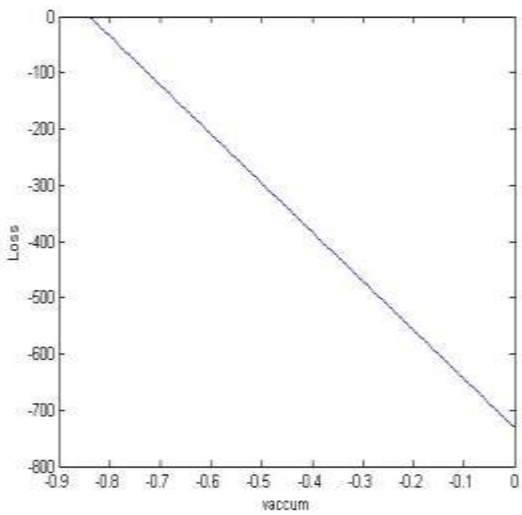
4. Conclusion:s

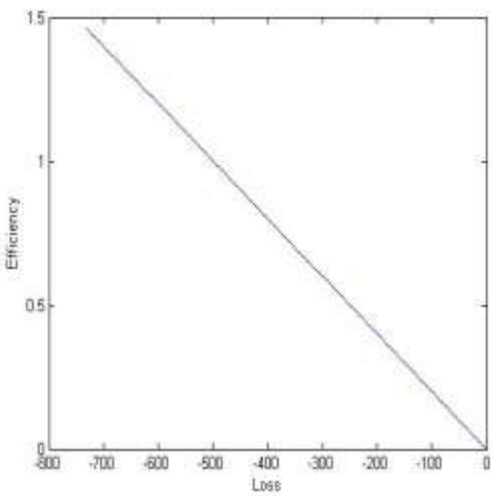
As per the contract, the instrumentation error at 1% can be added to the actual Design value 2296, so that heat rate to be proved by APTPEL is 2318.96.

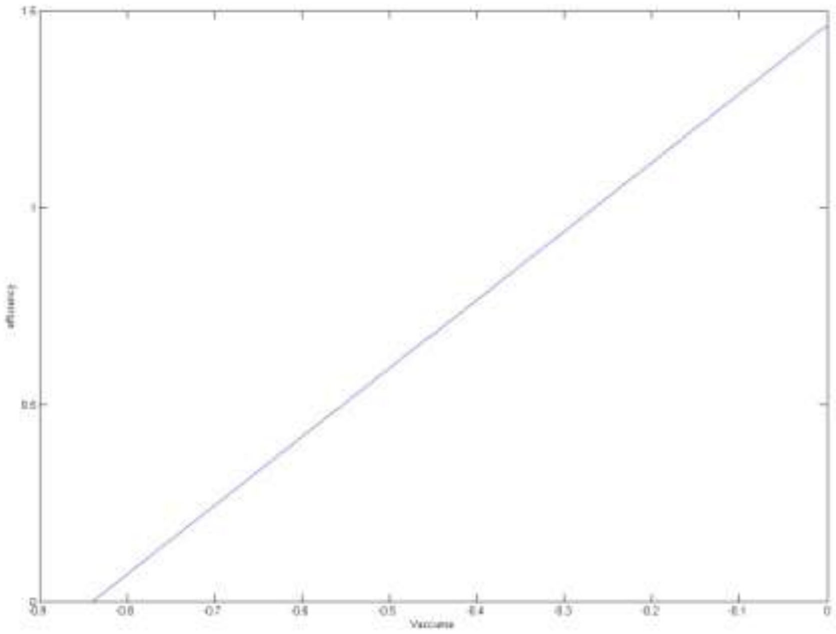
5. **Deviations (from SCL) :**

1. Insulation is not provided for the condensate pipe line between the LPH-1 Outlet to De- aerator.
2. Feed water flow meters are not working.

6. Results and discussion







7. Conclusion

After investigation this case found:

(a) The Efficiency is increased by 1.4728% between the Turbine and Gland Steam condenser.

(b)It save the heat 731.64 Kcal/KWh for 50 MW in XYZ Plant.The graph is plotted to find the calculation below.

(c) Heat increases the condensate temperature exchanging heat from the counter flow of steam.

(d) Heat removed of the air present in air cool condenser duct. Thereby, reducing steam consumption.

8. References

[1] "Performance of an Air-Air Ejector: An Attempt at Numerical Modelling" TASK QUARTERLY 7 No 3 (2003), 449–457 Division of Mechanics and Machinery Construction, Oczapowskiego 11, 10-736

[2] "HIGHER EFFICIENCY TARGETING IN A STEAM POWER PLANT BY USING PINCH TECHNOLOGY" by Fazlollah ESKANDARI and Masoud BEHZAD , U.P.B. Sci. Bull., Series D, Vol. 71, Iss. 4, 2009 ISSN 1454-2358

[3]"AN EXPERIMENTAL INVESTIGATION OF AN EJECTOR OPERATING WITH R245FA" By David SCOTT, Zine AIDOUN and Mohamed OUZZANE, International Seminar on ejector/jet-pump technology and application Louvain-la-Neuve, Belgium Paper No. 21