# Boosting Steam to Boost Profits- The Thermocompressor Way

**Kuvalekar D. K. ,**


## ABSTRACT

*Thermal Vapor recompression can bring about drastic reduction in your steam consumption and help your paper mill to be more competitive. The payback periods for such system are generally less than a year and would contribute substantially to the improved bottom lines.*

*However a word of caution - Benefits can accrue only if the system has been designed well and the Thermocompressor design parameters match that of the specific machine.*


## INTRODUCTION

The paper industry is an highly intensive user of energy. If considers steam alone, It accounts for almost 60-70% of the total energy bill of the paper machine. If one looks at the paper mill economics, it is the raw material and labor costs which are dominating with Steam accounting for almost 10% of all direct costs. However if one looks at the paper machine only, then steam Costs assume a very significant proportion exceeding 30% of all conversion costs.

In the context of global paper prices crashing and the need for paper manufacturers to be highly cost conscious, energy conservation in general and specifically that of steam becomes an absolute necessity. Paper makers who can produce high quality paper at the least cost have a chance of surviving the cut throat competition, and that energy optimization has the biggest potential to contribute to this cost cutting. Typically for a 50 TPD plant a 20% reduction in steam consumption can result in annual savings exceeding USD 1,00,000 (and is equivalent to selling 150 tonnes of extra paper !!). These mind boggling numbers are not just a figment of one's imagination but are actually possible and have been implemented using the Thermal vapor recompression technology.

## ......SO WHAT IS THERMAL VAPOR RECOMPRESSION TECHNOLOGY ?

Thermal vapor recompression is a process by which low pressure steam (which is normally condensed or vented) is compressed to a higher pressure and reused inside the paper machine cylinders. This is achieved by using a specially designed equipment known as Thermocompressor. The function of the Thermocompressor is to recirculate the low pressure steam into higher pressure header. The thermocompressor has been explained in detail in later paragraphs.

M/s Forbes Marshall Limited
Mumbai-Pune Road,
Kasarwadi
PUNE - 411 034

In order to understand more about this technology, it will be necessary to go back to a little bit of basics and to understand the paper machine mechanics.

The paper machine is the equipment used to make paper from wet pulp. Paper machines are available in several designs and speeds. However their basic function remains the same-To dry paper.

The paper machine consists of a train of cylinders on which wet pulp is passed. The pulp contains 65-70% water which needs to be dried and during this process the formation of paper takes place. These values ofcourse depend on the type of size press and their efficiency. The paper coming out of the machine should not contain more than 3-4% moisture for writing printing paper and may go to as much as 6-7% for board paper. The drying of the pulp is achieved by steam heated cylinders over which this pulp moves. Steam is fed into the cylinders, which heats up the cylinder surface which in turn dries the wet pulp. The steam that enters the cylinder condenses and is removed from the cylinder by either scoops or siphons. As the pulp moves over the cylinders, paper is formed which is rolled onto steel rolls. These paper rolls are then subsequently taken for either calendering or coating. The heated cylinders are further classified into thermal groups. The basic theory behind this is that in order to get good quality paper, a certain temperature profile must be maintained along the length of the paper machine. The cylinders, at the point where wet pulp enters, need to be at lower temperatures as compared to those which are located after them. The most common configuration is the three group one where there is a predryer, a main section and the post dryer. In some paper machines you will encounter only one large cylinder (no Pre and Post dryers). This machine is called a Yankee machine. Its function is also to dry wet paper and this is normally used in the manufacture of light weight tissue paper.

Paper machines are broadly classified into two categories:

1) The conventional or trapped system

2) Blow-through system

The older machines normally would be trapped systems where the steam traps are installed on the condensate outlet pipes of individual cylinders This system is normally restricted to low speed low capacity machines. The Steam is injected into the cylinders and the condensate is removed either through scoops or siphon pipes. The condensate is then discharged into a flash vessel, where the condensate flashes to a lower pressure. The flash steam which is generated is traditionally either vented or used for air heating or cascaded into the previous groups. In most of the plants the energy advantages of such traditional methods are not really fully utilized and hence Thermal vapor recompression offers a better solution. In this case the Flash tanks would be fitted to individual groups and the flash would then be recirculated locally using thermocompressors.

The other type of system is that where traps are not required and are known as "Blow through" machines. The world wide trend in paper machines is now moving towards higher cylinder pressures and higher speeds (> 500 m/mpm). But the problem at higher speeds is the removal of condensate from the cylinders. At higher speeds the condensate tends to "rim" at the inside periphery of the cylinder. If we even have a siphon, we need a large differential pressure to overcome the centrifugal force. This is where the blow through system overcomes these problems. In this system an additional amount of steam is fed into the cylinder (over and above that required for effective drying of the paper). This additional steam is used to achieve an improved condensate removal by effectively "blowing through" along with the condensate. A rotary or stationary siphon is used to suck up the condensate along with the "blow through steam". An additional benefit of "blow through" is that air and non-condensable gases are also purged from the cylinder along with the condensate. No steam traps are present in this system. The condensate, along with the blow through is taken to a flash vessel where flash is generated and the condensate from the flash vessel is returned to the boiler. Typically the amount of additional steam required ranges between 15-20% of the normal steam consumption.This additional steam does not condense inside the cylinder and therefore comes out with the condensate. This steam is separated inside a level controlled separator and now is available for reuse. Traditionally the "Blow through" steam is cascaded into previous groups. The disadvantages of conventional cascade systems have been dealt with later, however it will suffice to say that here too use of Thermal vapor recompression offers a better solution.

In all the cases, low pressure steam is available at the condensate end of the process and

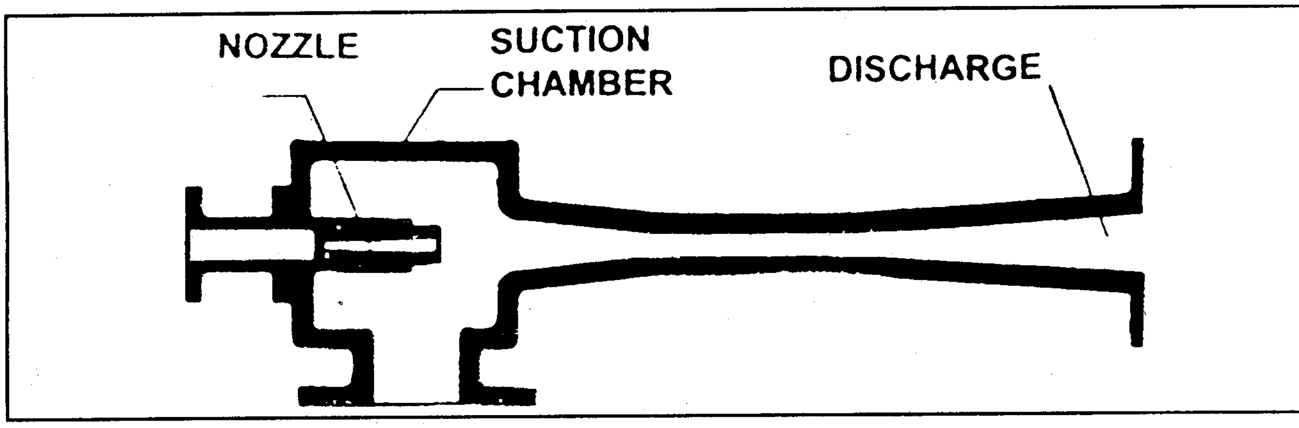


*Fig. 1 - Schematic of a Thermocompressor*

Thermocompressors provide the most energy efficient way of using the low pressure steam. This is where maximum potential for savings can be realized if the system has been designed taking into account the specific paper machine parameters.

## THERMOCOMPRESSORS

Historically, the first use of thermocompressors has been in the paper industry. Thermocompressors have been available since the early 1900s and in between had almost ceased to be talked about. This was largely due to lack of information and awareness about Thermocompressors and more often due to improper design and its consequent application which resulted in energy consumption increasing rather than decreasing which caused papermakers to abandon the concept!! However that is slowly changing with designs becoming more efficient and with increasing use of computers and Computational Fluid Dynamics Software which are capable of handling supersonic flow analysis encountered in Thermocompressor design.

Thermocompressors are used primarily in recovering low pressure flash steam and boosting it to a higher pressure thus reclaiming flash steam. By using Thermocompressors steam savings to a tune of 15-20% can be achieved, thus providing tremendous cost benefits to the paper mill.

The basic Thermocompressor consists of a suction chamber, a nozzle, and diffuser, (Fig. 1).

Motive steam (High pressure steam) is expanded in the nozzle from the inlet pressure to that in the suction chamber, thus converting the pressure energy into velocity energy. The motive steam leaves the nozzle at a high velocity in the order of 900-1000 m/s. Lower pressure suction steam is sucked and entrained in the motive flow steam as it passes through the suction chamber diffuser where the mixture velocity decreases as the velocity energy is converted to a pressure energy at the discharge. The performance of the Thermocompressor is controlled by means of the Control system that needs to be an integral part of the Thermocompressor. Fig. - 2)
Thermocompressors are available in the Fixed nozzle design, The variable nozzle design and the multiple nozzle design, each having their specific application areas. For the paper industry, the fixed nozzle and the variable nozzle design with the integrated control system have been used.

## THERMOCOMPRESSOR CONTROL SYSTEM

The control system that froms part of the package is designed to ensure a smooth, automatic and trouble free operation. The control system should also seamlessly integrate with the existing QCS (Quality control system) or the SCADA or the DCS system that may already exist in the plant.

To ensure that the discharge steam from the Thermocompressor is maintained at desired pressure a control loop consisting of a flow control valve, a pressure transmitter, a controller, two I/P converters and a vent valve is used.

The pressure transmitter mounted on the steam headers senses the pressure and sends a signal to the controller. The controller signals the converter which then operates the flow valve on the motive line. This operation of the flow control valve regulates the motive flow such that the discharge pressure from the

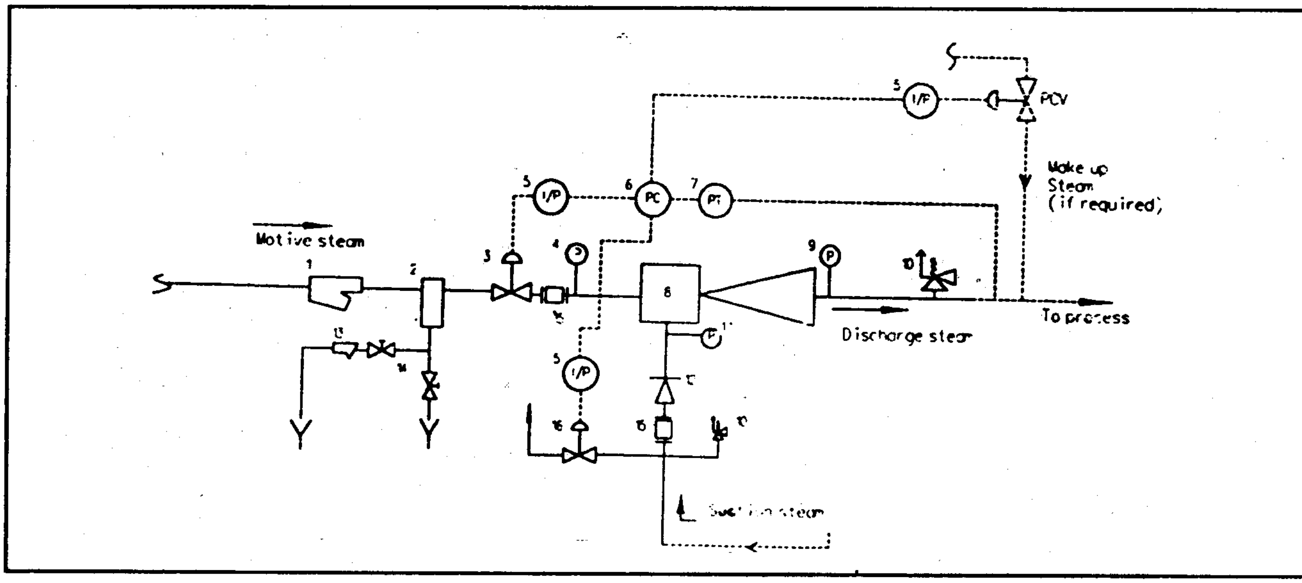


*Fig. 2 - Typical Control System for a Thermocompressor*

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| 1. STRAINER | 9. PRESSURE GAUGE |
| 2. MOISTURE SEP | 10. SAFETY RELIEF VALVE |
| 3. CONTROL VALVE | 11. PRESSURE GAUGE |
| 4. PRESSURE GAUGE | 12. NON RETURN VALVE |
| 5. I/P CONVERTER | 13. STEAM TRAP |
| 6. PRESSURE CONTROLLER | 14. STOP VALVE |
| 7. PRESSURE TRANSMITTER | 15. FLOW METERS |
| 8. THERMOCOMPRESSOR | 16. VENT VALVE |

Thermocompressor remains constant. A make up valve is also controlled by the same transmitter via the controller to ensure that the right amount of make up quantity of steam flows into the header. Thus the exact required quantity of steam for drying of paper can be obtained by regulating the flow control valve and make up valve. *The control loop is such that the make up valve will open only after the Thermocompressor is discharging its full capacity.* Hence, under normal operating conditions, maximum savings will result by the reuse of flash steam in the Thermocompressor. In other words the Motive control valve and the Make up valve are split ranged (Motive valve 4-12 mA and the Make up valve 12-20 mA). In addition the pressure Transmitter also signals the vent valve through the controller. During start up, when the cylinder pressure is small, the vent valve opens automatically. This is done as the pressure of flash steam will be very small. Once the desired pressure in the cylinder header is achieved, the vent valve shuts automatically and flash steam passes into the Thermocompressor and is boosted to the discharge pressure.

The strainer on the motive line (High Pressure line), is to prevent foreign particles from eroding the nozzle. A moisture separator is provided to remove any moisture particles present in the motive steam. To prevent steam loss through the discharge line of the moisture separator, a Thermodynamic trap is provided (with provision for bypass).

A safety relief valve is installed on the discharge line as a precautionary measure against excessive pressure buildup. Similarly on the suction line, to guard against excessive pressure build up in the line, a safety valve is provided.

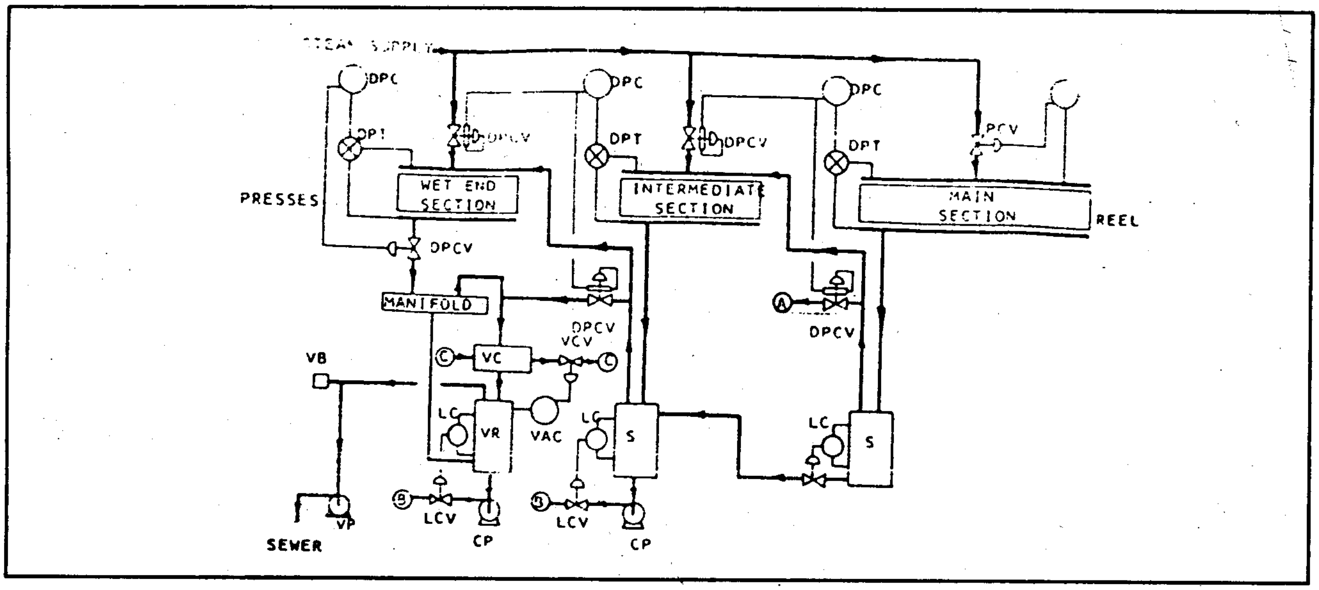


*Fig. 3 - A conventional Cascade System*

Under conditions when the pressure in the discharge rises to a large valve, there is a possibility of reversal of flow and steam moves into the suction line. To prevent this, a non-return valve is installed on the suction line.

The Thermocompressor discharge steam is discharged to the group steam header where it effectively contributes to the heating of paper.

As has been detailed above, the ability to cascade blow thru steam from one section to another requires that the section receiving the blow thru steam operate at a lower steam pressure. The lower pressure is equivalent to the required differential pressure across the steam joint to produce the proper blow thru flow plus the piping friction losses in the steam supply, condensate return and the blow thru flow piping. Therefore it is not uncommon to have as much as a 15 psi difference between the pressure in the main steam section and the middle section as well as between the middle section and the wet end section. Once the operating pressure of the main steam section has been established and differential pressures are set so as to bring about the highest production rates, the entire machine steam drying system is. dependent upon the operating of the main section. Reductions in the steam pressure of the main section automatically result in pressure reductions to the remaining steam sections in a cascade drying configuration. This is the greatest draw back of the cascade system. Each group is interlinked and change in pressure in one group changes pressure elsewhere and control is rigid. Moisture control and temperatures are difficult to control as result of this complex link up. In many cases the energy benefits of cascading too are not realized due to mass flow imbalance as well as pressure imbalance.

The Thermocompressor based steam section arrangement provides for recirculation of blow thru steam within the same steam section. Each group now becomes an individual module not linked up to any other group. The advantage is that each group can be operated at the highest steam pressure as governed by the temperature profile for the gsm of paper. This increased average steam pressure equates directly to increased production rates. Depending upon the number of dryers and number of groups, a 1% to 3% increase in production capacity can be expected strictly from the higher steam pressures being made available to more dryers based on Thermocompressor recirculation. Another advantage of Thermocompressor based system is that this configuration allows each individual steam section to be controlled independently of the other steam section. In the cascade system arrangement, the operating pressure of the main steam section dictates the operating pressure limits of the remaining dryer section. Therefore whenever changes occur on the dry end of the machine necessitating reduction in the main steam section pressure, the result is a swing in dryer pressure through out the entire machine. The implementation of Thermocompressor recirculation eliminates the interdependence between the conrtrols of the steam sections in the dryer arrangement. Thus if operating conditions dictate the capability exists in the Thermocompressor based system to run higher pressures in the early sections of the dryer system than in the later parts of the dryer section. Steam pressure changes in one section of a Thermocompressor based system has no impact upon the operating pressure of any other steam in the system. The Thermocompressor system provides operations with a greater degree of flexibility in addressing drying problems than with a conventional cascade system.

Thermocompressors also contribute to enhancing condensate removal thereby effectively improving heat transfer conditions inside the dryer which leads to lower steam consumption. The temperature profile also becomes more uniform as a result of the effective blow off effect provided by the higher velocity steam injected by Thermocompressors. Faster Condensate removal means faster machine and greater production. All this makes the thermocompressor a tool for improving not only the energy economics but also productivity and quality. It therefore makes a great deal of economic sense to go in for Themocompressor based system.

The question most papermakers would have is how does he know that this energy consumption has really been slashed ? How does one really monitor energy economics of the paper machine in the days of escalating fuel prices? Energy management has become of prime importance in the scenario where oil prices are rapidly escalating. Every kg of steam conserved adds to your bottom lines. Hence it not only becomes essential to conserve steam consumption, but to also monitor it continuously. Hence steam metering is of vital importance to the economics of paper

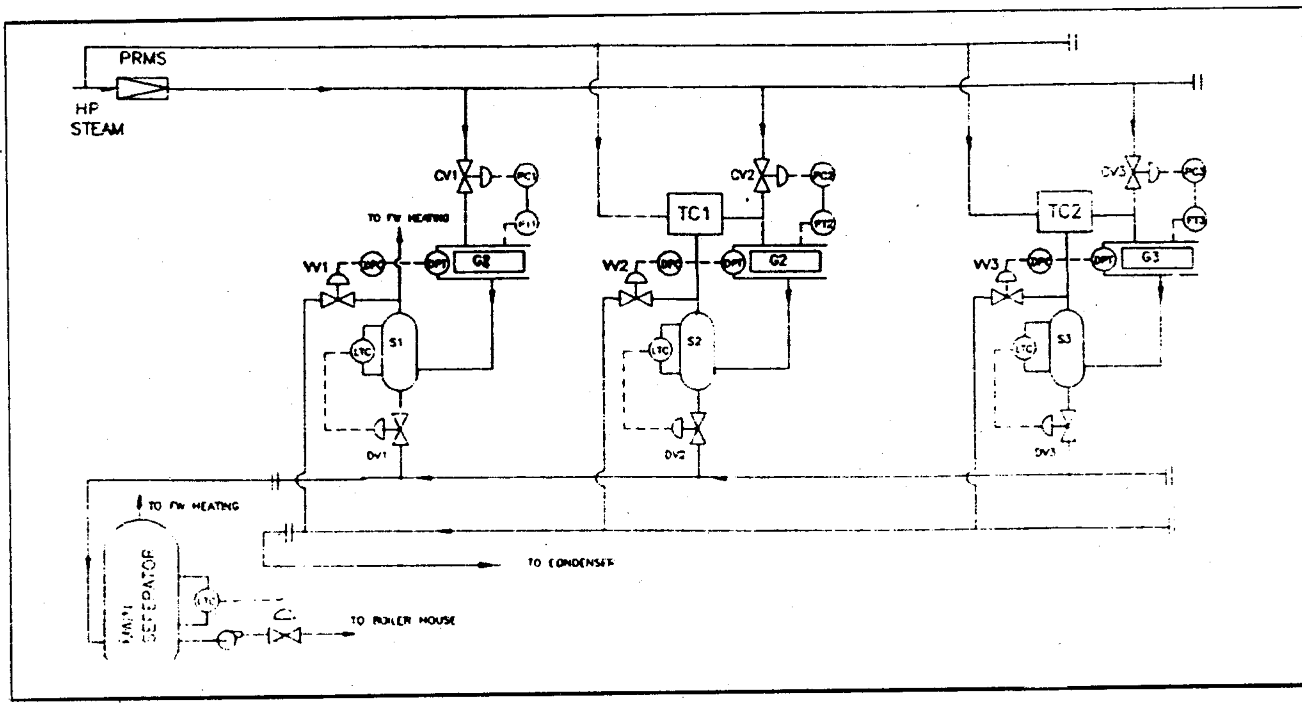


*Fig. 4 - Thermal Vapour Recompression System*

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| TCT & TC2 | Reters to Thermocompressor System |
| G1, G2, G3 | Refers to Groups |
| PT | Refers to Pressure Transmitters |
| PC | Refers to Pressure Controllers |
| CV | Refers to Control Valves |
| DPT | Refers to Differential Pressure Transmitters |
| LTC | Refers to Level Transmitter/Controller |
| W | Refers to Vent Valves |
| S | Refers to Condensate Sepearlor |

machine. The recommended steam meter is the vortex flow meter which is an excellent tool to accuarately measure steam flow and also provides for pressure/temperature compensation. This would be installed on the main steam header coming to the paper machine. Therefore the benefits of implementing the vapor recompression technology would also be validated.

The System being offered has distinct advantages not only in terms of the energy economics but also in terms of the operational features.

1) The system is totally automatic and reliable. It can be easily operated by operators without any problem.

2) The system provides accurate control on steam pressures thereby enhancing paper quality.

3) The system ensures continuous condensate removal, thereby operating speed of the machine can be increased.

4) The system removes non-condensibles regularly, providing uniform cylinder temperature and thereby improving on the paper quality.

5) The system recirculates flash steam and Condensate and thereby cuts down your energy bill and improves profitability of your plant (as shown above)

## CASE STUDIES

Thermocompressor systems have been implemented in several plants.The case studies indicated below are leading players in the paper industry and the system performance has exceeded customer expectations.

## CASE 1

The system has been implemented on a multi grade fourdrinier machine. The 40 TPD Machine operates under 18 to 60 gsm and machine speeds ranging from 150 mpm to 300 mpm. Installation of one such system slashed their specific steam consumption from 3.0 kg of steam/kg of paper to 2.1 kg of steam/kg of paper. This translated into a savings of Rs 58 lacs per annum and the Capital investment was in the range of Rs 12 lacs provinding a very attractive payback.

## CASE 2

The complete steam and condensate system was revamped using one Thermocompressor system. Estimated saving are in the range of 20%. Based on a 85 TPD capacity, this translates into a saving of Rs 70 lacs and the payback is again less than one year.