Energy saving in steam systems.

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Substantial quantity of savings in steam is possible by adopting the following thumb rules. Most important operating parameters to minimize steam consumption include using dry saturated steam having saturation temperature equal or very nearly equal to the required process temperature in steam consuming devices such as

- Steam heaters
- Steam heated reboilers
- Steam tracers etc.

On the contrary, superheated steam must be used in

- Back pressure turbines
- Extraction turbines and
- Total condensing turbines.

Steam temperature or degree of super heat is an important factor that minimizes steam consumption. **Since steam temperature is related to steam pressure, temperature parameter automatically sets the steam pressure**. This would mean that various steam heated devices require various steam pressures and super heats, depending on the process configuration. Following table shows, how steam temperature plays an important role in controlling steam consumption in various heating devices.

Process temperature required oC	Steam temperature oC	Corresponding steam pressure .in bar (on process temp)	Steam enthalpy Kcal/kgm	Latent heat Kcal/kgm
100	130	1.03	650.8	516.7
150	180	5.00	671.2	503.4
200	230	15.0	676.3	464.7
250	280	40.0	680.8	409.1
300	330	85.0	667.0	336.0

Steam temperature is selected 30 oC higher than the required process temperature.

The best steam for industrial process heating is dry saturated steam, which is neither wet not highly super heated. Wet steam reduces heat transfer while super heated steam is not desirable for process heating because of the **problems in temperature control** of the process fluids and the **low heat transfer coefficient**. Condensation heat transfer is best suited for process heating applications. Available enthalpy in wet steam is reduced depending on the moisture content present in the steam. ***For example, latent heat available in a 95% dry steam, with 5% moisture shall have a latent heat of 478.2 kcal/kgm against the value of 503.4.***

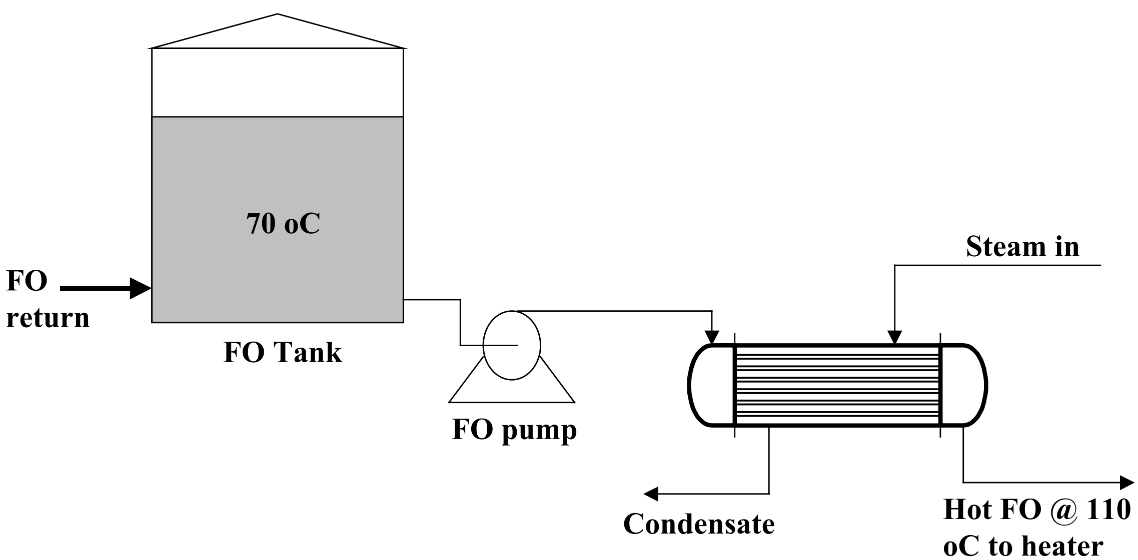
It **is only the latent heat of steam that takes part in the process heating**. Hence it is essential that the latent heat of steam used for process heating is **as high as possible**. From the above table it is obvious ***that lower the steam pressure, the higher is the latent heat*** of steam. It may also be noted from the above table that as the steam pressure comes down, the saturation temperature also comes down. The steam pressure for process heating must therefore, be selected based on the required process temperature. The saturation temperature may be selected a few degrees higher (10 to 20 oC) and the steam pressure fixed accordingly.

For example, when the process temperature to be maintained is between 100 to 200 oC, it is economical to select steam pressure whose saturation temperature just matches the process temperature plus 5 to 10 oC. Using dry saturated steam for process heating is efficient due to **it's film heat transfer coefficient** which is comparatively higher than highly super heated steam.

Example : Furnace oil is used as a fuel in a fired heater. The furnace oil is stored in a tank and maintained at 70 oC. The oil is heated in a steam heated exchanger to 110 oC using a steam heater. The flow rate of furnace oil is 10 tons /hr. the specific heat of FO is 0.68. Determine the optimum steam pressure for this system and calculate the steam rate?

Following figure shows the arrangement for heating the furnace oil. There are two reasons for heating the furnace oil, before it goes to the burner. The primary reason is to reduce the viscosity of the furnace oil at burner tip, so that it is atomized easily and the secondary reason is to increase the burner efficiency and accelerate ease of combustion.

Furnace Oil Heating using dry saturated steam



Heat required to increase FO temperature from 70 to 110 oC is given by

$$= \text{Mass x Sp.heat x } \Delta t$$

$$= 10 \times 1000 \times 0.68 \times (110-70) \text{ kcal/hr}$$

$$= 272000 \text{ kcal/hr.}$$

Steam data:

Steam pressure kg/cm2a	**Saturation temp oC**	**Latent heat kcal/kg**	**Enthalpy in kcal/kg**
1.5	110.8	532.1	643.1
2.0	119.6	526.4	646.3
2.5	126.8	521.4	648.7
3.0	132.9	517.3	650.8

Since the FO to be heated is from 70 oC to 110 oC, the driving force for the last three cases in terms of average temperature is calculated as shown below. The first case is neglected, as the driving force is too low.

Steam pressure kg/cm2a	**Saturation temp oC**	Δt1	Δt2	Δt=(Δt1+Δt) /2	Steam required in kg/hr
2.0	119.6	49.6	9.6	29.6	516.7
2.5	126.8	56.8	16.8	36.8	521.6
3.0	132.9	62.9	22.9	42.9	525.8

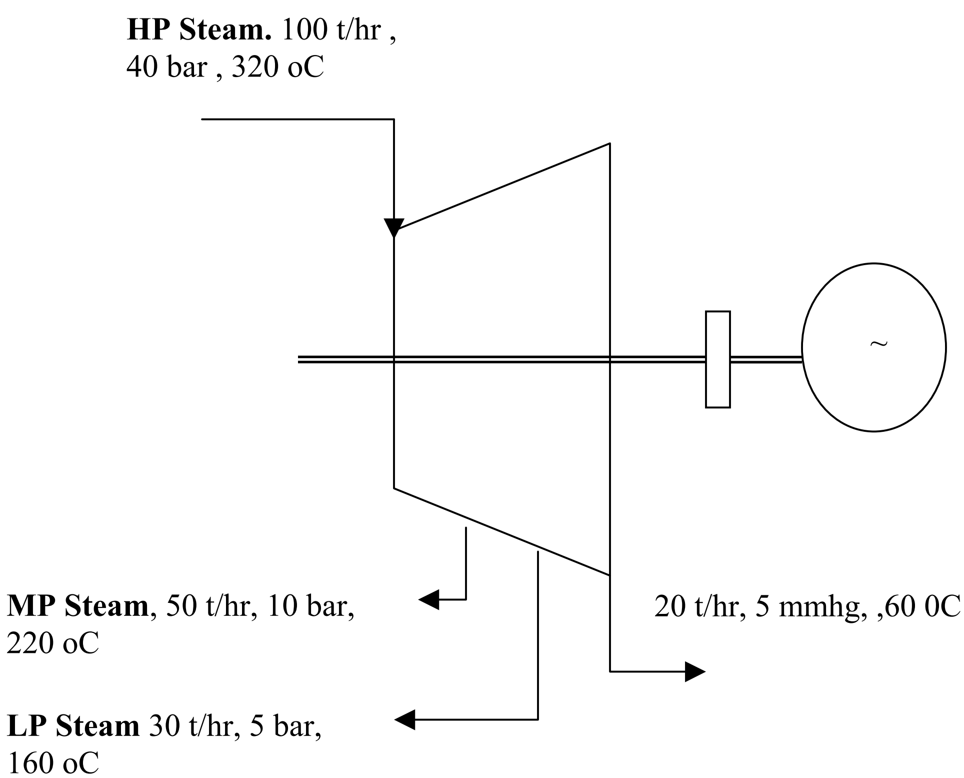
Taking an average overall heat transfer coefficient of 220, 225 & 230 kcal/hr/m2/oC respectively for the above three cases, the heat transfer area requirement for the above cases works out to 41.77, 32.85, 27.57 m2 respectively. Steam requirement for the above process heating is given in the last column.

It may be noted from the last column that the steam requirement in the above cases increase with increasing steam pressure.

Based on 8000 operating hours per year, the steam consumption works out to 4133.6, 4172.8 & 4206.4 tons respectively. While the above example refers to a single steam heater, there will be substantial savings in steam in major process industries comprising a number of such steam devices.

Using exhaust steam in LP service : For the **LP (low pressure)** process steam service, it is economical to use exhaust steam from back pressure turbines, extraction turbines, extraction cum condensing turbines, steam de super heaters, pressure reducers etc as ***direct production of LP steam is not energy efficient***. By using turbine exhaust steam, overall thermal efficiency of the system will be high as shown in the figure1 below.

Fig 1. Extraction turbine lay out.



Theoretical Carnot cycle efficiency of the turbine in Stage I, II & III are 16.86, 12.17 and 23.09 respectively. This is calculated by the relationship

$$\eta_{carnot} = (T_1 - T_2) \text{ x}100 / T_1$$

where T_1 & T_2 are steam inlet and outlet temperatures absolute (oK) at each stage.

Theoretical power generation for the above parameters may be calculated by enthalpy values at inlet and outlet conditions at each stage.

Though the turbine efficiency is less than 25%, the integrated overall plant **efficiency will be high,** when the two extraction steam flows are used in the plant. This is because of the fact that the entire latent heat available in these steams will be utilized for process heating and only the condensate will be returned to the condensate recovery system. A typical break up of energy is shown in the following table.

Energy Utilized in Turbine alone

Steam	Enthalpy Kcal/kg	Flow in kg/hr	Energy input '000Kcal/hr	Energy output '000kcal/hr	Energy used '000kcal/hr	% utilized on input
HP (40 bar, 320 oC	720.6	100000	72060			
MP (10 bar,220 oC	685.3	50000	36030	34265	1765	2.45
LP (5 bar ,160 oC)	658.6	30000	21618	19758	1860	2.58
Vac 25mmhg	608.63	20000	14412	12172.6	2239.4	3.11
Total					5864.4	8.14

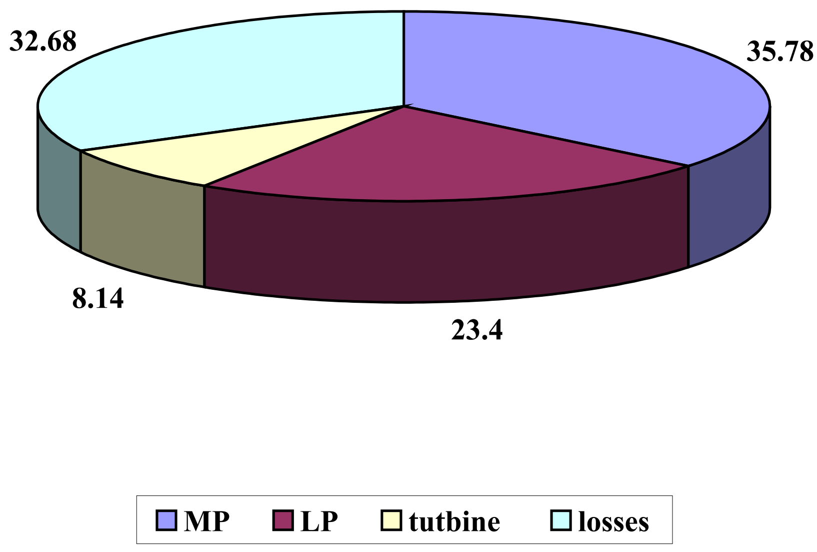
Energy utilization in total process

Steam	Enthalpy / Latent heat in Kcal/kg	Flow in kg/hr	Energy input '000Kcal/hr	Energy output '000kcal/hr	Energy used '000kcal/hr	% utilized on input
HP (40 bar, 320 oC	720.6	100000	72060			
MP (10 bar,220 oC	685.3 / 480.3	50000	36030	10250	25780	35.78
LP (5 bar ,160 oC)	658.6 / 500.0	30000	21618	4758	16860	23.40
Total in process					**42640**	**59.18**
Total in tutbine section					**5864.4**	**8.14**
Overall plant					**48504.4**	**67.32**

As could be seen from the above tables, energy utilization is the highest, when the MP and LP steams are used in the process units. ***The balance of 32.68 %*** include hot condensate at each pressure level plus the loss of steam / condensate due to leaks, draining etc.

Following **figure2** shows the energy consumption break-up in a two stage extraction steam turbine.

Fig 2. Energy Utilization level for two stage extraction turbine



Economizing Steam consumption in typical back pressure / condensing steam turbines.

Steam turbines may be operated in different ways to meet the power demand. For example, the turbine may be operated in total condensing mode or back pressure mode depending on the steam and power demand of the process. Steam turbines used in the process are major energy consumers. Optimizing process operating conditions can considerably improve turbine efficiency , which in turn will significantly reduce energy requirement. Various operating parameters affect ***condensing and back pressure turbine steam consumption and efficiency.***

Turbine efficiency – Significance.

The industrial sector is the largest energy consumer, accounting for about 30 % of total energy used. With the present trend of energy prices and scarcity of hydrocarbon resources, lowering energy requirement is a top priority. Energy conservation benefits depend on applying certain minor or major modifications and using the modern operational features. Energy conservation does not mean curtailing energy use alone at the cost of industrial and economic growth. In major / mega process industries, steam turbines are the main energy consumers. Savings achieved here will be significant, with a better return on investment than for most other equipment.

Effect of operating conditions on steam turbines

A condensing turbine system is shown in ***figure 3.*** Turbine exhaust operating below atmosphere, is condensed in a shell and tube exchanger called **surface condenser as shown in fig 3a**.

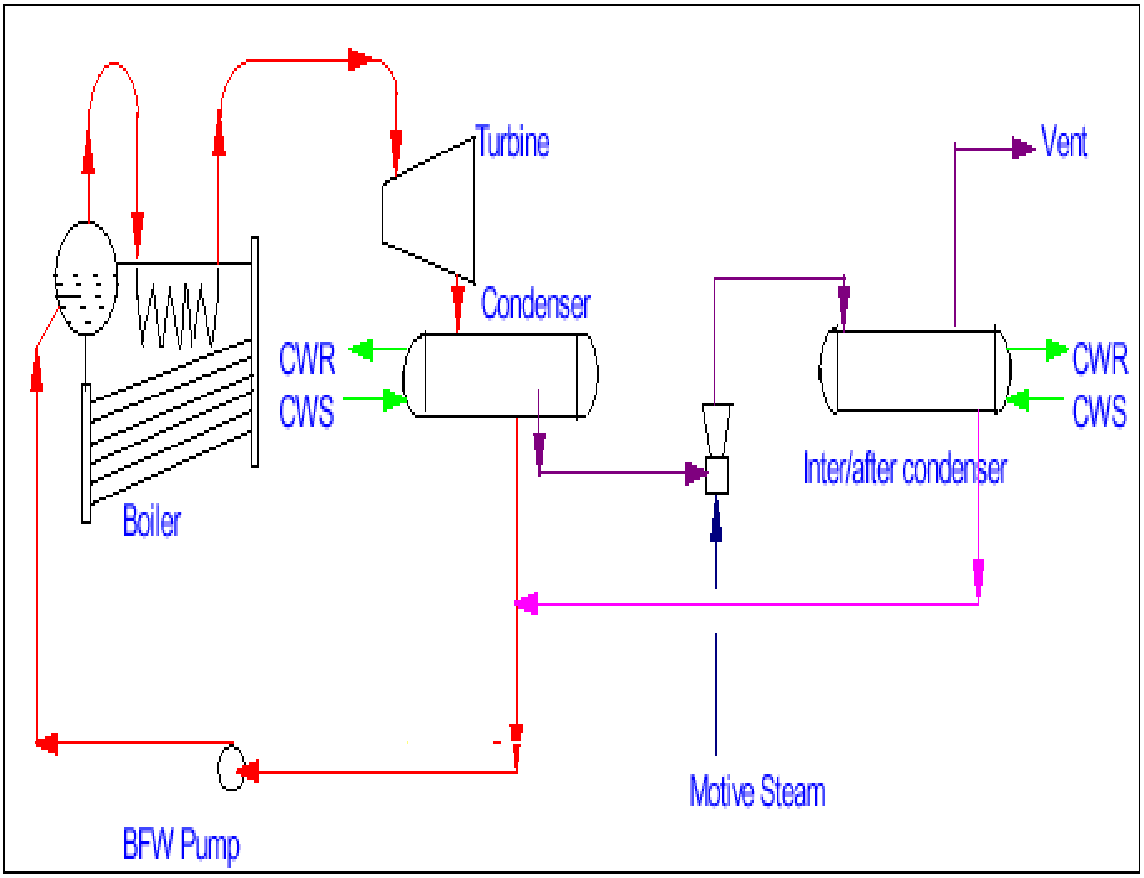


Fig 3. Diagrammatic details of a condensing type turbine.

Refer to **fig 3a**. Condensate flows in the shell side of the condenser and steam is condensed by the cooling water. Vacuum in the surface condenser i.e. turbine exhaust vacuum is controlled / maintained by vacuum ejector system of the surface condenser. **Figure 3a** shows the layout of a typical surface condenser used in steam turbines.

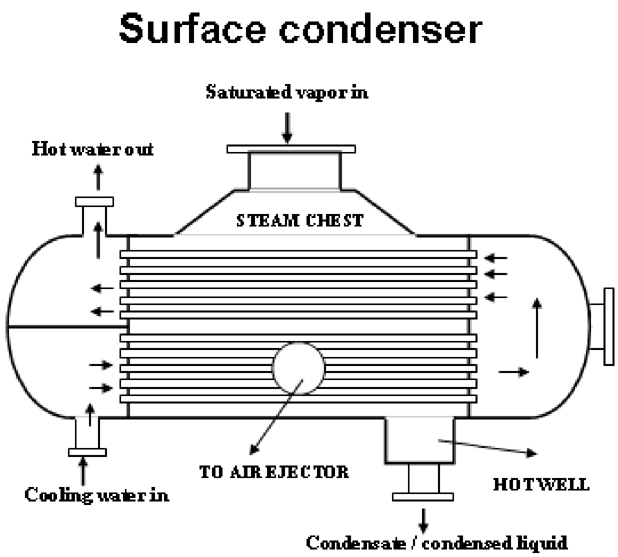


Fig 3a. Layout of surface Condenser

Turbines are designed for a particular operating conditions like steam inlet pressure, steam inlet temperature and turbine exhaust pressure/ exhaust vacuum, which affects the performance of the turbines in a significant way. Variations in these parameters affects the steam consumption in the turbines and also the turbine efficiency.

Theoretical turbine efficiency is calculated as work done by the turbine to the heat supplied to generate the steam.

Impact of various operating conditions on turbine performance is shown in the table below, considering the steam conditions used in the turbine.

TABLE : Steam Consumption comparison for constant BHP

Condensing Type Turbine	**Back pressure type turbine**
Steam Inlet Pressure 40 kg/cm2a	Steam inlet pressure 40 kg/cm2a
Steam inlet temperature 350 oC	Steam inlet temperature 350 oC
Exhaust Vacuum 657 mmhg	Exhaust Pressure 4.5 kg/cm2a
Turbine rated BHP 2000 HP	Turbine rated BHP 2000 HP
Steam consumption 27785 Kg	Steam consumption 57960 Kg

In the above referred turbines, 1 % reduction in steam consumption saves around \$ 47000 annually for condensing turbines and around \$ 84000 annually in back pressure turbine. LHV of the fuel for generating steam is considered as **10500 kcal/kg and boiler efficiency is taken as 87 %.**

Energy Balance:

Case : Condensing Turbine

Enthalpy of input steam at 40 kg/cm2a & 350 oC = 737.9 kcal / kg

Saturation temperature = 249.0 oC : Enthalpy : 669.0 kcal/kg @ saturation temperature.

Enthalpy @ outlet conditions : 647 mmhg vacuum = 113 mmhg pressure absolute

= 620.5 kcal/kgm

Saturation temperature = 53.5 oC

Net energy input = steam rate (kg/hr) *Δ Enthalpy kcal /hr

= 27785 * (737.9 – 620.5) = 27785 * 117.4

= 3261959 kcal /hr

Carnot cycle efficiency = (350 – 53.5) x 100 /(350+273) = 47.59 %

Energy equivalent power generated = 2000 * 0.746 * 860 = 1283120 kcal /hr

Actual efficiency on energy input = 39.33 %

Case : Back pressure Turbine

Enthalpy of input steam at 40 kg/cm2a & 350 oC = 737.9 kcal / kg

Enthalpy @ outlet conditions : 4.5 kg/cm2a & 148 oC = 655.2 kcal/kgm

Saturation temperature = 147.2oC

Net energy input = steam rate (kg/hr) *Δ Enthalpy kcal /hr

= 57960 * (737.9 – 655.2) = 57960 *82.7

= 4793292 kcal /hr

Carnot cycle efficiency = (350 – 147.2) x 100 /(350+273) = 32.55 %

Energy equivalent power generated = 2000 * 0.746 * 860 = 1283120 kcal /hr

Actual efficiency on energy input = 26.77

Case : Back pressure Turbine –with exhaust steam to process.

Latent heat of steam consumed in
process = Steam rate x Latent heat (@4.5 kg/cm2a, 147.2 oC)

= 57960 x 507.1 = 29391516

Total Energy utilized = 1283120 + 29391516 = 30674636

(power) (Heat)

Overall system efficiency = 71.72 %

This example shows the practical energy efficiency improvement which may be achieved by using the combined heat power cycle as shown above.

Steam system efficiency.

In conventional process plants, steam boilers are used to generate steam for the process and generate power required by the process using steam turbine. The demand scenario of power and steam (heat) is always dynamic and depends on a number of process parameters such as through put (capacity utilization), feed quality, operating severity, down stream operations etc.

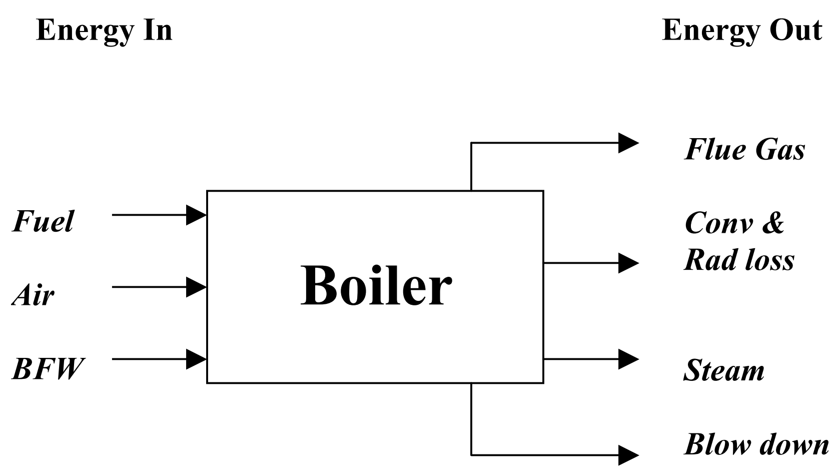
A critical analysis of the process shall reveal that the overall steam system efficiency is a function of

- Boiler efficiency
- Turbine efficiency
- Steam transmission efficiency
- Individual steam consuming device efficiency
- Specific consumption of process steam in processes.
- Steam losses due to leaks, blow downs, flashing venting etc.

For maintaining steam system efficiency, it is imperative to monitor all the above factors meticulously. Boiler efficiency is a function of excess air, burner efficiency, type of fuel used , convection and radiation losses and blow down losses.

Boiler feed water quality also plays an important role in heat transfer in the boiler water tubes, economizer section and super heating section. Hence boiler efficiency is a function of economizer efficiency, water evaporation efficiency in the boiler and super heater efficiency. A simple method of determining boiler efficiency is by indirect method in which the sum of energy losses is determined from boiler operating data as % of energy input and subtracted from 100 to get the boiler efficiency. This method is good enough for monitoring purposes. **Figure 4** shows the various losses associated with boiler efficiency and the table shows a typical boiler efficiency program output.

Fig 4. Energy Input / Output Diagram - Boiler



A heat balance of boiler indicates the type of heat losses which could be used for identifying areas of improvement . A number of parameters affect the thermal efficiency of the boiler. They are

- Sensible heat in flue gases
- Convection and Radiation losses.
- Unburnt Combustibles in flue gases.
- Unburnt combustibles in refuse
- Blow Down losses etc

Sensible heat loss in flue gases:

This loss is the largest in a boiler and represents the heat carried away by the flue gases and released to the atmosphere without doing any useful work . Hence it is obvious that if more than the required quantity of air is used in a boiler , more will be the loss in flue gases and the thermal efficiency of the boiler will be reduced correspondingly.

Convection and Radiation losses :

This depends on the temperature of boiler's external surface . Quantity of heat lost by convection and radiation is a function of shell temperature and wind velocity. This loss occurs basically due to poor insulation and poor design characteristics .

If the refractory lining and other insulating materials are not in good condition , these losses will tend to increase and reduce the thermal efficiency of the boiler. Hence it is imperative that the surface temperature at various sections should be monitored periodically and corrective actions taken to minimize this loss.

Unburnt matter in flue gas:

When combustion is incomplete , part of the carbon present in the hydro carbon fuel may be converted into carbon monoxide instead of carbon-di-oxide. When the carbon content of the fuel is not fully burnt to carbon-di-oxide, there will be substantial energy loss to the atmosphere from the flue gases (besides atmospheric pollution) , the loss being proportional to the amount of carbon monoxide produced .

This could be estimated by a carbon balance across the boiler taking into consideration carbon content in fuel , carbon-di-oxide and carbon monoxide in the flue gases and carbon content in the refuse.

Unburnt matter may show itself in the flue gas in the form of black smoke which represents presence of carbon particles in the flue gas. It may also show itself as Carbon monoxide in the flue gas While every kg of carbon present in the flue gas represents a loss of 8084 kcals , every kg of Carbon partially oxidized to CO results in a loss of 5654 kcals . This situation could be controlled with optimum excess air input to the boiler.

Blow Down Losses:

Dissolved salts find entry to the boiler through make-up water which is continuously fed by the Boiler Feed Water pump (bfw) . In the boiler , there is continuous evaporation of water into steam . This leaves behind the salts in the boiler. Concentration of these salts , tend to increase in the boiler drum and starts precipitation after certain concentration level .

Water from the drum should be blown down to prevent concentration of salts beyond certain limits . Since the water in the boiler drum is at a high temperature (equivalent to it's saturation temperature at boiler drum pressure) , excess blow-down will lead to **loss of energy known as 'blow-down losses** ' . Blow-down rate reduces the boiler efficiency considerably as could be seen from the figure 3. Hence it is imperative that blow-down rates are optimized ,based on the hardness levels of boiler drum water which is a function of the operating pressure.

The program output given in the Annexure 1 shows, how various losses are calculated for the boiler. Basis for the energy evaluation is unit weight of fuel. For determining the quantity of energy lost in flue gas, air input quantity is calculated by the excess oxygen leaving the stack as given by O2 monitor readings or flue gas analysis (Orsat Analysis).

Typical energy losses in a boiler plant is shown in **fig 5**. These losses are

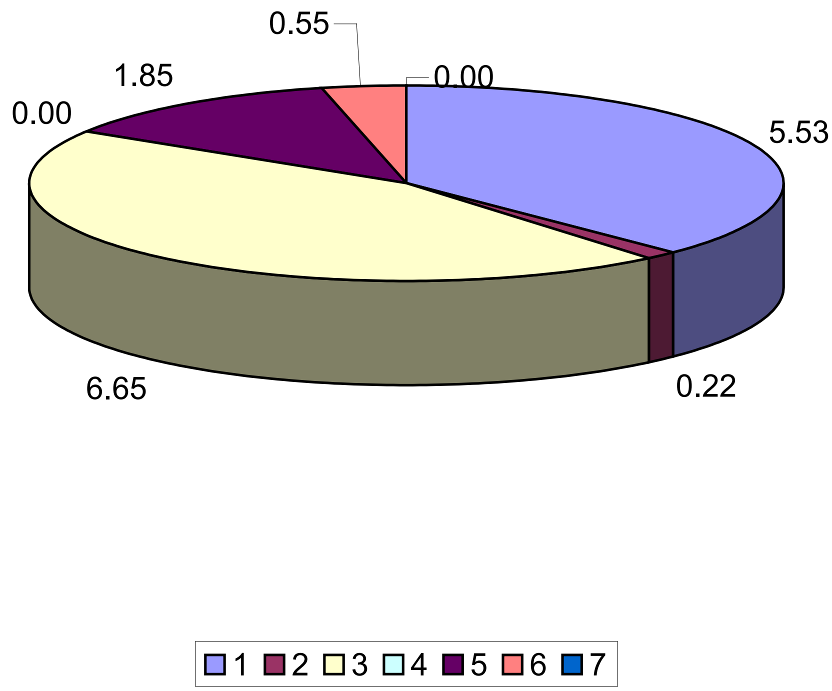
1.Dry gas loss
2.Air moisture loss
3. Combustion moisture loss.
4.Fuel moisture loss

5.Convection and Radiation losses

6.Blow down loss.

7. Loss due to incomplete combustion of fule.

Fig 5. Energy losses in steam generation using liquid fuel

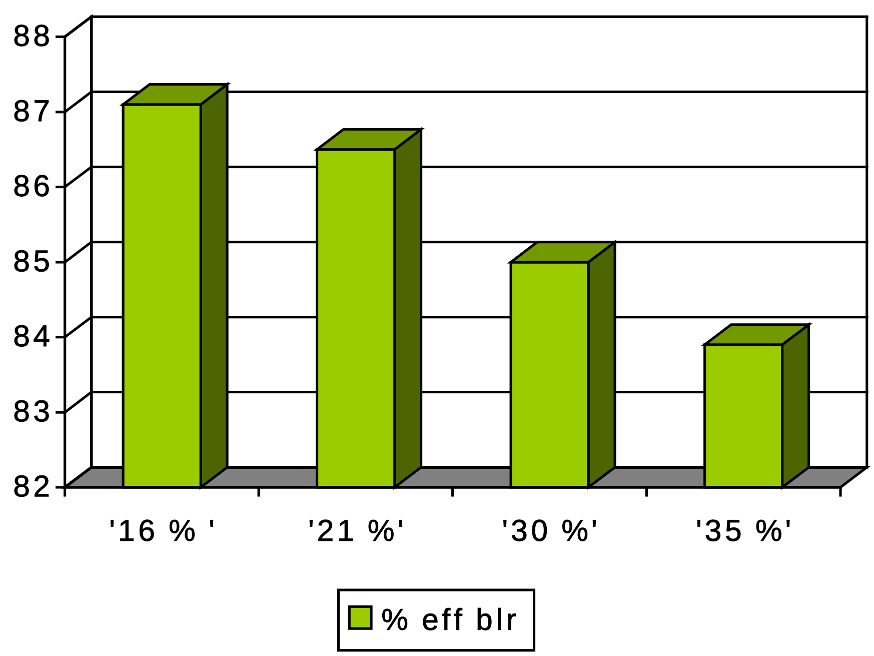


Dry gas loss is controlled by the excess air used in the combustion of boiler fuel. This is the energy picked up by CO_2, excess O_2 and N_2 from ambient temperature to stack temperature.

Combustion moisture is controlled by the type of fuel used. High Carbon / Hydrogen ratio of the fuel minimizes combustion moisture. But the calorific value of high carbon fuel will be lower than lower Carbon fuel. Hence type of fuel used in the boiler determines this loss. An optimum fuel mix (considering the cost) may be used to minimize this loss.

In case of solid fuels, **Ash content** in the fuel reduces the boiler efficiency for the same steam generation as shown in **fig 6**.

FIG 6. Ash content in Coal vs Efficiency (LHV)



Since the cost of coal is determined by the ash and sulfur content present in the coal, it is possible to optimize the coal blend that will minimize the fuel cost for the same steam generating capacity.

Other two controllable losses are Convection and Radiation Loss and Blow down losses. Convection and Radiation losses may be controlled by periodic Boiler Shell temperature survey.

Convection and Radiation losses .

For this purpose, the entire boiler shell may be divided into a number of sections and the average temperature physically measured using a digital thermo meter or contact thermometer. During the survey, wind velocity in the vicinity of the section may be measured using an anemometer. Area of the section surveyed is also measured

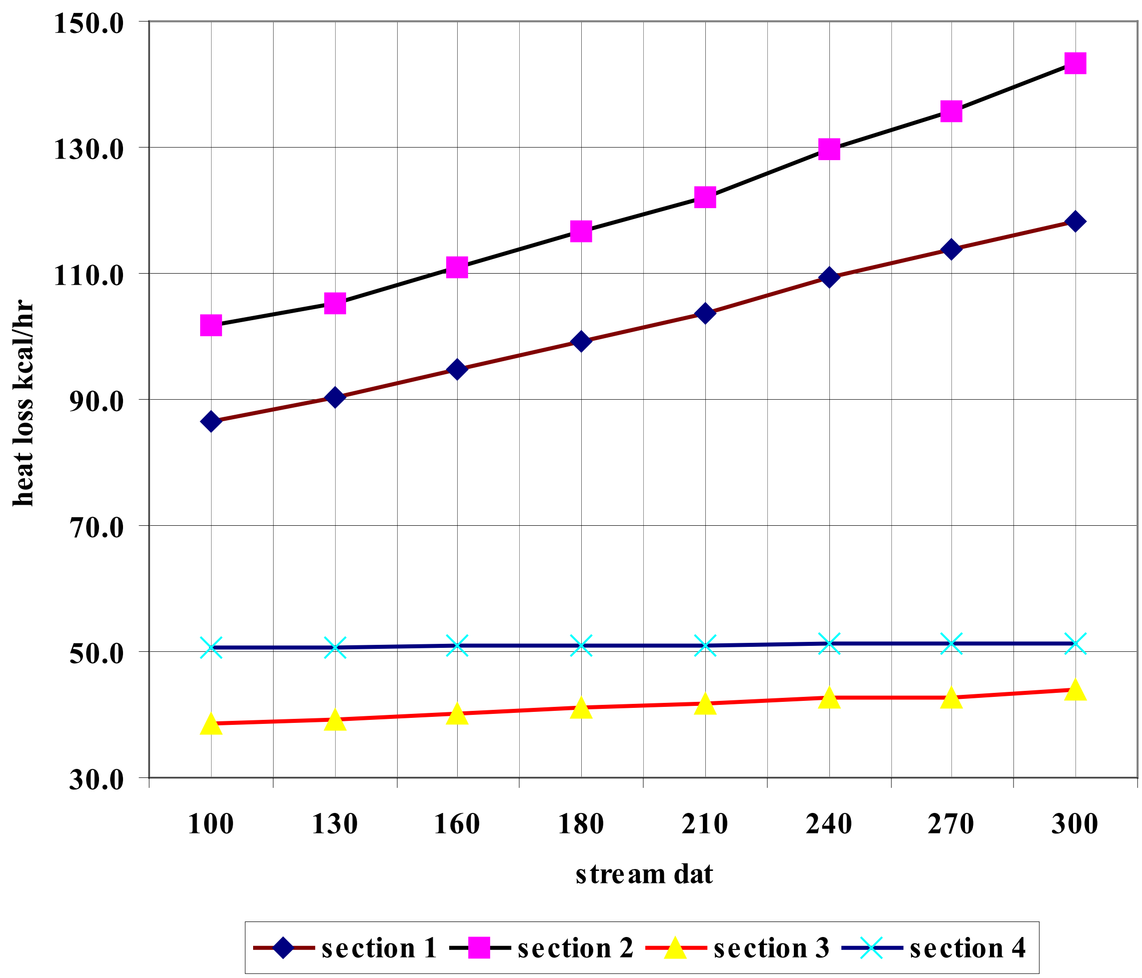
From the shell temperature and the wind velocity, heat loss from the section is give by standard programs in kcal / hr / m2 / oC. Multiplying this coefficient by the area and the measured temperature, the convection and radiation loss is obtained as kcal /hr. The sum of these values will represent total heat loss from the boiler shell due to convection and radiation.

Annexure II gives the output of the program used to calculate the convection and radiation loss from a boiler. Periodic monitoring of the convection and radiation loss from boiler shall reveal the boiler refractory / shell condition.

When any hot spot develops in the **boiler shell**, heat loss will be more and boiler efficiency will start dropping down. Using convection and radiation loss historic data , it is possible to estimate the boiler efficiency deterioration as a function of time for taking corrective action.

Fig 7 shows how the convection and radiation loss survey results are used for developing a time dependant model.

Fig 7. Heat Loss from Boiler Sections



It may be noted from the figure that convection and radiation loss from the sections 1 and 2 show an increasing tendency, while other sections are in tact. Hence necessary corrective action may be taken at the appropriate time to restore the heat loss to the base level.

Blow down losses :

Dissolved salts find entry to the boiler through make-up water which is continuously fed by the Boiler Feed Water pump (bfw) . In the boiler , there is continuous evaporation of water into steam . This leaves behind the salts in the boiler. Concentration of these salts , tend to increase in the boiler drum and starts precipitation after certain concentration level .

Water from the drum should be blown down to prevent concentration of salts beyond certain limits . Since the water in the boiler drum is at a high temperature (equivalent to it's saturation temperature at boiler drum pressure) , excess blow-down will lead to **loss of energy known as 'blow-down losses** ' .

Blow-down rate reduces the boiler efficiency considerably as could be seen from the **figure 8**. Hence it is imperative that blow-down rates are optimized, based on the hardness levels of boiler drum water which is a function of the operating pressure.

In boiler operation practice, rate of blow down increases with steam pressure as the scaling tendency increases with high temperature because the hardness limits are very stringent .While **figure 8** gives an estimate of % blow down on losses ,the same may be calculated from the hardness levels of make-up water , flow rate ,steam generation rate and the hardness level of drum water (observed).

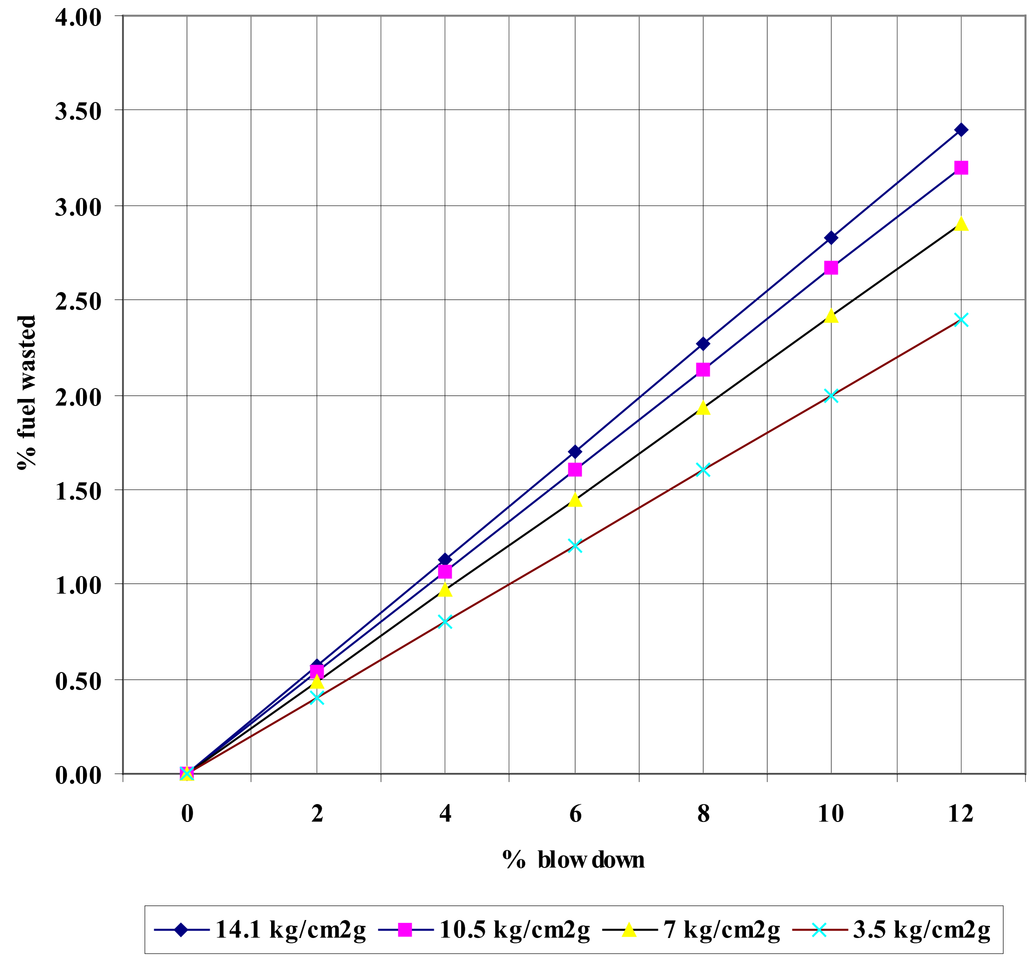
Model given below could be used to determine the maximum limits of TDS (total dissolved solids) that could be tolerated in the boiler drum operating at various pressures . The correlation developed by the author is based on American Boiler Manufacturers' Association code of practice.

However, if the limits stipulated by the Boiler Designer is less than this value , the lower of the two must be taken as the tolerance limit.

$$TDS = 3.306188 \times 10^{-6} \times Pr^{3} - 5.825077 \times 10^{-3} \times Pr^{2} + 2.174783 \times 10^{-2} \times Pr + 3621.537$$

Where TDS is the permissible Total Dissolved Solids in ppm at the boiler drum and Pr is the drum pressure in psig.

Fig 8. Impact of Blow Down Rate of fuel loss.



The quantity of blow down to maintain the given status of boiler water in terms of TDS is determined by the material balance of solids across the boiler drum as given in the figure below.

Blow Down Rate Estimation :

For estimating the boiler drum blow down rates, we will use following nomenclatures are used.

Let

F = feed water in t/hr

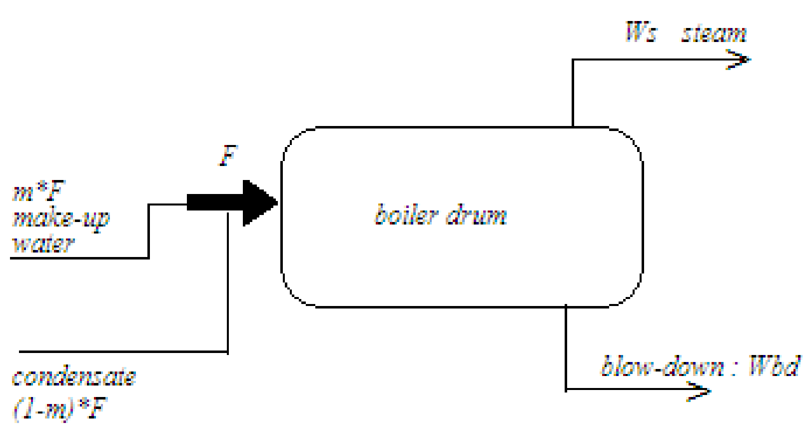
C_m = Concentration of TDS in make-up water in ppm

C_f = Concentration of TDS in feed water in ppm.

C_b = Concentration of TDS in blow-down water

m = weight fraction of make-up water in feed water.

Typical Blow - Down Rate Estimation



For establishing the blow-down rate, a material balance on TDS is developed as shown.

TDS balance:

$W_{bd} * C_b = F * m * C_m$ -------------------i

$F = W_s + W_{bd}$ ---------------------ii

Therefore equation i may be written as

$W_{bd} * C_b = (W_s + W_{bd}) * m * C_m$ -----iii

If C_f is the TDS present in the combined feed water to the boiler, above equation may be written as

$W_{bd} * C_b = (Ws + W_{bd}) * C_f$ -----iv

If more than the required quantity (i.e W_{bd} t/hr) is blown down, the excess quantity will result in lower boiler efficiency . Hence, it is imperative that boiler blow down rate is monitored continuously for achieving high boiler efficiency. An optimal blow down rate may be calculated taking into consideration the impact of high TDS on poor heat transfer vs boiler efficiency.

In this section practical methods of improving the boiler efficiency was discussed with examples. Program outputs are shown in the **Annexure I & II.**

Improving steam system efficiency:

Steam system efficiency may be improved by

- Minimizing steam transmission losses from the steam generating plant to the consuming sections
- Minimizing steam leaks in the plant area and periodic monitoring and control of steam leaks
- Condensate recovery and
- Flash steam recovery.

Steam transmission losses can be minimized by using adequate steam insulation thickness in the steam lines and periodic monitoring of insulation efficiency by surveys. Slightly super heated steam must be used while transferring steam to far off distances, to minimize steam condensation in the steam line itself.

One practical way of determining the line losses is to take the steam temperature readings at various plant battery limits and calculating the energy loss from enthalpy data, Stefan Boltzmann and Langmuir equations. A detailed steam line insulation survey is imperative in steam intensive sections to identify critical areas for corrective action. Typical steam line audit survey data and observation is given in **Annexure III.**

Steam leak survey.

There are many methods of evaluating steal leaks from pin holes whose diameter is known. Following table shows the steam leak from a known hole diameter and pressure.

As the hole diameter increases, the issue of steam to atmosphere is proportional to the square of the hole diameter, for the same header pressure. Similarly, when the pressure inside the header increases, steam loss also tends to increase.

Steam Loss Chart

Monetary loss due to blowing traps in the system can have a dramatic effect on the bottom line. The chart below is based a steam cost of $ 8.00/1,000 lbs. of steam produced.

Orifice Size	5 PSI	15 PSI	30 PSI	50 PSI	75 PSI	100 PSI	125 PSI
.03	130.66	197.74	296.62	431.32	594.56	62.44	928.33
.125	520.24	790.98	1,186.46	1725.27	2,378.23	3,049.77	3,713.34
.25	2,080.96	4,745.85	3,163.90	6,901.13	9,512.94	12,199.07	14,855.30

To compute steam loss through an orifice:

24.24 x PSIA x (diameter of orifice in inches)

To convert psi to PSIA: add 14.7. Therefore, 100 PSI steam is 114.7 PSIA (absolute)

Example: Compute steam loss through a 1/8" orifice at 100 PSI steam?

24.24 x 114.7 x (.125 x .125) = 43.44

To estimate total cost of system-wide loss: Multiply the steam loss by hours of operation, steam cost (usually between $4.00 and $14.00 per 1,000 lbs.) and by the number of faulty traps.

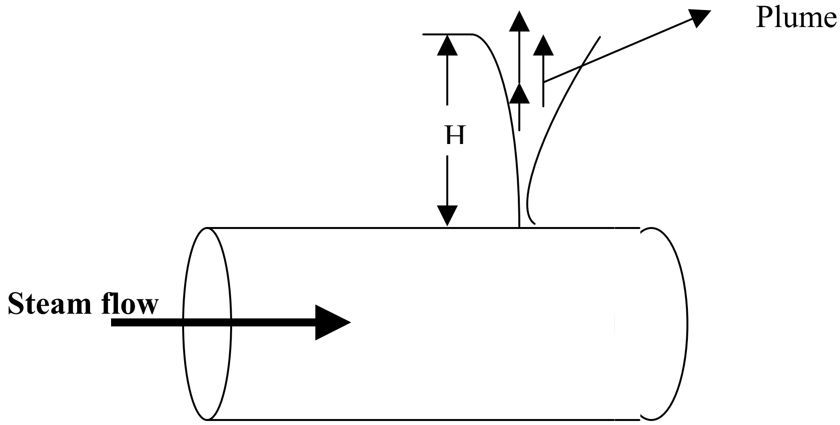
Another method of identifying steam leak is to measure the plume length of the steam length, leaking from a spot and use the following equation to assess the approximate quantity of steam leak.

Steam Leaks are categorized into 5 types as given below.

category	*type of leak.*
a	valve/trap flange leak
b	valve gland leak.
c	pin hole leak
d	trap blowing
e	Venting from vents / Desuper Heating/Depressurizing Stations.

stmleak = 2.5678 * EXP(1.845 * plume)
where
plume is the height of plume in meters and
stmleak is the steam leak from the measured section in kg/hr.

Figure given in the next page shows the layout of a pipe line carrying steam. Whenever any hole develops on the surface, steam will start leaking through it. The height of plume may be measured by a steel tape or a metre scale as accurate as possible. Another method of measuring the plume height is to hold a light metal plate perpendicular to the direction of leak and measure the height at which the leaking steam hits the surface with least force.



H = plume height in metres

A detailed survey carried out in the plant shall reveal the type of steam leak that is dominant over others. Quality of gasket and valve gland materials play an important role in flange gasket and valve gland leaks.

Besides, workmanship related to proper alignment, tightening etc also tend to increase the leak from these sections. Corrective actions may be taken to avert steam loss due to leaks using the steam loss survey data. **Annexure III** shows the output of a steal leak survey with minimum readings. A critical analysis of the type of steam leaks may be used for improving material quality or workmanship or both based on the survey results.

Conclusion :

In this paper a number of methods related to steam system management and energy efficiency improvements have been high lighted. A number of practical examples and cases have been covered. Since this is an area of continuous improvement and the controlling techniques vary with cost of energy from time to time, it is imperative to adapt to the changes as and when called for. Only by this approach , Steam system efficiency shall be maintained at the peak.

RESULTS - BOILER EFFICIENCY		
I.Fuel Data		
Carbon		0.870
Hydrogen		0.125
Moisture		0.000
Oxygen		0.000
Sulfur		0.005
Nitrogen		0.000
Ash		0.000
II.Observed Process parameters		
Boiler Duty mmkcal/h		60
% Unburnt matter in refuse		0
Amb.Temperature oC		30
Flue Gas Temp oC		180
Relative Humidity		78
Excess Air		20
High Heating Value	kcal/kgm	11325
Low Heating Value	kcal/kgm	10650
III.Energy Losses		
a.Dry Gas Loss		5.53
b.Air Moisture loss		0.22
c.Combustion Moisture Loss		6.65
d.Fuel Moisture Loss		0.00
e.Radiation Loss		1.85
f.Blow down Losses		0.55
g.Loss due to combustib		0.00
Total Loss % (dry basis)		14.58
IV.Boiler Efficiency		
a.EFFICIENCY HHV basis		**85.42**
b.EFFICIENCY LHV basis		**90.84**

NOTE:

a.Air misture loss is due to moisture present in combustion air.

b.Combustion moisture is due to combustion of H_2 in fuel to water.

c.Fuel moisture is due to presence of water in the fuel fired.

d.Radiation loss is due to heat loss from the exposed boiler surface.

e.Calorific Value of combustibles in refuse is taken as 7800 BTU/Lb.

Annexure II

HEAT LOSSES FROM HOT PRODUCT AND STEAM LINES USING STEFAN BOLTZMANN & LANDMUIR EQUATIONS.

Unit Name	pipe_no/ code	length metres	dia in mm	Surface Temp oC	insuln in mm	fluid temp in oC	Conv. Loss kcal/ /hr/m2	Rad. Loss kcal /hr/m2	Total Losses '000 kcal/hr	Surface temp oC temp oC
crude	FSS401	300	250	75	50	150.0	514.4	217.0	248.6	75.0
crude2	FSS403	350	150	65	50	130.0	375.7	160.8	152.0	65.0
Vacuum	FSS401	300	100	70	60	200.0	443.9	188.3	135.1	70.0
Vac	FSS401	300	200	75	80	250.0	514.4	217.0	255.7	75.0
DC 1	FSS401	300	180	80	90	300.0	586.8	246.9	291.5	80.0
DC 3	FSS401	300	200	85	90	340.0	661.0	278.2	346.6	85.0
ARU	FSS401	300	190	65	80	250.0	375.7	160.8	182.4	65.0
WHB	FSS401	300	180	65	80	265.0	375.7	160.8	177.2	65.0
OMS	LSHS	1000	200	85	100	130.0	661.0	278.2	1216.1	85.0
OMS	Bit 200	1000	150	85	100	140.0	661.0	278.2	1064.1	85.0
UTIL	ut4001	2000	150	80	25	230.0	586.8	246.9	1079.5	80.0
							Total Energy Loss from system '000 kcal/hr		5148.6	

Note:
1.Ambient Temperature used in the program in oC : 30
2.Wind velocity for the program in km/h : 7.5

Annexure III

STEAM LEAK SURVEY

UNIT CODE	TAG NO	LEAKAGE CATEGORY	PLUME ht (metre)	STM Loss kg/h	Remarks
I	1	a	2.00	102.83	
I	2	a	1.50	40.88	
I	3	c	0.67	8.84	
I	4	b	2.67	353.97	
I	5	d	1.20	23.50	
I	6	a	0.96	15.09	
I	7	a	0.65	8.52	
I	8	b	1.12	20.28	
II	9	b	1.21	23.94	
II	10	c	0.76	10.44	
II	11	a	0.32	4.63	
II	12	a	0.21	3.78	
II	13	b	1.11	19.91	
III	14	b	0.32	4.63	
III	15	c	0.54	6.95	
III	16	a	0.96	15.09	
III	17	a	1.23	24.84	
III	18	a	1.08	18.83	
III	19	b	0.45	5.89	
III	20	b	0.23	3.93	
III	21	b	0.98	15.66	
III	22	a	1.05	17.82	
III	23	a	0.99	15.95	
IV	24	a	1.21	23.94	
IV	25	b	0.91	13.76	
IV	26	c	0.45	5.89	
IV	27	b	0.99	15.95	
IV	28	a	1.25	25.77	
IV	29	a	1.99	100.95	

Total Steam Leaks in kg/h	952.4613
Equivalent Fuel in kg/h	68.57722
Note : Steam Enthalpy for estimation (kcal/kg) : 720	
Fuel Calorific Value in kcal/kg :	10000