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Design of Steam Pipe Layout and Hanger Support in Thermal Power Station

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Abstract- ***Steam piping layout in thermal power station is used to transfer steam from one area to another area to perform the work. The present paper is related to steam piping layout between Boiler outlet & Turbine inlet i.e. main steam line. The steam piping layout directly impacts the drop in pressure of the steam. The ideal condition is that the pressure require at turbine inlet should be equal to boiler super heater out let pressure. But due to various factors there is 7 to 9 Kg/cm2 pressure drop. By changing the steam piping layout pressure drop can be minimized. The slight change in pressure drop result less power require to increase the pressure of steam (i.e. Boiler feed Pump) throughout life cycle of power plant. It means auxiliary consumption can be reduce by doing modification in steam piping layout. The change in piping layout also changes the hanger support position.***

Keywords: Steam piping layout, main steam line, Pressure drop, Hanger support

I. INTRODUCTION

Generally, in thermal power station steam piping layout of main steam piping consist of combination of vertical & horizontal piping. To connect vertical and horizontal pipes 90^0 bend is used but 90^0 bend create major role in steam pressure drop. So wherever possible (considering expansion loops) vertical and horizontal pipe replace by incline pipe having 30^0 to 45^0 bends result steam pressure drop can be minimized. In this paper, pressure drop calculation in 90^0 bend & 45^0 bend is calculated & compared. Also for Hanger & support, forces exerted on incline piping are calculated.

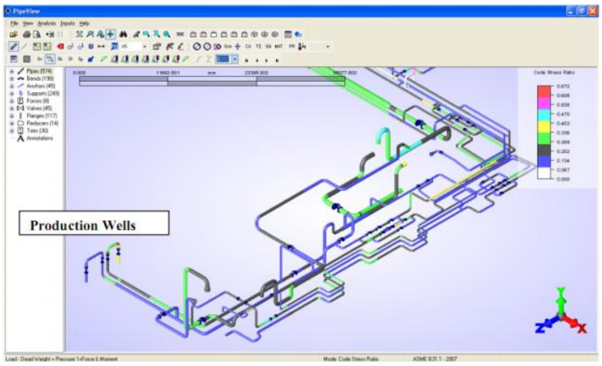

Fig.1 Steam piping layout in (coal base) Thermal Power station.

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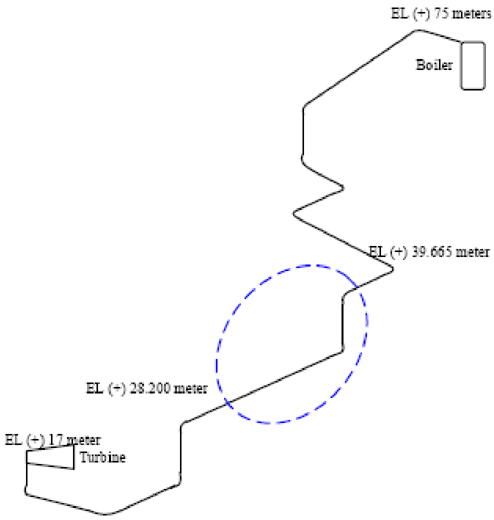

Fig.2 Existing steam piping layout (left hand side) from boiler to turbine

In fig. 2 there are 12 nos. of 90^0 bends. Dotted circle represent area where incline can be used its detail is shown in fig. 3

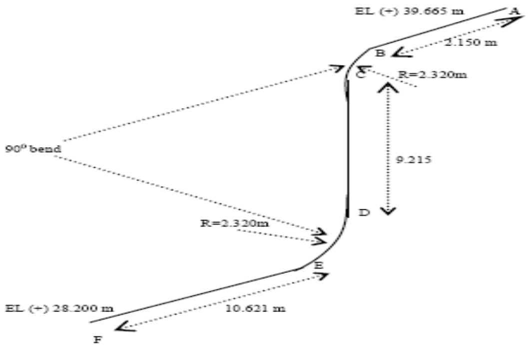

Fig.3 Existing steam piping layout (left hand side) from EL (+) 39.665 meter to 28.200 meter.

In fig. 3, ratio of radius (r)/ Pipe Diameter (D) is 3

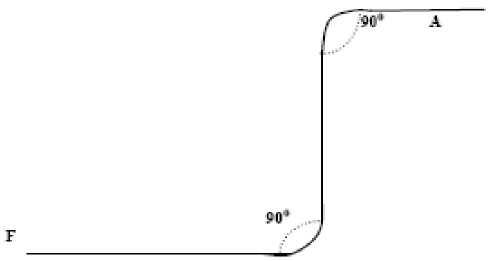

Fig.4 Side view of existing steam piping layout (left hand side) from EL (+) 39.665 meter to 28.200 meter.

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II. CALCULATION OF PRESSURE DROP IN PIPE

Calculation of pressure drop between point A to F refer figure.3

Darcy-Weisbach Equation (Pipe friction)

$$h_L = h_{Lpipe} + h_{Lfitting} \quad \text{.........(i)}$$

$$h_{Lpipe} = \lambda L V^2 \ / \ D2g \quad \text{......(ii)}$$

$$h_{Lfitting} = \sum k_{fitting} \ V^2 \ /2g \quad \text{...(iii)}$$

h_L - Pressure drop (m)
λ - pipe friction coefficient (0.00015)
L- Length of pipe (m),
V- Velocity of steam (45.14m/sec)
D- Inner dia. of pipe (0.336m)
k- Resistance coefficient for fitting

In fig. 3 A to B, C to D, E to F pipe are straight pipes so friction in that area is-

$$h_{Lpipe} = \frac{\lambda(L_{(AB)} + L_{(CD)} + L_{(EF)})V^2}{D2g}$$

$$h_{Lpipe} = \frac{0.00015 \times (2.150 + 9.215 + 10.621) \times 45.14^2}{0.336 \times 2 \times 9.81}$$

h_{Lpipe} = 1.019 m

In fig. 2: B to C & D to E are 90^0 bend so friction in that area is-

$$h_{Lfitting} = \frac{(k_{(BC)} + k_{(DE)}) \times V^2}{2g}$$

From table A- value of k for long radius 90^0 bend & 12-16 inch nominal pipe size is 0.17

$$h_{Lfitting} = \frac{(0.17 + 0.17) \times 45.14^2}{2 \times 9.81}$$

$h_{Lfitting}$ = 35.310 m

Putting the above calculated value of h_{Lpipe} & $h_{Lfittings}$ in (i)

$h_L = h_{Lpipe} + h_{Lfitting}$

h_L = 1.019 + 35.310= 36.329 m

$$\text{Drop in pressure} = \frac{h_L \times \text{Density}}{10000}$$

$$\text{Drop in pressure} = \frac{36.329 \times 73.22}{10000}$$

Drop in pressure = 0.266 kg/cm² ....(iv)

From above calculation, pressure drop between A & F is 0.266 kg/cm².

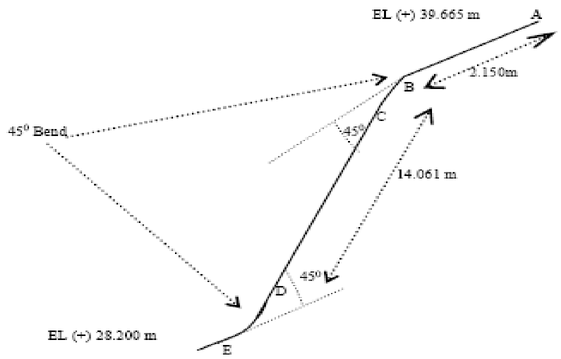

Fig. 3 Proposed steam piping layout (left hand side) from EL (+) 39.665 meter to 28.200 meter.

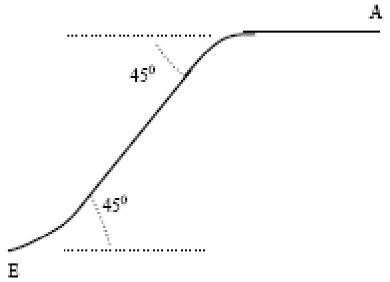

Fig. 4 Side view of proposed steam piping layout (left hand side) from EL (+) 39.665 meter to 28.200 meter.

Proposed piping layout in which wherever possible (considering expansion loop) 90^0 bend is replace by 45^0 bend. Pressure drop calculation for this proposed layout is as below

In fig. 3 A to B, C to D pipe are straight pipes so friction in that area is-

$$h_{Lpipe} = \frac{\lambda(L_{(AB)} + L_{(CD)}) \times V^2}{D2g}$$

$$h_{Lpipe} = \frac{0.00015 \times (2.150 + 14.061) \times 45.14^2}{0.336 \times 2 \times 9.81}$$

h_{Lpipe} = 0.751 m

In fig. 3: B to C & D to E are 45^0 bend so friction in that area is-

$$h_{Lfitting} = \frac{(k_{(BC)} + k_{(DE)}) \times V^2}{2g}$$

From table A- value of k for long radius 45^0 bend & 12-16 inch nominal pipe size is 0.14

$$h_{Lfitting} = \frac{(0.14 + 0.14) \times 45.14^2}{2 \times 9.81}$$

$h_{Lfitting}$ = 29.079 m

Putting the above calculated value of h_{Lpipe} & $h_{Lfittings}$ in (i)

$h_L = h_{Lpipe} + h_{Lfitting}$

h_L = 0.751 + 29.079= 29.830 m

$$\text{Drop in pressure} = \frac{h_L \times \text{Density}}{10000}$$

$$\text{Drop in pressure} = \frac{29.83 \times 73.22}{10000}$$

Drop in pressure = 0.218 kg/cm².....(v)

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Friction Losses in Pipe Fittings Resistance Coefficient K (use in formula hf = Kv²/2g)														
Fitting		LD	Nominal Pipe Size											
			½	¾	1	1¼	1½	2	2½-3	4	6	8-10	12-16	18-24
			K Value											
Angle Valve		55	1.48	1.38	1.27	1.21	1.16	1.05	0.99	0.94	0.83	0.77	0.72	0.66
Angle Valve		150	4.05	3.75	3.45	3.30	3.15	2.85	2.70	2.55	2.25	2.10	1.95	1.80
Ball Valve		3	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04
Butterfly Valve								0.86	0.81	0.77	0.68	0.63	0.35	0.30
Gate Valve		8	0.22	0.20	0.18	0.18	0.15	0.15	0.14	0.14	0.12	0.11	0.10	0.10
Globe Valve		340	9.2	8.5	7.8	7.5	7.1	6.5	6.1	5.8	5.1	4.8	4.4	4.1
Plug Valve Branch Flow		90	2.43	2.25	2.07	1.98	1.89	1.71	1.62	1.53	1.35	1.26	1.17	1.08
Plug Valve Straightaway		18	0.48	0.45	0.41	0.40	0.38	0.34	0.32	0.31	0.27	0.25	0.23	0.22
Plug Valve 3-Way Thru-Flow		30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36
Standard Elbow	90°	30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36
	45°	16	0.43	0.40	0.37	0.35	0.34	0.30	0.29	0.27	0.24	0.22	0.21	0.19
	long radius 90°	16	0.43	0.40	0.37	0.35	0.34	0.30	0.29	0.27	0.24	0.22	0.21	0.19
Long radius 45⁰ bend		10	0.31	0.29	0.27	0.25	0.24	0.22	0.21	0.19	0.17	0.16	0.14	0.14
Standard Tee	Thru-Flow	20	0.54	0.50	0.46	0.44	0.42	0.38	0.36	0.34	0.30	0.28	0.26	0.24
	Thru-	60	1.62	1.50	1.38	1.32	1.26	1.14	1.08	1.02	0.90	0.84	0.78	0.72
90 Bends, Pipe Bends, Flanged Elbows, Butt-Welded	r/d=1	20	0.54	0.50	0.46	0.44	0.42	0.38	0.36	0.34	0.30	0.28	0.26	0.24
	r/d=2	12	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.20	0.18	0.17	0.16	0.14
	r/d=3	12	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.20	0.19	0.18	0.17	0.15
	r/d=4	14	0.38	0.35	0.32	0.31	0.29	0.27	0.25	0.24	0.21	0.20	0.18	0.17
	r/d=6	17	0.46	0.43	0.39	0.37	0.36	0.32	0.31	0.29	0.26	0.24	0.22	0.20
	r/d=8	24	0.65	0.60	0.55	0.53	0.50	0.46	0.43	0.41	0.36	0.34	0.31	0.29
	r/d=10	30	0.81	0.75	0.69	0.66	0.63	0.57	0.54	0.51	0.45	0.42	0.39	0.36

Table A: Resistance coefficient k

Description	Pressure drop (Kg/cm2)
Existing piping layout with 90^0 bend in 2 nos.	0.266
Proposed piping layout with 45^0 bend in 2 nos.	0.218
Differences in pressure drop in 2 bends	0.048
Difference in pressure drop in 1 bend	**0.024**

III. CALCULATION OF LOAD EXERTED ON HANGER IN PROPOSED PIPING LAYOUT

Span Between Supports																		
Nom. Pipe Size (In.)	1	1½	2	2½	3	3½	4	5	6	8	10	12	14	16	18	20	24	30
Span Water (Ft.)	7	9	10	11	12	13	14	16	17	19	22	23	25	27	28	30	32	33
Steam, Gas, Air (Ft.)	9	12	13	14	15	16	17	19	21	24	26	30	32	35	37	39	42	44

Table B: Distance between hanger supports

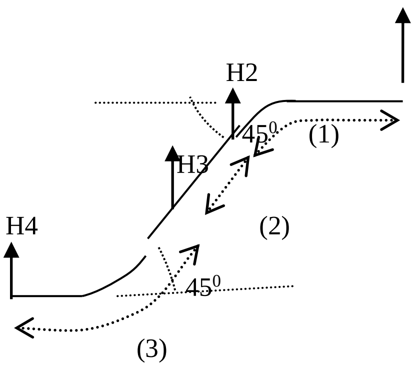


Fig.5 Position of hanger support & part (1), (2), (3)

In fig. 5: H1, H2, H3 & H4 are the hanger supports
To calculate the forces exerted on proposed piping layout shown in fig. 4 it need to draw free body diagram.

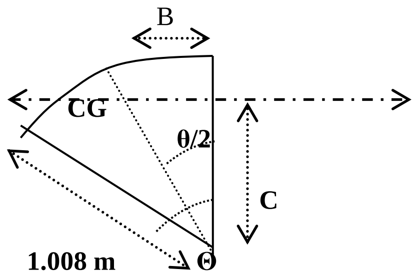
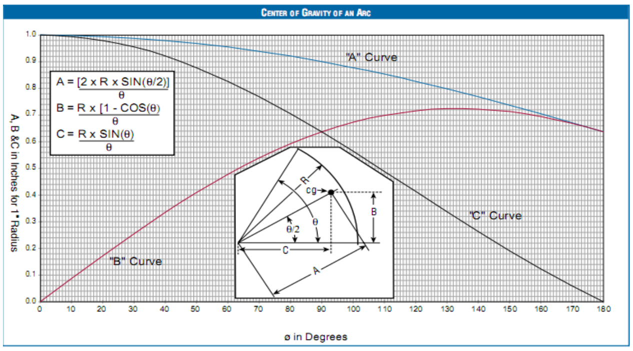


Fig.6 Center of Gravity (CG) of 45^0 bends

In fig 6 Center of gravity (CG) of θ=45^0 bend is calculated from graph A



Graph A: Center of gravity of an arc

From Graph A:
C=0.9 x 1.008= 0.91 m
B=0.38 x 1.008= 0.38 m
From table B: distance between hanger H_1 & H_2 for 12 inch diameter pipe in 30 feet i.e. @ 10 meter. When change in direction of the piping of any critical system occur between hangers, it consider good practice to keep the total length of pipe between the supports less than ¾ the full span in table B. The hanger should be located immediately adjacent to any change in direction of piping.
So distance between hangers H_1 & $H_{2'}$ is 10 x ¾ =7.5 m
Length of straight pipe (2.150) + Length of bend (0.792) + Length of inclined pipe (4.558) =7.500 m shown in fig. 7

W= Weight of pipe + insulation

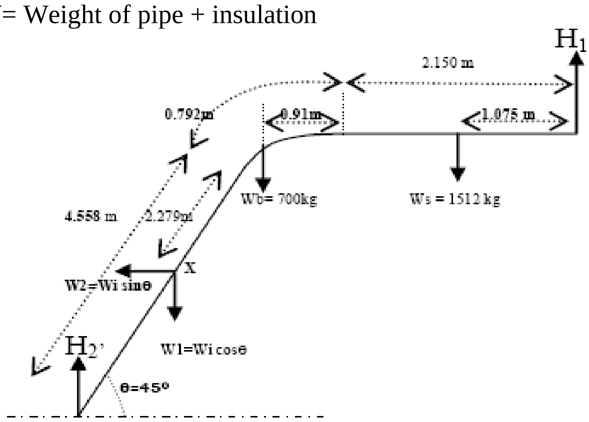


Fig.7 Showing all supporting forces & pipe weight of part (1)

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In fig. 7, Ws, Wb & Wi are the weight of straight pipe, 45^0 bend & inclined pipe resp.
As inclined pipe is 45^0 inclined then its force resolved into two components i.e. vertical (W1) & horizontal (W2).

Considering section between H_1 & $H_{2'}$ i.e. part (1)

W1= Wi' x Cosθ =3150 x Cos 45^0
W1= 2227 kg

W2= Wi' x Sinθ = 3150 x Sin 45^0
W2=2227 kg

To determine weight distribution between H_1 & $H_{2'}$
$\sum M_{H1} = 0$,

1.075xWs+3.06xWb+4.75xW1-6.36x$H_{2'}$=0

1.075x1512+3.06x700+4.75x2227-6.36x$H_{2'}$=0

$H_{2'}$= 2255.6 kg………….. (vi)

$\sum M_{H2'} = 0$

1.611xW1+3.30xWb+5.29xWs-6.36xH_1=0

1.611x2227+3.30x700+5.29x1512-6.36xH_1=0

H_1=2184.933 kg………………(vii)

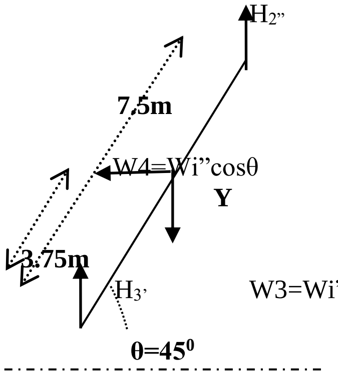

Fig.7 Showing all supporting forces & pipe weight of part (2)

W3= Wi" x Cosθ =5100 x Cos 45^0
W3= 3606.24 kg

W4= Wi" x Sinθ = 5100 x Sin 45^0
W4=3606.24 kg

To determine weight distribution between $H_{2''}$ & $H_{3'}$
$\sum M_{H2''} = 0$,

W3 x 2.65 – $H_{3'}$ x 5.30 = 0

3606.24 x 2.65 – $H_{3'}$x 5.30=0

$H_{3'}$= 1803.12 kg …………(viii)

$\sum M_{H3'} = 0$,

W3 x 2.65 – $H_{2''}$ x 5.30 = 0

3606.24 x 2.65 – $H_{2''}$x 5.30=0

$H_{2''}$=1803.12 kg……………(ix)

From (vi) & (ix)

$H_2 = H_{2'} + H_{2''}$
H2=2255.6+1803.12
H2= 4058.72 kg

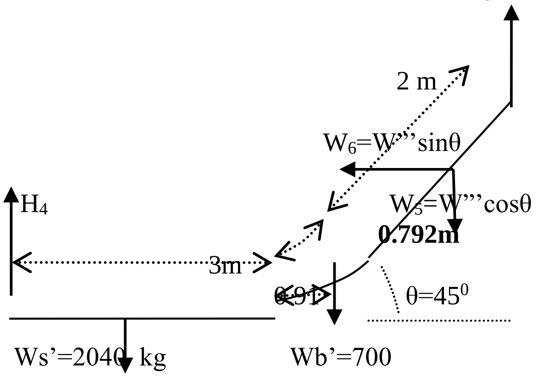

Fig.8 Showing all supporting forces & pipe weight of part (3)

W_5= Wi''' x Cosθ =1360 x Cos 45^0
W_5= 961.66 kg

W_6= Wi''' x Sinθ = 1360 x Sin 45^0
W_6=961.66 kg

$\sum M_{H3''} = 0$,

0.71 x W5 + 1.49 x $W_{b'}$+ 3.9 x Ws'- 5.39 x H_4= 0
0.71 x 961.66 + 1.49 x 700+ 3.9 x 2040'- 5.39x H_4 =0
H_4= 1622.1 kg…………..(x)

$\sum M_{H4} = 0$,

1.5 x Ws' + 2.41 x $W_{b'}$+ 3.12 x W_5- 5.39 x $H_{3''}$= 0
0.71 x 2040 + 2.41 x 700+ 3.12 x 961.66- 5.39x $H_{3''}$ =0
$H_{3''}$= 1138.4 kg…………..(xi)

From (viii) & (xi)
$H_3 = H_{3'} + H_{3''}$
H3=1803.12+1138.4
H3= 2941.52kg

Table C

Support Hanger	support forces (kg) in down word direction
H1	2184.93
H2	4058.72
H3	2941.52
H4	1622.10

Table D

Support Hanger	support forces (kg) in left side direction
W2	2227.00
W4	3606.24
W6	961.66

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IV. CONCLUSION

From above pressure drop calculation, it is clear that instate of 90^0 bend if 45^0 bend is used then there is 0.024 kg/cm2 pressure drop can be minimized. In 660 MW thermal power stations, steam pressure in main steam line is @256 kg/cm^2 at this stage pressure drop 0.024 kg/cm2 is huge. Also length of piping is reduced. It results less heat dissipation throughout its life cycle of thermal power station.

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