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Towards Suistanable Engineering

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PENGANTAR

Kemajuan suatu bangsa atau negara tidak terlepas dari tingkat penguasaan teknologi bangsa tersebut. Teknologi berperan penting dalam meningkatkan kemampuan atau kemakmuran suatu negara. Dengan teknologi manusia dapat memberikan nilai tambah terhadap sumber daya alam yang ada menjadi produk-produk yang bermanfaat bagi kepentingan masyarakat. Namun, di sisi lain kemajuan teknologi ini juga kadanng membawa kadampak yang tidak menguntungkan terutama pada alam.

Ekploitasi sumber alam yang berlebihan, pembuangan sisa-sisa aktifitas industri, serta penggunaan energi yang boros, memberikan dampak negatif pada keseimbangan alam. Pemanasan global dan perubahan cuaca yang sangat ekstrim telah dirasakan oleh seluruh penduduk di dunia. Kesulitan sumber air bersih pun juga telah dirasakan oleh masyarakat yang tinggal di kota-kota besar ataupun di pedesaan. Di sisi lain, banjir justru menjadi sebuah bencana bagi beberapa kota dimana pada dasarnya, hal itu dipicu oleh tata kelola yang tidak seimbang dengan alam.

Bertepatan dengan Hari Pendidikan Tinggi Teknik ke-65 Fakultas Teknik Universitas Gadjah Mada, Badan Pengelola Penelitian Fakultas Teknik sebagai panitia mengundang para akademisi, peneliti, maupun praktisi lingkungan untuk mepresentasikan gagasan ilmiah, karya ilmiah, dan hasil penelitian melalui Seminar Teknik 2011 yang mengambil tema: Towards Sustainable Engineering.

Dengan tema tersebut, solusi untuk melindungi kelestarian lingkungan dan sumber daya alam diterapkan dapat menjadi bagian dalam pengembangan teknologi di masa depan. Oleh karena itu, seluruh masyarakat seharusnya bersama-sama ikut berpastisipasi dalam pengembangan teknologi yang ramah lingkungan supaya bermanfaat bagi generasi selanjutnya.

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PRESSURE AND TEMPERATURE DROP IN THE STEAM PIPELINE

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Abstract

This report presents an estimation for both pressure and temperature drop along a steam pipeline, in addition, to know whether the steam condition at the pipeline outlet is in saturated condition. The steam pipeline considered is a pipeline system to supply steam from some steam production wells to a geothermal power plant which has capacity 1 x 55 MW. The steam pipeline as a steam gathering system will transport steam from eight production wells to the scrubber of the power plant. The steam fields comprises of two cross country pipelines, the east steam field with six production wells and the west steam field with two production wells. The two cross country pipelines are jointed together to the steam pipeline that is connected to the scrubber of the power plant before the steam supplied to the steam turbine. The steam pipeline has a total length 3.88 km and the pipe size is started from 400mm (16 in), 500mm (20 in), 750mm (30 in), 900mm (36 in) and 1050mm (42 in) in diameter at the outlet section (downstream). Furthermore, the pipeline is insulated by an insulation made of calcium silica with 50 mm in thickness. The steam at inlet section of the steam pipeline (upstream) is in saturated condition at pressure 11.14 bar(a). The pressure drop of steam has been estimated involve both frictions along pipes and resistance through fittings. Moreover, the temperature drop of steam along pipeline has been carried out by considers heat loss from steam to ambient that has temperature 6.7 C. The calculation result gives the pressure and temperature of steam at the outlet section is 7.14 bar(a) and 170.59 C when the steam condition at the upstream is 11.14 bar(a), saturated and the insulation thickness is 80 mm. To achieved the steam pressure around 8 bar(a) and saturated then the steam pressure at upstream is 11.8 bar(a) minimum and the insulation thickness is 80 mm.

Keyword: Steam pipeline, pressure drop, temperature drop

1. BACKGROUND OF PROBLEM

This paper describes the pressure and temperature drop along the steam pipeline from production well to a power plant, in addition, to know whether the steam condition at the inlet of the scrubber is as per requirements with design data that have been planned before (saturated steam).

The steam pipeline considered is a pipeline system to supply steam from some steam production wells to a geothermal power plant which has capacity 1 x 55 MW. The steam pipeline as a steam gathering system will transport steam from eight production wells to the scrubber of the power plant. The steam fields comprises of two cross country pipelines, the east steam field with six production wells and the west steam field with two production wells. The two cross country pipelines are jointed together to the steam pipeline that is connected to the scrubber of the power plant before the steam supplied to the steam turbine. The steam pipeline has a total length 3.88 km and the pipe size is started from 400mm (16 in), 500mm (20 in), 750mm (30 in), 900mm (36 in) and 1050mm (42 in) in diameter at the outlet section (downstream). Furthermore, the pipeline is insulated by an insulation made of calcium silica with 50 mm in thickness. The steam at inlet section of the steam pipeline (upstream) is in saturated condition at pressure 11.14 bar(a).

2. GIVEN DATA FOR ESTIMATION

Table 1 shows the data used in the estimation of both pressure and temperature drop along steam pipeline. Figure 1 PIPELINE MODEL illustrates the steam pipeline that is under consideration in this estimation, schematically.

The following are the other data that is taken into estimation

- Pipe insulation:
    - Material : Calcium silica
    - Thermal conductivity: 0.06 W/m.K
    - Insulation complete with metal jacketing (Aluminum, 0.9 mm)
- Minimum ambient temperature: 6.4 C
- Steam condition at node (1):
    - Saturated at 11.14 bar(a)

3. PRESSURE DROP

Pressure drop of steam along pipe can be evaluated by Unwin's formula as follows:

$$\Delta P = \frac{0.6753x10^6 M^2 L(1 + 91.4/d)}{\rho\ d^5} \qquad (1)$$

Where :

P = Pressure drop (Pa)
M = Mass flow rate (kg/h)
L = Length of pipe (m)
d = Pipe inside diameter (mm)
ρ = Steam density (kg/m^3)

Pressure drops mentioned above is due to friction along steam pipeline. Pressure drops through fittings such as elbows, tees, valves, etc vary in proportion to the pressure drop through straigth pipe. Because of this fact, it is posible to express the resistance of fittings as equivalent lengths of straight pipe.

The following formula can be used for predicting the resistance generated by fittings:

$$h_m = \sum K \frac{V^2}{2g} \qquad (2)$$

4. HEAT LOSS

Heat loss from steam to ambient air can be estimated by carry out a composite heat transfer analysis through insulation and jacketing. To minimize heat loss from steam, the pipe should be insulated and then jacketing metal to shield the insulation from weather covers it. Figure 2 shows the heat transfer from pipe to ambient air through the insulation. It is assumed that the pipe temperature has the same value as the steam temperature inside.

Heat transfer from steam pipeline to ambient air,

$$Q = \frac{T_s - T_\infty}{\left(\ln(r_2/r_1)\big/2\pi k_1 L\right) + \left(\ln(r_3/r_2)\big/2\pi k_2 L\right) + \left(\frac{1}{2\pi h r_3 L}\right)} \qquad (3)$$

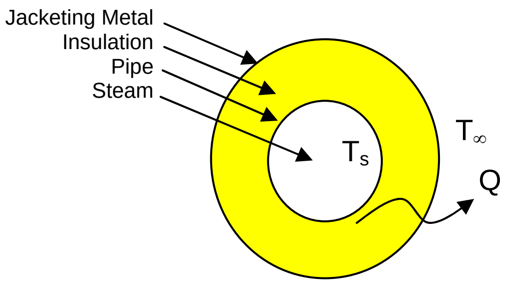


Figure 2 Steam pipe and insulation

Where :

Q = Heat transfer (W)
T_s = Steam temperature ©
T_∞ = Ambient temperature ©
L = Length of pipe (m)
r_1 = Insulation inner radius (mm)
r_2 = Insulation outter radius (mm)
r_3 = Jacketing metal outter radius (mm)
k_1 = Thermal conductivity of Insulation (W/m.K)
k_2 = Thermal conductivity of jacketing metal (W/m.K)
h = Natural heat transfer convection coeficient (W/m^2K)

5. ENEGRY CONSERVATION EQUATION (STEAM TEMPERATURE)

Final temperature of steam would be decrease due to heat loss along pipe; it can be estimated by using the following equation that is formulated from the energy conservation equation.

$$M(h_1 - h_2) = Q$$
$$h_1 - h_2 = \frac{Q}{M} \qquad (4)$$

Where :

Q = Heat transfer or heat loss (W)
h_1 = Initial entalphy (Kj/kg.K)
h_2 = Final entalphy (Kj/kg.K)
M = Mass flow rate (kg/s)

The above equation can be simplified become as follow:

$$h_1 - h_2 = cp(T_1 - T_2) = \frac{Q}{M}$$
$$T_2 = T_1 - \frac{Q}{cp.M} \qquad (5)$$

Where :
Q = Heat transfer or heat loss (W)
T_1 = Initial temperature of steam ©
T_2 = Final temperature of steam ©
M = Mass flow rate (kg/s)
Cp = Specific heat of steam (J/kg.K)

6. TEMPERATURE EQUILIBRIUM

The temperature equilibrium of steam at mixing section (tee) can be predicted by the following equation,

$$T_3 = \frac{M_1 T_1 + M_2 T_2}{M_3} \quad (6)$$

Where :
T_1 = Temperature of steam at section 1
T_2 = Temperature of steam at section 2
T_3 = Temperature of steam at section 3
M_1 = Mass flow rate at section 1
M_2 = Mass flow rate at section 2
M_3 = Mass flow rate at section 3

7. ESTIMATION RESULT

Table 9.1 and Table 9.2 show the result of pressure and temperature drop estimation along steam pipeline and also it is illustrated schematically in figure 1 PIPELINE MODEL – PRESSURE AND TEMPERATURE DROP.

Estimation has been done based on the following idealization and assumptions:

- Fittings consist of valves, reducers/expanders, tees, elbows, entrance section, and exit section.
- Insulation made of calcium silica with 0.06 W/mK in thermal conductivity with 50mm and 80mm in thickness for table 9.1 and table 9.2, respectively.
- Ambient temperature is 10 C and 6.7 C for table 9.1 and table 9.2, respectively.

8. ANALYSIS

The estimation shown in table 9.1 describes that the steam pressure at the inlet section of the scrubber is 7.14 bar(a) when the initial pressure at node (1) for about 11.14 bar(a). The temperature of steam at each nodes show that the condition of steam is superheated.

Table 9.2, to obtain the steam pressure for about 8 bar(a) at the inlet section of the scrubber then the initial pressure of steam at node (1) is 11.7 bar(a), minimum. Moreover, the condition of steam is saturated at the inlet section of the scrubber.

9. CONCLUSION

The initial pressure for about 11.14 bar(a) at node (1) gives the steam pressure 7.14 bar(a), approximately.

The steam condition at the inlet section of the scrubber is saturated at 8.12 bar(a) when the initial pressure at node (1) is 11.8 bar(a), minimum.

The insulation thickness is 80 mm to maintain the saturated condition of the steam along the steam pipeline.

10. REFFEECES

[1] ASME B31.1. Power piping
[2] J.P Holman, 1986, *Heat Transfer,* Sixth Editionn Mc-Graw Hill Inc., New York.
[3] Reynolds, C. William, Perkins, C. Henry, 1987, *Termodinamika Teknik,* Edisi ke-2, Erlangga, Jakarta.
[4] Nayyar, 2000, Piping Handbook, 7th edition, Mc-Graw Hill, Inc. New York.

Table 4.1 SGS Pipeline Data

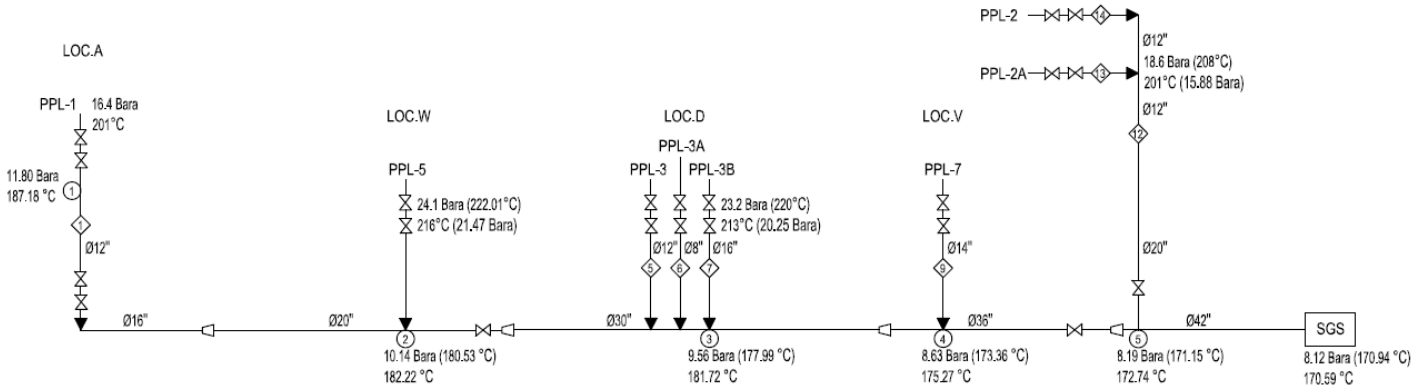
Steam System Description	**Line Size**	**t**	**Length**	**Mass flow rate**
	(in)	**(in)**	**(m)**	**(kg/s)**
Node (1) – Node (2)	16	0.5	1170	23.36
Node (2) – Node (3)	20	0.5	680	29.94
Node (3) – Node (4)	30	0.5	1190	82.00
Node (4) – Node (5)	36	0.5	815	100.97
Node (5) - SGS	42	0.5	25	125.84

Table 9.1 Pressure and temperature drop estimation with initial pressure 11.14 Bar(a)

No.	**Node**	**Mass**	**Length**	**d**	**t**	**Rho**	**dP**	**P1**	**P2**	**T2**	**Tsat of P2**
		kg/s	**m**	**in**	**in**	**kg/m3**	**Bar**	**Bara**	**Bara**	**C**	**C**
1	PPL-1 to PPL-5	23.36	1.17E+03	16	0.5	5.69700	1.514771	11.14	9.63		184.64
						Minor losses	0.236053		9.39	182.22	177.13
2	PPL-5 to PPL3B	29.94	6.80E+02	20	0.5	4.81425	0.503470	9.39	8.89		
						Minor losses	0.125334		8.76	181.72	174.16
3	PPL-3B to PPL-7	82.00	1.19E+03	30	0.5	4.41996	0.821293	8.76	7.94		
						Minor losses	0.213837		7.73	175.27	168.75
4	PPL-7 to PPL-2	100.97	8.15E+02	36	0.5	3.66576	0.393979	7.73	7.33		
						Minor losses	0.119223		7.21	172.74	166.06
5	PPL-2,2A - SGS	125.84	2.50E+01	42	0.5	3.66676	0.008392	7.21	7.20		
							0.068524	7.20	***7.14***	***170.59***	***165.70***

Table 9.2 Pressure and temperature drop estimation with initial pressure 11.80 Bar(a)

No.	**Node**	**Mass**	**Length**	**d**	**t**	**Rho**	**dP**	**P1**	**P2**	**T2**	**Tsat of P2**
		kg/s	**m**	**in**	**in**	**kg/m3**	**Bar**	**Bara**	**Bara**	**C**	**C**
1	PPL-1 to PPL-5	23.36	1.17E+03	16	0.5	6.00765	1.436444	11.80	10.36		187.18
						Minor losses	0.223847		10.14	182.22	180.53
2	PPL-5 to PPL3B	29.94	6.80E+02	20	0.5	5.21024	0.465205	10.14	9.67		
						Minor losses	0.115808		9.56	181.72	177.99
3	PPL-3B to PPL-7	82.00	1.19E+03	30	0.5	4.92187	0.737541	9.56	8.82		
						Minor losses	0.192031		8.63	175.27	173.36
4	PPL-7 to PPL-2	100.97	8.15E+02	36	0.5	4.29662	0.336132	8.63	8.29		
						Minor losses	0.101717		8.19	172.74	171.15
5	PPL-2,2A - SGS	125.84	2.50E+01	42	0.5	3.88292	0.007924	8.19	8.18		
							0.064709	8.18	***8.12***	***170.59***	***170.94***



NODE	Mass (kg/s)	Length (m)	d (in)	t (in)	P initial (Bara)	P final (Bara)
①-②	23.26	1170	16	0.5	11.80	10.14
②-③	29.94	680	20	0.5	10.14	9.56
③-④	82.00	1190	30	0.5	9.56	8.63
④-⑤	100.97	815	36	0.5	8.63	8.19
⑤- SGS	125.84	25	42	0.5	8.19	8.12

Figure 1 Pipeline Model – Pressure and Temperature Drop