5.0 HEAT LOSS ALONG THE PIPELINE

5.1 Thermal Conductivity of Soil and Sand

The prediction of the heat loss for a buried pipeline which transports the liquid or the gas is a useful value for the pipeline design and also indicates the effect of the depth, cover and the coating material, climate conditions on cooling and hydrate formation possibility.

Followings are to be considered as the main factors for the heat loss event:

- For the soils studied, thermal conductivity increased with increasing soil density and moisture content.
- Thermal conductivity ranged from
  - a) for sand : 0.58 to 1.94 W/m K,
  - ***b) for sandy loam : 0.19 to 1.12 W/m K ,***
  - c) for loam : 0.29 to 0.76 W/m K,
  - d) for clay loam : 0.36 to 0.69 W/m K
  - e) Density range : 1.23 to 1.59 g/cm^3
  - f) Water content : 1.4 to 21.2 %
- The results also show that an increase in the amount of **added salts** at given moisture content **decreased** thermal conductivity.
- Increasing the percentage of **soil organic** matter **decreased** thermal conductivity.
- Finally, it was found that **the sand** had **higher values of thermal conductivity** than the clay loam for the **same salt type** and concentrations.

5.2 Pipeline Heat Loss

The lengths of the gas pipelines from the station to well heads are different, very far one is about 10 km, near one 5 km from the compressor stations. Here, estimations are based two values of the pipeline depth, 0.75 m (750 mm) and 1.00 m which are the acceptable values for Amal field pipeline construction and specification.

The thermal conductivity is a important data to determine the rate of heat loss, assumption is made that the cover soil is a sandy loam so the thermal conductivity will be is a value between 0.19 to 1.12 W/m K, so it has a wide range, depending on the structure where it may have salt or organic material which all effect the conductivity positive or negative. The a reasonable value is a average of this range, that will be around 0.650 W/m K, but this is can be determined by the laboratory examination of the soil used for the cover of the line

Heat Loss Formula

This equation is simple way to predict the heat loss between along the buried line and surrounded, depending on the temperature difference of the fluid and ambient. More complex methods and formulas are available by using more specific data and thermal conductivity estimation but the lacking of those detailed data restricts the use of the other complex methods.

$$Q = Fk(T_g - T_{amb})$$

Where

Q	: Heat loss, (W)
F	: Geometric factor
k	: Thermal conductivity (W/m K)
T	: Temperature ^oC
D	: Diameter of pipe, m
R	: Radius, m

Data:

k	= 0.650 W/m K
T_g	= 70 ^oC (158 ^oF)
T_{amb}	= min. 5 ^oC to max. 29 ^oC (winter time)
D	= 3” (0.0762 m)
R	= 1.5 “ (0.0381 m)

Formula for the geometric Factor:

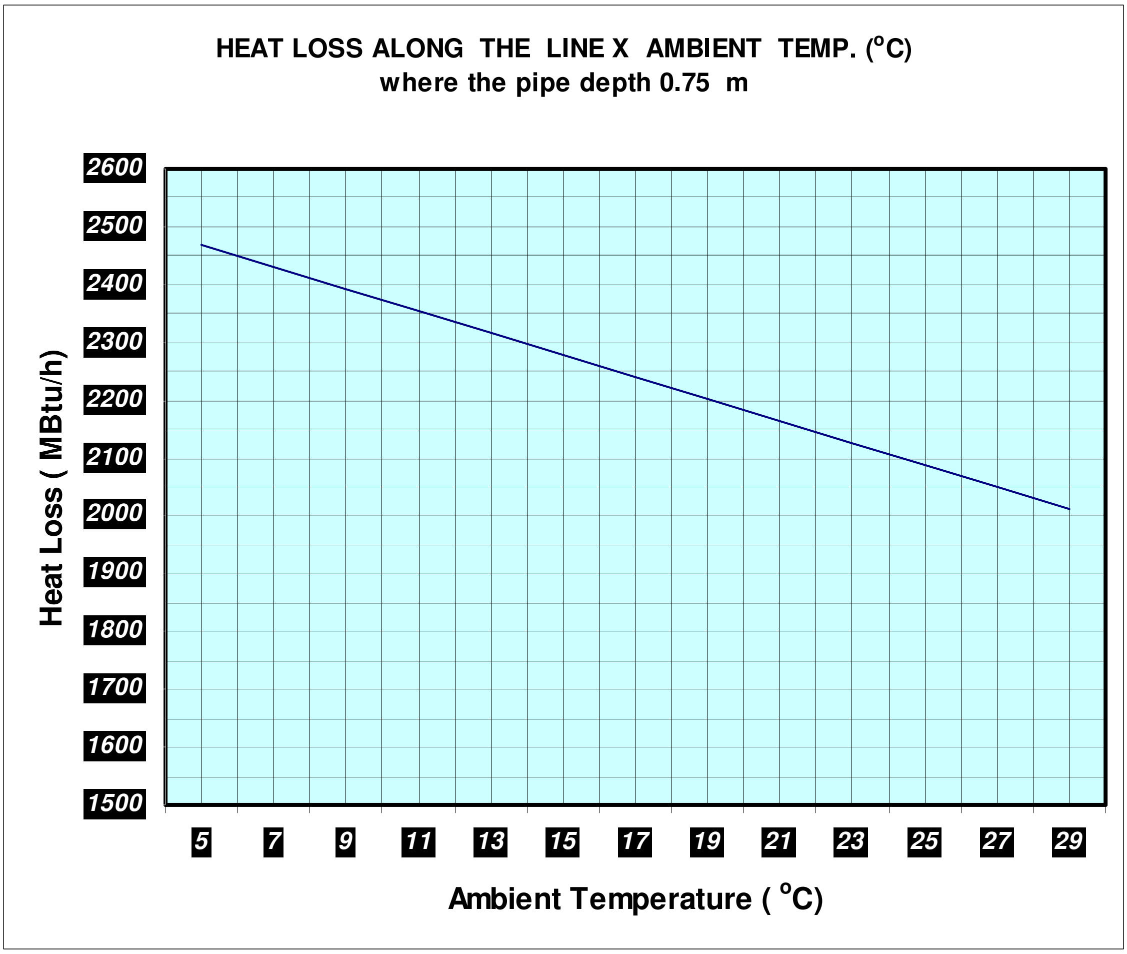
$$F = \frac{2\pi L}{Cosh^{-1}(d / R)}$$

Conversion : 1 Btu/h = 0.2928 W

Calculated values are in the table. Last column indicates heat loss in MBtu/h along the line verses different ambient temperature given in first column where the pipe **depth 0.75 m** (750 mm) below the ground.

Table-4 Heat loss rate where pipe depth is 0.75 m

Tc	T_{amb}(K)	T_g (°C)	T_g(K)	T_g (°C)	F	k(w/(mK))	F x k	Q(w)	Btu/h	MBtu/h
5	278	70	343	65	17109	0.65	11121.13	722874	2467890.2	2467.89
7	280	71	344	64	17109	0.65	11121.13	711752	2429922.6	2429.92
9	282	72	345	63	17109	0.65	11121.13	700631	2391955.1	2391.96
11	284	73	346	62	17109	0.65	11121.13	689510	2353987.5	2353.99
13	286	74	347	61	17109	0.65	11121.13	678389	2316020	2316.02
15	288	75	348	60	17109	0.65	11121.13	667268	2278052.5	2278.05
17	290	76	349	59	17109	0.65	11121.13	656147	2240084.9	2240.08
19	292	77	350	58	17109	0.65	11121.13	645026	2202117.4	2202.12
21	294	78	351	57	17109	0.65	11121.13	633904	2164149.8	2164.15
23	296	79	352	56	17109	0.65	11121.13	622783	2126182.3	2126.18
25	298	80	353	55	17109	0.65	11121.13	611662	2088214.8	2088.21
27	300	81	354	54	17109	0.65	11121.13	600541	2050247.2	2050.25
29	302	82	355	53	17109	0.65	11121.13	589420	2012279.7	2012.28



Heat loss is very dependable on the depth of the pipe and the thermal conductivity of the medium. Increased pipe depth gives the result decreased the heat loss and moisture in the cover of the pipe has also increasing effect of the heat loss.

For the comparison of the heat loss how it changed with the depth is given blow for the min and max winter ambient temperatures. As an example, the heat loss rates are given below at the low and high ambient temperatures in winter time and two applicable pipe depths.

Heat loss values at pipe depth d = 0.75 m :

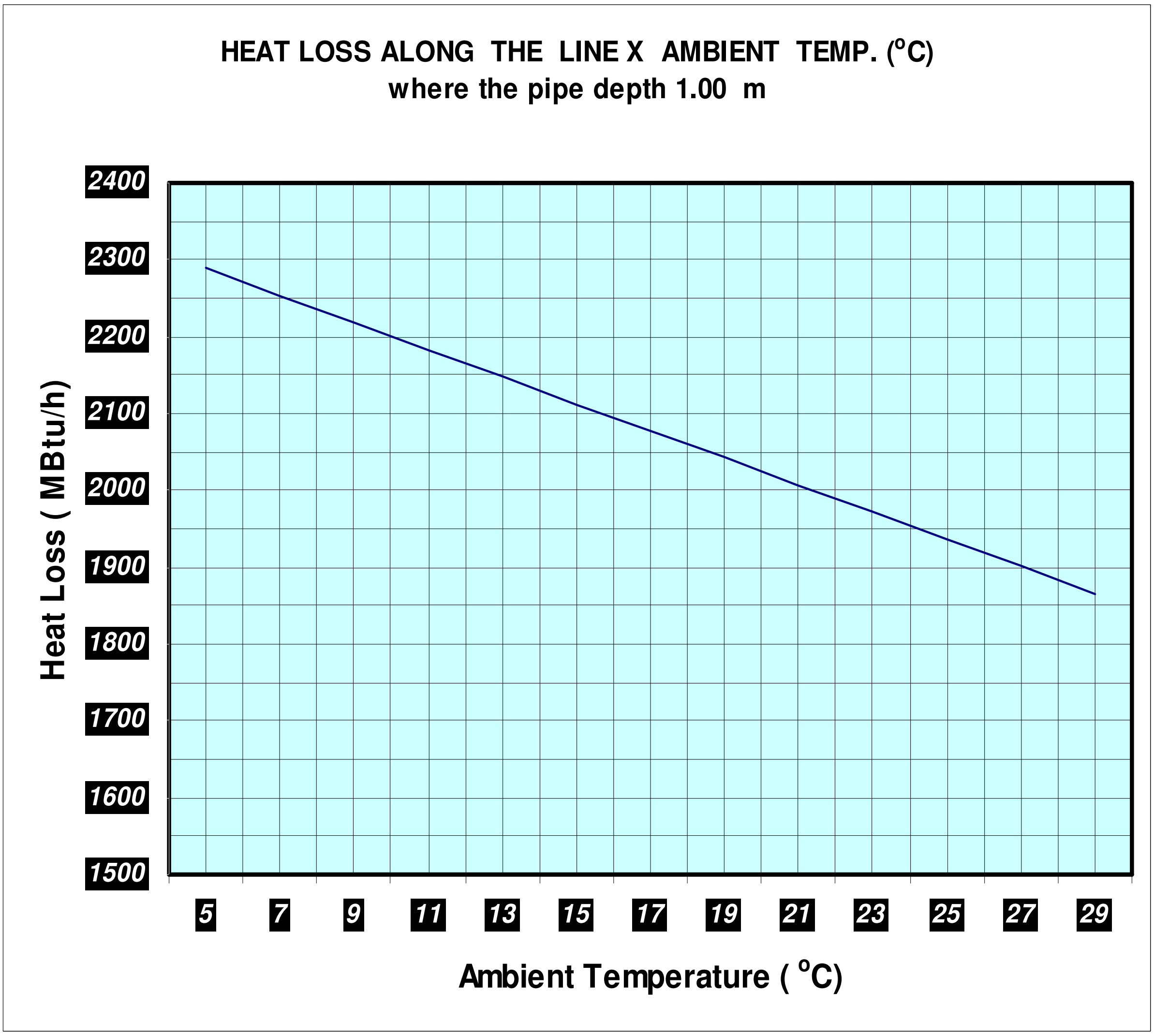
Heat loss : 2012 MBtu/h at 29 ºC (84 ºF)
Heat loss : 2391 MBtu/h at 9 ºC (48 ºF) is

Heat loss values at pipe depth d= 1.00 m :

Heat loss : 1865 MBtu/h at 29 ºC (84 ºF)
Heat loss : 2218 MBtu/h at 9 ºC (48 ºF)

Table-5 Heat loss rate where pipe depth is 1.00 m

Tc	T_{amb}(K)	T_g (ºC)	T_g(K)	T_g (ºC)	F	k(w/(m K)	F x k	Q(w)	Btu/h	MBtu/h
5	278	70	343	65	15865	0.65	10312.49	670312	2288443.9	2288.44
7	280	71	344	64	15865	0.65	10312.49	659999	2253237.1	2253.24
9	282	72	345	63	15865	0.65	10312.49	649687	2218030.3	2218.03
11	284	73	346	62	15865	0.65	10312.49	639374	2182823.5	2182.82
13	286	74	347	61	15865	0.65	10312.49	629062	2147616.6	2147.62
15	288	75	348	60	15865	0.65	10312.49	618749	2112409.8	2112.41
17	290	76	349	59	15865	0.65	10312.49	608437	2077203	2077.20
19	292	77	350	58	15865	0.65	10312.49	598124	2041996.1	2042.00
21	294	78	351	57	15865	0.65	10312.49	587812	2006789.3	2006.79
23	296	79	352	56	15865	0.65	10312.49	577499	1971582.5	1971.58
25	298	80	353	55	15865	0.65	10312.49	567187	1936375.6	1936.38
27	300	81	354	54	15865	0.65	10312.49	556874	1901168.8	1901.17
29	302	82	355	53	15865	0.65	10312.49	546562	1865962	1865.96


HEAT LOSS ALONG THE LINE X AMBIENT TEMP. (°C)
where the pipe depth 1.00 m
Heat Loss (MBtu/h)
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
5
7
9
11
13
15
17
19
21
23
25
27
29
Ambient Temperature (°C)