Heat Sink for Underground Pipe Line

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ABSTRACT
There is a need for temperature drop in a buried pipeline based on the media and process. Need of some methodology and design requirement for a set of conditions by reducing pipeline surface temperature and the temperature drops to atmospheric temperature at a particular distance of pipeline. Based on the conduction principle, desire reduction up to atmospheric temperature can be possible. Let us understand by below methods and design of Heat sink for buried pipe line.

Basic principles of heat transfer:
Conduction:
$$Q = k*A*(T1 - T2) / L$$

where k is the thermal conductivity of the material, A is the cross sectional area, T1 is the initial (pre-diffuse or inner surface) temperature, and T2 is the temperature at the final cross-sectional area (or outer surface). You can look of the k value for your material very easily.

Convection:
$$Q = h*A*(T.s - T.f)$$

where h is the convective heat transfer coefficient, A is the surface area, T.s is the surface temperature of the object cooling, and T.f is the temperature of the fluid or air which is cooling (or heating the object).

If you want just a basic value for h… use 20 in moderate air with low speed winds, and use 50 in moderate water (moving with low speed currents).

Thermal radiation:
$$Q = s*e*A*(T.s^4 - T.surr^4)$$

where s is the Stefan-Boltzmann constant $(s = 5.67*10^{-8}$ J/kg*k), e is the emissivity of the material (most materials, besides metals, on the surface of the earth which make solid objects will have an emissivity of about 0.9), A is the surface area of the radiating object, and T.s is the surface temperature in Kelvin (very important) raised to the fourth power, and T.surr is the surface temperature (or temperature of empty space) surrounding the object, again raised to the fourth power.

If you want to calculate the total heat dissipation of the object, then you can add all three of these together.
Traditional Uenvironment (For Buried pipes)
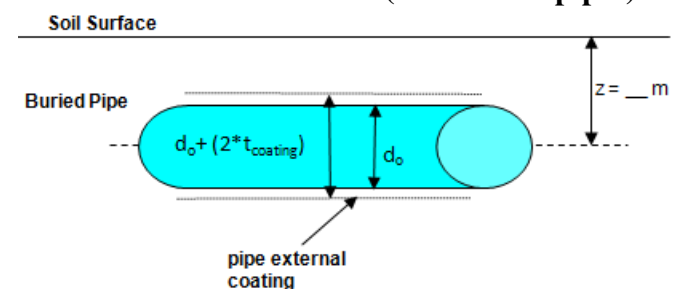
$$U_{soil\,cross\,sect} = \frac{2 \times \lambda_{soil}}{(d_o + 2 \times t_{coating}) \times \ln\left(\frac{4 \times z}{(d_o + 2 \times t_{coating})}\right)}$$

Where:

$U_{environment}$ = heat transfer coefficient to the environment, W/m^2-K

λ = thermal conductivity of material, W/m-K

z = burial depth of the pipe up to the pipe axis, m

Thermal Conductivities of typical soil surrounding pipeline

Soil Type	Thermal conductivity, λ_{soil}, W/m-K
Peat (Dry)	0.17
Peat (Wet)	0.54
Peat (icy)	1.89
Sandy Soil (dry)	0.43-0.69
Sandy Soil (moist)	0.87-1.04
Sandy Soil (soaked)	1.90-2.42
Clay soil (dry)	0.35-0.52
Clay soil (moist)	0.69-0.87
Clay soil (wet)	1.04-1.56
Clay soil (frozen)	2.51
Gravel	0.9-1.25
Gravel (sandy)	2.51
Limestone	1.3
Sandstone	1.63-2.08

PROPOSED THERMALLY CONDUCTIVE MATERIALS ENVIORNMENT OTHER THEN SOIL FOR BURIED PIPELINE

1. DIAMOND – 2000 – 2200 W/m•K

Diamond is the leading thermally conductive material and has conductivity values measured 5x's higher than copper, the most manufactured metal in the United States. Diamond atoms are composed of a simple carbon backbone that is an ideal molecular structure for effective heat transfer. Often, materials with the simplest chemical compositions and molecular structures have the highest thermal conductivity values.

Diamond is an important component of many modern hand held electronic devices. Their role in electronics is to facilitate heat dispersion and protect sensitive computer parts. The high thermal conductivity of diamonds also proves useful when determining the authenticity of stones in jewelry. Incorporating small amounts of diamond into tools and technologies can have a drastic impact on the thermal conductivity properties.

2. SILVER – 429 W/M•K

Silver is a relatively inexpensive and abundant thermal conductor. Silver is a component of numerous appliances and is one of the most versatile metals due to its malleability. 35% of silver manufactured in the U.S is used for electrical tools and electronics (US Geological survey mineral community 2013). A bi product of silver, silver paste, is increasing in demand due to its use for environmentally friendly energy alternatives. Silver paste is used in the production of photovoltaic cells that are a major component of solar energy panels.

3. COPPER – 398 W/M•K

Copper is the most commonly used metal for manufacturing conductive appliances in the United States. Copper has a high melting point and a moderate corrosion rate. It is also a very effective metal for minimalizing energy loss during heat transfer. Metal pans, hot water pipes and car radiators are all appliances that utilize the conductive properties of copper.

4. GOLD – 315 W/M•K

Gold is a rare and expensive metal that is used for specific conductive applications. Unlike silver and copper, gold rarely tarnishes and can withstand conditions that experience large amounts of corrosion.

5. SILICON CARBIDE – 270 W/M•K

Silicon carbide is a semiconductor that is composed of a balanced mixture of silicon and carbon atoms. When manufactured and fused together, silicon and carbon bind to form an extremely hard and durable material. This mixture is often used as a component for car brakes, turbine machines and in steel mixtures.

6. BERYLLIUM OXIDE– 255 W/M•K

Beryllium oxide is used in many high-performance parts for applications such as electronics, as it has a high thermal conductivity and is a good electrical insulator.

7. ALUMINUM – 247 W/M•K

Aluminum is generally used as a cost-effective replacement for copper. Although not as conductive as copper, aluminum is abundant and easy to manipulate due to its low melting point. Aluminum is a crucial component of L.E.D lights (light emitting diodes). Copper aluminum mixes are gaining popularity as they can harness the properties of both copper and aluminum and can be manufactured at a lower cost.

8. TUNGSTEN – 173 W/M•K

Tungsten has a high melting point and a low vapor pressure making it an ideal material for appliances that are exposed to high levels of electricity. Tungsten's chemical inertness enables it to be used in electrodes that are a part of electron microscopes without altering the electrical currents. It is also often

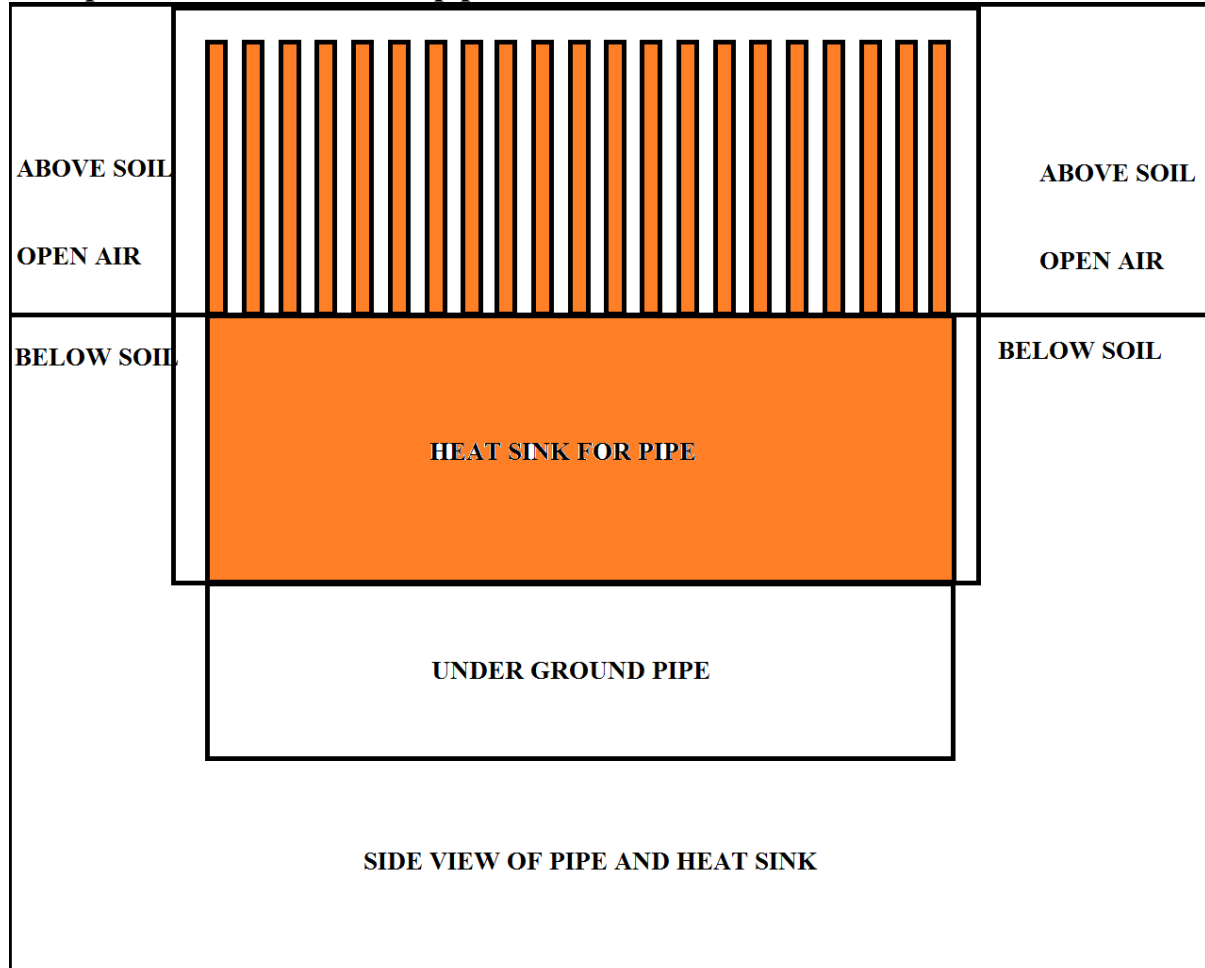used in lightbulbs and as a component of cathode ray tubes.

9. GRAPHITE 168 W/M•K

Graphite is an abundant, low cost and lightweight alternative compared to other carbon allotropes. It is frequently used as an addition to polymer mixtures to enhance their thermal conductivity properties. Batteries are a familiar example of an appliance that harnesses graphite's high thermal conductivity.
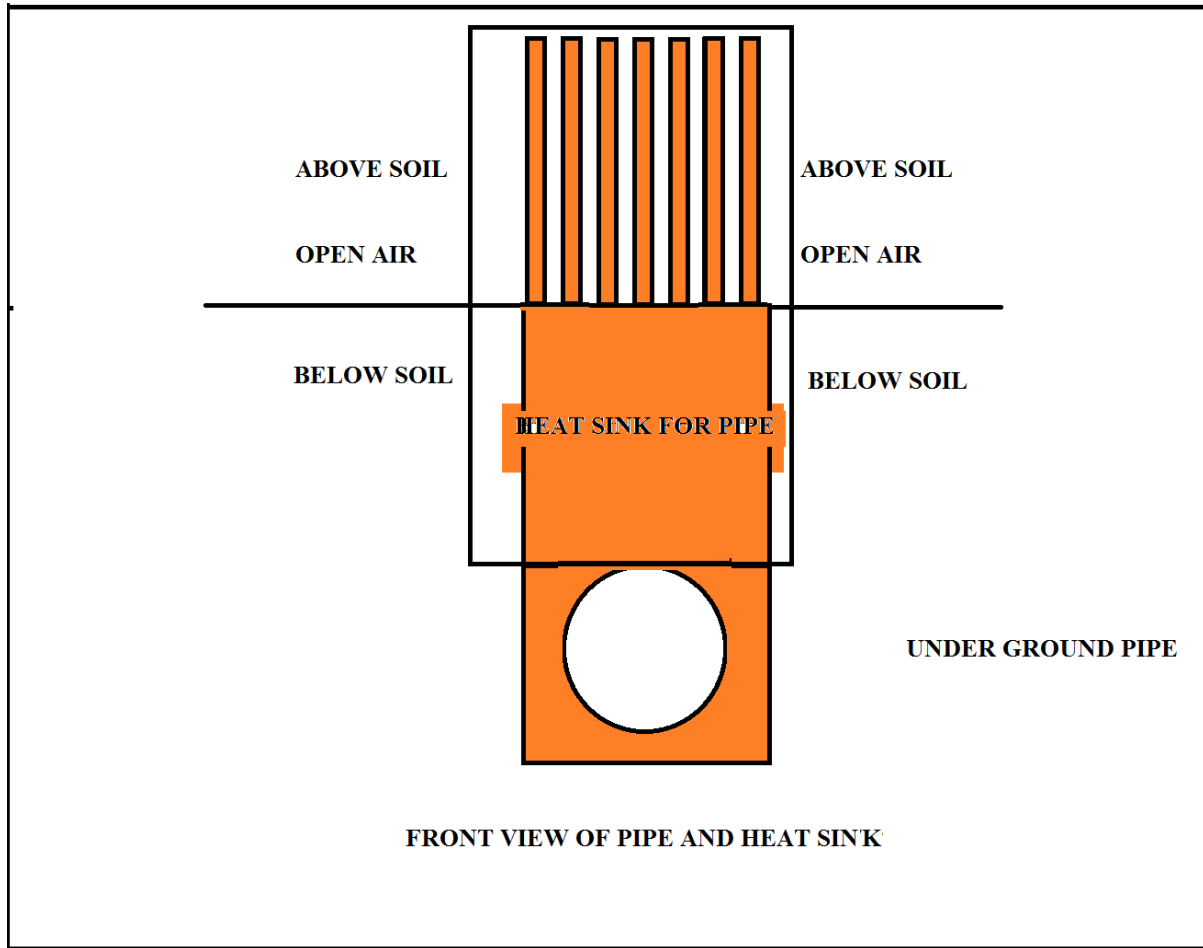
10. ZINC 116 W/M•K

Zinc is one of few metals that can easily be combined with other metals to create metal alloys (a mixture of two or more metals). 20% of zinc appliances in the U.S are composed of zinc alloys. Galvanizing uses 40% of manufactured pure zinc. Galvanizing is the process of a applying a zinc coating to steel or iron that is designed to protect to metal against weathering and rust.

Design example of heat sink of buried pipe line:

Figure (1)

Figure (2)

Conclusion: By applying design(figure 1 and 2), calculation(as described above) and materials for buried environment (as per mentioned material list other than soil ingredients) and by using convection methodology of heat transfer, designed heat sink of buried pipeline, can reduced temperature up to atmospheric temperature for particular buried pipe line.