Underground Heat And Chilled Water Distribution System For District Cooling and Heating System

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Abstract : Distributed energy systems have gained attention due to high efficiency and environmental friendliness. However, the energy performance of such integrated systems is not sufficiently studied yet. To provide energy planning suggestions in these areas, this paper aims to study the benefits and challenges related to underground water distribution system for air conditioning and heat purposes. Various aspects of distribution system (underground) is analyzed using previous research and studies done in the concerned field of subject. The subject of matter covered in the paper includes energy distribution system, economics of the system, classification in distribution system, Challenges faced in the adaptation of the system, future scope of District Cooling and Heating System.

***IndexTerms* - underground water distribution system, economics, types, Challenges, District Cooling and Heating System**

I. INTRODUCTION

In the past two decades, the world has witnessed a exponential growth in the usage of air conditioning in both residential and commercially places throughout the year in every part of the world. Today it has received such economical and communal embrace, that every Indian hotel, library, museum, office, store, hospital, government office and residential flats/buildings is now fully air conditioned. In the last twenty years, the yearlong need for human comfort from uneasiness due to high surrounding temperature has resulted in expenditure of many crore of rupees of appliances and establishment/fabrication cost. A lot of areas have shown to be less expensive and dependable to deploy it, either independently or in combination of centralized air conditioning and heat system. It is most appropriate alternative for any energy supply system of its type due to its efficiency and least side effects. It connects on-site power generation with thermal energy production to facilitate electricity, air-conditioning and heat to end user. Distribution system has negligible effect on environment and provides high efficiency when coupled with renewable energy. In order to achieve these benefits it is crucial to have optimum design and technological assistance. This is to decrease capital investment and CO_2emission. But the faced with design of the system with such a high capital investment is a matter of concern. All these concerns are addressed in further headings.

II. UNDERGROUND DISTRIBUTION SYSTEM

Heat distribution system for bigger spaces have been extensively utilized in the past few years[2]. Under the ground equipments have been fabricated to dispense hot water or steam and cooled water as per the demand. The primary purpose to put heat distribution system below the surface is to deliver a certain amount of general fluids like hot water or steam from one place to other, through underground piping, with no leakage or unwanted loss of heat. Large pipes carrying either hot water or chilled water as per the application are buried under the earth surface. Adaption of distribution system advantages in many ways and is least interference at the user end. Channels carry water from the central system location to transfer the energy at the user end using an heat transfer plates or the Air Handling Units. Underground distribution system is a crucial part of the complete cooling or heating system. A large share of the capital investment is spend on the installation process. In order to keep the system operating without any failure it is very important that the complete underground water distribution channel is functional and in most appropriate condition. Failures are costly and also result in collapse of the system, risky situations, causing disasters and troubles to people engaged in the space and the community. Therefore an attempt is made to develop a foolproof underground distribution system by testing different types available discussed in further section.

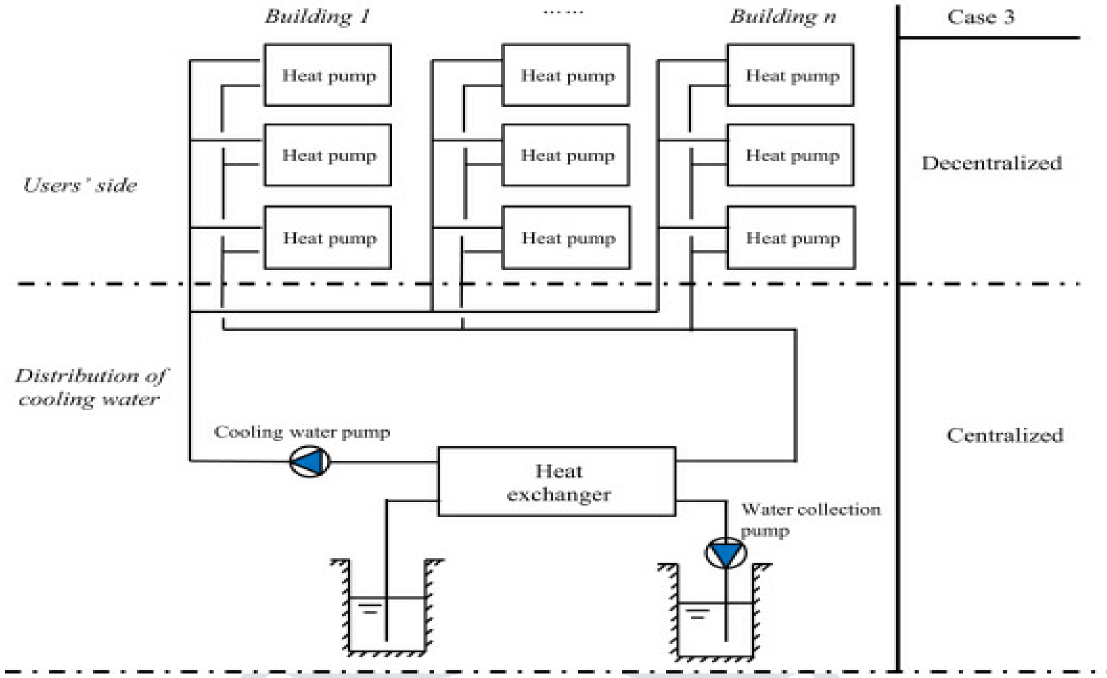


Fig 1. Distribution System

III. TYPES OF UNDERGROUND DISTRIBUTION SYSTEM

A. Figure 2 shows cement Trench System. It is essentially a poured-in-place reinforced concrete box with removable concrete cover. A concrete trench is also called as a free-draining system meaning that it is fabricated in a manner that any fluid which is lost in the trench will be unloaded in the man- hole or space linked to the trench. The concrete trench is very sturdy, almost imperishable [1]. The system cannot be owned privately, which states that any service provider can rebuilt it. The primary limitation is that it is very costly as compared to other varieties of mechanism, and it is hard to make leak proof. To add to that, due to higher ground water states concrete trenches leaks are common. So to function desirably links must be given to drain the fluids into the trench. Places with poor water state cannot use the system.

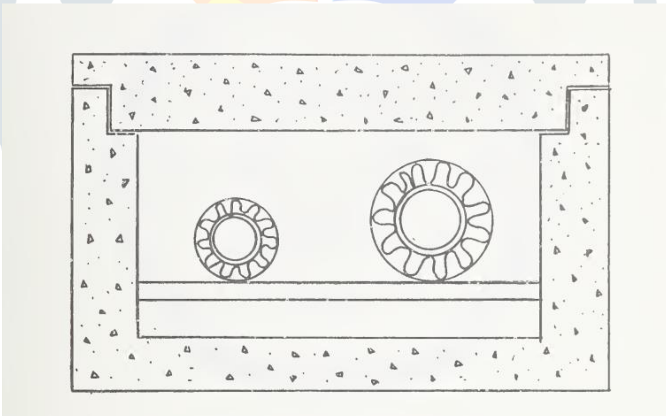


Fig 2.Concrete Trench System

B. Figure 3 describes the Prefabricated Pressure-Testable, unloadable and dryable mechanism. The mechanism comprising an outer casing made of steel (which is smooth or grooved and galvanized or un-galvanized) ,more than one carrier pipes can been cased to prevent loss of heat with variety of insulated preformed pipe, generally calcium silicate along with various types of pipe supports, essentially made of a material which is heat resistant[1]. The mechanism will probably cost lesser than some other of its type and will be very hostile to water infiltration and can be reconditioned wherever required. The limitations of the system are that its outer steel casing is liable to corrosion, and the leakages which can in occur to the carrier piping or the casing on the outside which can be difficult to detect.

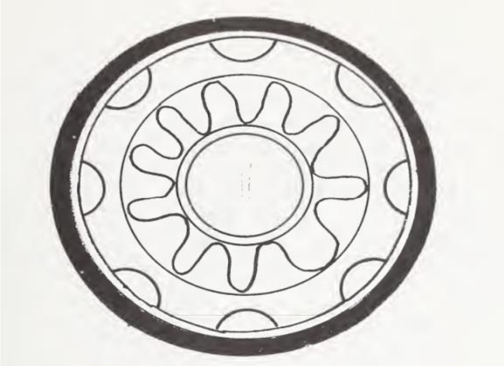


Fig 3. Prefabricated Pressure-Testable

C. Figure 4 shows a Pre-fabricated Sectionalized System. The mechanism made of a single carrier pipe enclosing a insulated coating of calcium silicate and also a coating sheet urethane foam. The casing on the outside is made of asbestos cement. The system is pre manufactured in a section of about 13 foot. Every section is tightly enclosed on either ends so as to stop the migration of any water which may enter into the system and is transferred to adjoining sections. All sections are inter-linked to the field with joints fastened by 0-ring seals and gaskets specifically fabricated for it. The mechanism is fabricated to be very hostile to water being in filtered. Even if water get sin a section, it will be restricted to only that section of the system. As the casing on the outside is of asbestos cement, it will not corrode and the system will require less field maintenance to establish the system. Even still, the verification of the pressure-tightness of the conduit sections is not possible in the field.

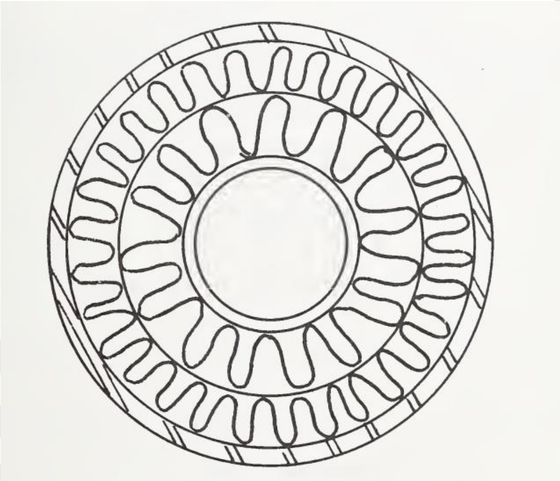


Fig 4. Prefabricated Sectionalized System

D. An Insulating Concrete Envelope System is described in Figure 5. The mechanism is made of a concrete slab base supporting the carrier piping encasing a wrapping of heat resisting concrete. The wrapping is enveloped in a kind of layered material to make it water proof. Drain holes are made inside the concrete envelope to allow the surplus water used in mixing the heat resistant concrete (and the water which will gain entry in the envelope later on) to be unloaded outside the system. Different kinds of heat resistant concrete are being used with a system of such type. Nevertheless, the best prevalent kind of concrete is Portland cement/vermiculite aggregate, a newly developed concrete which employs an aggregate of polystyrene bead. It is highly resistant to water which is better than vermiculite aggregate concrete which is not water resistant [1]. So, waterproofing of the best type is necessary to make sure that the performance of the system is better in which the vermiculite concrete is utilized.

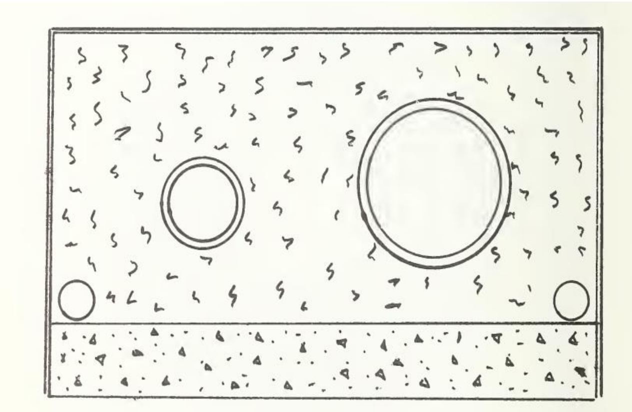


Fig 5.Insulating Concrete Envelope System

IV. CHALLENGES OF DISTRIBUTION SYSTEM

A. Heat Transfer from the system

These pipeline distribution system is the link between the central plant and consumer systems. Commonly used laying for pipelines are: overhead laying, buried pipeline laying and inclusive type trench laying. Under earth most preferable because of convenience in construction and low movement. But inconvenience to maintenance and repair is its main shortcoming.

_A.1_ Factors which effects rate of heat transfer calculation

The primary factors influencing the heat loss of underground system include the difference in temperature of water and soil surface, the earth surface insulation of pipeline. Along with these level of pipeline under earth surface, heat transfer capacity of soil and the separation between two pipes, two adjacent to each other. Poor insulation system results in increase in effect of soil conductivity and level of burial. Composition of soil and its water content also effects the rate of heat transfer[3].

A.2 Calculation Method of Heat Transfer of Single Direct-buried Pipe

The single direct-buried pipeline system includes single direct-buried un-insulated pipe (Figure. 6) and underground insulated pipe (Figure. 7). The resistance to heat transfer of system is primarily composed of soil thermal resistance, thermal resistance of pipe and thermal resistance of thermal insulation layer.

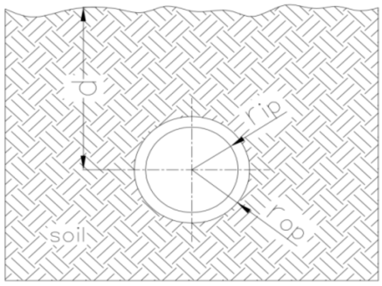


Fig 6. Pipe without insulation

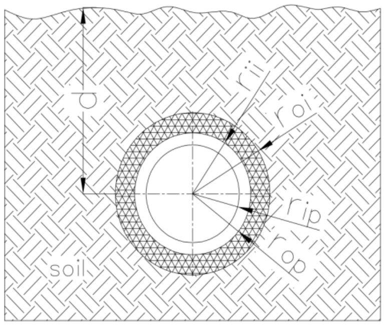


Fig 7. Insulated Pipe

Calculation of Soil Thermal Resistance

According to the ratio of burial depth to pipe radius, a method for estimating soil thermal resistance is given in reference[2]. The estimation error is less than 1% in formula.

$$R_s = \frac{ln\left\{(d/r_{op}) + \left[(d/r_{op})^2 - 1\right]^{1/2}\right\}}{2\pi k_s} \quad (d/r_{op} > 2)$$

$$R_s = \frac{ln(2d/r_{op})}{2\pi k_s} \quad (d/r_{op} > 4) \qquad \ldots\ldots(1)$$

Where,

R_s –thermal resistance of soil, (m·K)/W

d –burial depth to centerline of pipe, m

r_{op}–outer radius of pipe or conduit, m

k_s –thermal conductivity of soil, W/(m·K)

Calculation of Thermal Resistance of Pipe and Insulation Layer

The formula can be used to calculate the thermal resistance of the pipe itself and the insulation layer, which is used to calculate the heat transfer resistance of the cylinder wall in the heat transfer theory[3]. The iterative method should be used, when the thermal conductivity of thermal insulation material is a function of temperature. In general, the thermal resistance of the pipe itself and the protective casing is less than 5% of the total thermal resistance when the pipe is insulated. In order to simplify the calculation, the thermal resistance of the pipe itself and the protective casing can be neglected for the insulated pipe.

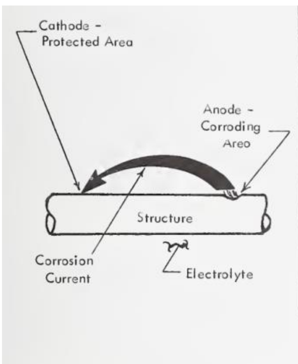
$$R_p = \frac{ln(r_{op}/r_{ip})}{2\pi k_p} \qquad \text{……(2)}$$

Where,
R_p–thermal resistance of pipe wall, (m·K)/W
k_p –thermal conductivity of pipe, W/(m·K)
r_{ip} –inner radius of pipe, m

Calculation shows that the thermal resistance of the insulation layer takes a large proportion of the total thermal resistance, so the calculation can be further simplified, which the thermal resistance of the pipe and air layer can be neglected. This method avoids the complicated calculation process and greatly simplifies the calculation workload, and the calculation results can meet the needs of the engineering, which is suitable for popularization and application in engineering.

B. Corrosion

Failures will occur in all the different commonly used systems unless properly engineered precautions are taken to protect the pipe. Modern industrial plants, hospitals, universities, cities and other institutions utilize these systems and corrosion failures become expensive, cause shutdowns, hazardous conditions, occasional cotastrophies and result in inconvenience to involved personnel and the general public alike. Corrosion leaks also cause wetting of thermal insulation, thus causing excessive thermal losses [4]. When planning new construction, or when a corrosion problem or potential problem is discovered, a corrosion study should be made to obtain optimum action. Various approaches such as cathodic protection, use of nonmetallic materials, utility tunnels and future or continued failures must be compared, considering economics, safety, practicability, etc.
Corrosion is on electrolytic chemical reaction between a metal and its environment. It always involves the flow of direct current electricity through an electrolyte (such as soil or water) from one point to another on the metal surface. Figure 8 illustrates the general corrosion cell. There are two major causes of underground corrosion - galvanic corrosion and stray current. Galvanic corrosion is in effect a battery. Current flows from the anode (corroding) area to the cathode (protected) area because of the potential difference between them. A current will be generated by connecting two different metals. Galvanic corrosion also results from dissimilar surface conditions, differences in oxygen concentration or differences in environment around a structure. The second major type of corrosion is caused by the discharge of stray direct current from the surface of a buried metal[4]. Stray currents may emanate from welding or plating operations, electrified railways, cathodic protection systems and other sources of direct current. In travelling through the earth, these currents frequently are taken by a buried or submerged structure at one point and discharged at another. Corrosion occurs at the discharge point. Coatings jacketstower is treated with water from STP, hence conserving fresh water. Corrosion-resistant metals, nonmetallic and cathodic protection are used to combat corrosion. Cathodic protection Is an electrical process involving the flow of direct current from special anodes to the system subjected to corrosion. There are two types of cathodic protection systems, and current using impressed system. In the galvanic system, an anode, usually made of magnesium or zinc, is located adjacent to the structure and connected to it. Because of the difference in potential anode and the structure, a battery (corrosion cell) is created and due to which flow of current takes place. These are connected to a rectifier or other source of direct current, which in turn is wired to the structure. Figure 9 illustrates cathodic protection. Non-metallic piping is also used to combat corrosion. These materials, however, also have limitations and can be highly affected by temperature, pH or, as with reinforced concrete, stray current. Instead of being buried, lines are sometimes installed in tunnels. While these are usually very expensive, there are times when o tunnel may be the best answer. This is acceptable in cases of many utilities and perhaps a pedestrian passage shore the same tunnel. Overhead construction is sometimes used, although aesthetics, cost and practicability often make buried structures more desirable.



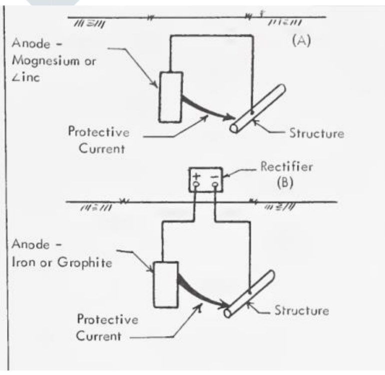


Fig 8. Basic Corrosion Cell Fig 9. Cathodic Protection

V. ECONOMICS OF DISTRICT COOLING SYSTEM

DCS ensures sustainable development through the following Features:

1. Lowering down the power demand and air conditioning system of high efficiency , decrease in CO_2 emission.
2. Lower make up water consumption.
3. Make up water for cooling Corrosion is a major cause of failure in heat and chilled water distribution systems.
4. Chiller is selected with non-CFC green refrigerant gasR134a and the refrigerant is stored at DCS plant location only, thus reducing the environmental impact due to the refrigerant[5].
5. Reducing the plant capacity, which minimizes the use of natural resources.

Some of the factors that contribute to the economic advantage of district heating and/or cooling systems over individual local building plants are[6]:

1. Reduction in consumption of fuel for the production of heating and /or cooling energy on account of increased plant efficiency and a more skilled operation of the large boiler /chiller plants.
2. Potential of burning low cost coal as basic fuel, thereby reducing requirements for oil import.
3. Potential of burning low cost, low quality, high sulfur content coals in pollution free, compact, low cost, high efficiency fluidized-bed boilers.
4. Reduction of total capital investment and consumption of steel for the boiler and chiller facilities due to increased unit capacity, use of improved boiler / chiller designs and reduction of required standby reserves.
5. Reduction of the number of operating personnel required for the heating/cooling plant operation.
6. Reduction of fuel transportation, handling and ash handling and disposal expenses.
7. Reduction of cost of heating and cooling systems as a whole due to the possibility of organizing the heat and cooling consumption conditions in a better way.
8. Elimination of smoke and dirt thereby decreasing building cleaning, painting, decorating costs.
9. Reduction of repair, insurance and inspection expenses
10. Availability of valuable space which can be rented or used, which otherwise would be occupied by local boiler and chiller plant, fuel storage and stack.
11. Lower cost of fuel and other supplies due to the quantity purchased and more competitive buying.
12. Reduced unit capacity cost and economical pollution control system operation.

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