An Introduction to Heat Transfer from Buried Distribution System Piping

ASHRAE/NYSERDA Webinar 12 presented March 9, 2022

Question Asked	Answer Given
Should earth scientists / engineers be involved more often in regards to soil thermal properties? Or can a mech eng stand behind their interpretations?	It really depends on how familiar the ME is with soils. If they are not familiar with soils they certainly should as a minimum run their findings by a geotechnical engineer. The problem, however, is that most geotechnical engineers don't really understand thermal properties well. But they can at least confirm the soil characterization and its state (i.e. compaction, moisture content).
We used frost shielding with rigid insulation for a district heating and GeoExchange system in northern Canada. Following water supply means and methods.	Any data you have on how it performs would be interesting.
Soil is usually a reference to top ground material of a depth of no more than perhaps 15ft. For systems that would consider deep earth vertical borehole heat exchangers do the same parameters apply to the rock strata in defining the average thermal properties?	The discussion in this webinar was regarding soil properties as they relate to horizontal piping of CHPS, not vertical ground coupling bore holes. For vertical GC systems refer to the ASHRAE Geothermal heat pump design guide (aka "The blue book")
I'm not following why you would want to insulated your buried pipes when the whole reason for putting them in the ground is to do heat exchange. If the idea is that you insulate the pipe that is above the heat exchange zone, I can understand that but that would also represent a relatively insignificant amount of pipe compared that which is doing the heat exchange right?	I will let Gary respond, but I think you are confusing GSHP well field piping with the district distribution piping that Gary is presenting now. Distribution piping from plant to customer, you don't want to lose energy. I agree with what Steve has said and I would just add that once you move from individual building ground coupled systems to "community" scale systems there will be much more horizontal distribution piping. And if you have high system diversity so that buildings acting as heat sources and sinks for other buildings, the amount and size of the horizontal piping is going to be an even larger fraction when compared to the ground coupling.
It sounds like this presentation has touched on two different concepts. One is a geothermal heat exchanger to pair with a heat pump, and the other is district heating/cooling distribution piping that is buried. The former would be uninsulated and the latter would be insulated.	Yes, that's basically it, although in this webinar we are really only talking about the later. Lisa covered the ground coupling in Webinar #10.
Are the manufactured insulated systems that work always a pre-insulated product (insulation on the carrier pipe)?	There is another class of systems that we sometimes call "field-erected." Successful versions of those systems are walk through tunnels, the shallow concrete trench I discussed in Webinar 11, deep buried trenches, and loose fill insulation. The Engineer of Record will typically be responsible for a larger portion of the system design details for field-erected systems.
Was EN 253 District heating pipes - Bonded single pipe systems for directly buried hot water networks - Factory made pipe assembly of steel service pipe, polyurethane thermal insulation and a casing of polyethylene been evaluated by ASHRAE for the integrity of its insulation value?	When ASHRAE conducted the insulation study, the use of EN253 systems in the US was very isolated and thus we did not include the insulations used in that system specifically. That said, the components of PUR foam are only supplied by a couple of large global chemical manufacturers. Thus, the EN253 PUR foam was likely very similar to what we were supplied by a US pre-insulated pipe manufacturer. If we were to repeat the tests today, I would lobby for testing to show that the PUR meets both the EN253 and the new ASTM C1847-21 requirements.

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For GSHP systems, the system lateral pipe bury depth is often based on local frost depth used for structural footings. You mentioned insulation is up to 7x better than soil. Does this allow for more shallow bury depth than the frost line estimate?	That ratio of around 7 in thermal resistances was for soil at the depth and thermal properties in the example versus the thermal resistance of the pipe insulation from the example; i.e. this is not a universal ratio that can be applied. Certainly insulating the pipe will allow lower burial depths for operating pipes, however you will likely need to run some calculations to determine how much insulation to use for a given shallow burial. You must also keep in mind that if for some reason the pipe is not operating, i.e. no flowing water within to provide a heat source, ultimately it will freeze regardless of how much insulation is used. The insulation will slow the process.
Are there instances where soil properties/conditions can change over time that may affect original design conditions?	I did answer that in the live session, but I will elaborate here. Yes, soil surrounding either heated or cooled pipes will dry or dampen, respectively, due to the moisture drive in the soil. The impact on the thermal conductivity will be to decrease from drying or increase with cooling. There is also a feedback mechanism in play as well; for example in the case of a heated pipe the drier, lower thermal conductivity soil will increase the thermal resistance in the soil and that will cause the temperature at the outside of the pipe (or its insulation/jacket for an insulated pipe) to increase further thus increasing soil thermal resistance and driving soil temperatures even higher. That feedback process will be faster at first and then decrease as a steady-state is established. Insulation always helps reduce
How relevant are these calcs for an ambient temp loop, feels like there would be a lot less heat transfer than a district heating system?	Heat losses will be less for ATLs in terms of absolute magnitude, however the consequences will be much greater as ATLs will be working with very low Δ T's compared to even 4th gen DH. Going back to my example in the Webinar 3 on planning were the ATL had a 10 degree a the 4th gen DH example had a ΔT of 40. The larger piping required for the ATL increases relative heat losses, but the lower temperatures reduce heat losses if the pipes are both insulated similarly. If the ATL system is uninsulated the losses could become very significant, plus we have the risk of freezing with the ATL. Much will depend on the specifics of each potential application.
Thanks for this excellent and comprehensive lecture. Concerning the utilidor in Alaska, is there a chance the soil temperature be above +20F at 1 m depth when the air temperature is -45F?	That certainly is possible, say early in the heating season before the surface temperature drops have had time to impact the soils at significant depth. Eventually as the heating season continues temperatures at significant depths will continue to drop, and as I've shown in with the whiplash solution, the subsurface temperatures will continue to drop even after the temperatures on the surface are moderating.
I believe the state transportation departments may also have boring data information in location near for bridges and highways.	Another good source, thanks.
Is there a specific depth for which the value of 2.16 W/m K be used?	Not universally. It depends on the soil type, moisture content, and insitu density.
How would one treat the heat transfer for pipes buried under a building structure?	The basement temperature would become the driving force, so it would replace the air/surface temperature.

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I was also confused at first, but realized that this is for supply and return lines for district heating. For GSHP, usually pipes are for heat exchange and no insulation is needed?	For geothermal heat pump systems with significant horizontal piping, as may be the case for CHPS, insulation may be needed. CHPS can be significantly different that geothermal heat pump systems for individual buildings. And, of course, we still have the case where a central plant type heat pump approach may be used and insulated piping would most likely be required.
Is there a recommended method to procure site or at least regional geotechnical data? Does ASHRAE own a database? Should it?	The sources I spoke about, and one attendee's comment that state DOT's are another source, are the major sources. ASHRAE does not have a database: that has been discussed as a potential research project but it was dropped out of concern over the potential misuse of the information.
Styrofoam board box with sand surround the pipe prevent frost damage?	Gary will cover this in the frost shielding concept. stay tuned.
To insulate some buried solar piping, I put urethane foam insul around the pipe, then built a box around the assembly out of rigid foam and spray foamed the interior of the box before putting the lid on. Should I assume that insulation is now ineffective after 10 years?	You should still have as a minimum the insulation provided by the extruded polystyrene assuming that's what you used for rigid insulation and you have not exceeded it's operating temperature limit. If you have opportunity to excavate a portion of the system take some samples of the PUR and have a laboratory measure its moisture content. And if you do so, please share the results with me! Be sure to bag samples as soon as they are removed.
Is soil testing required to install DH low temperature system underground piping ?	It would be important to establish any geotechnical challenges (expansive soils, etc.) along the route. If a soil restrained system such as EN253 was being used, then the soil conditions would need to allow adequate restraining forces. From a heat loss standpoint, as long as the system is well insulated, it would not be necessary to actually measure soil thermal properties, the insulation buys you lots of insurance, see my answer above to the question "Are there instances where soil properties/conditions can change over time that may affect original design conditions?".
Have you done any research on Gilsulate pourable insulation?	I have, but it was very limited and part of legal proceedings so it is proprietary. Now, I have done much more research and a lot of that is available, on Gilsulate's former competitor, DriTherm. The results are a bit "academic" now as that product is no longer on the market.