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CDA
Copper Development Association Inc.

May 12, 2008

Mr. Jerry Farrell Jr., Commissioner
c/o Ms. Elisa Nahas (elisa.nahas@ct.gov)
State of Connecticut
Department of Consumer Protection
State Office Building
165 Capitol Avenue, Room 103
Hartford, CT 06106

RE: Comments on Notice of Intent to Amend the Regulations of Connecticut State Agencies Section 25-128-34 Concerning Well Drilling

Dear Mr. Farrell,

This letter serves as a brief follow up to our oral testimony on the above proposed rule making given on April 22nd in Room 119 of the State Office Building. Thank you for the opportunity to comment on the above referenced proposed change to legislation regarding well drilling, in so much as the regulation directly impacts the use and installation of direct exchange ground source heat pump systems in the State of Connecticut. These systems have a history of successful installation in many states in the US as well as other important installations worldwide. The proposed revisions, as written, would inadvertently restrict the residents of Connecticut from using these systems that have shown remarkable energy efficiency improvements over traditional heating and cooling systems as well as other ground source or geothermal systems.

Specific to the proposed regulations, proposed new sections 25-128-39b, Closed-Loop Geoexchange System Fluid and 25-128-39c, Closed-Loop Geoexchange System Piping greatly restrict, or effectively prohibit the path to market of direct exchange ground source heat pump systems. These sections require, by reference, that system fluids be water-based antifreeze solutions, routed through a ground loop constructed of polyethylene piping materials.

As written these sections adequately address one specific ground source (geothermal) heat pump technology, those using plastic ground loops circulating water, while ignoring the other commercially available and more energy efficient direct exchange ground source heat pump systems using copper tube ground loops that circulate environmentally-friendly refrigerants rather than antifreeze solutions for heat exchange. In doing so, the proposed regulation makes it substantially more difficult, and in effect restricts the use of a commercially available, more energy efficient heating and cooling system by the consumers of the State. Systems that are currently being installed throughout the State under the current codes and regulations.

Throughout the course of this proposed rulemaking there have been anecdotal comments by others regarding the reliability, longevity and environmental impact on groundwater by the use of copper ground loops circulating refrigerants, as utilized by the direct exchange systems. It would be imprudent to try to respond to these nebulous and non-specific claims in this format, other than to say that neither copper, nor the refrigerants as used in these systems have shown to be an environmental concern, or have a negative environmental impact on air, earth or water that would justify regulation or restriction.

Copper is a metal that occurs naturally in the environment, and also in plants and animals. It is an essential nutrient that is required to ensure and maintain good human health. The impact of copper runoff on surface water sources have been studied by institutions including the University of Connecticut to find that little of the copper released from building products remains bioavailable in the environment, being quickly bound by other organic and inorganic compounds. Copper tube is certified to the ANSI/NSF 61 health effects standard for potable water use.

Copper tube has long been used for a myriad of services, domestic water supply and distribution, fuel gas distribution, snow and ice-melting systems, geothermal heating systems, HVACR systems and all have been installed successfully underground. The oldest known installation dating back over 5000 years to the Cheops Pharaoh's tomb, where copper was fashioned into pipe to carry water to the Pharaoh's bath. A remnant of that pipe was unearthed, still in usable condition; a testament to the durability and corrosion resistance of the material.

Copper's successful use in these applications is primarily due to its excellent resistance to corrosion in the underground environment and the longevity that copper provides. The most telling example of this is the use of copper piping in underground water service lines. Copper has been used in this application in the U.S. for more than 70 years and to this day continues to account for more than 60% of all water service lines installed. This installed base accounts for many millions of service lines, and with each service line averaging a minimum of 20 – 30 feet in length, several billion feet of copper tube installed in an underground environment throughout the United States. Copper failures due to corrosion in these systems may occur; however, the occurrence is rare and is considered the exception to the norm. In the majority of cases where copper failure does occur in the underground environment, it is not due to the native soil condition but rather to the introduction of, and collection of, aggressive materials such as deicing chemicals and fertilizers. The concentration of these aggressive materials normally cause a local attack not generalized attack or dissolution of the copper tube.

The enclosed publication "*Water- and Soil-Side Corrosion of Copper Water Service Lines*" offers testament to these expectations of longevity based on service lines removed for examination after 70 years of use.

Should there be areas where local soil conditions are likely to cause premature corrosion of copper materials, these issues are easily dealt with by using readily available, inexpensive backfill materials. Proper design and installation of the buried tube to eliminate the collection and concentration of aggressive materials/compounds will drastically increase the longevity of the installed copper tube. In the specific case of geothermal heating/cooling systems, the specialized backfills, recommended for use in the well, not only provide for and provide increased heat transfer benefits, but also act as a protective backfill.

Other alternate materials (primarily plastics) have, and continue to be used in underground applications. Although, their (alternate materials) use is based primarily on material cost and not their superior performance. There are a number of municipalities that have begun to change their specifications to require only copper water service lines due to increased occurrences of breakage and failure of underground plastic service lines. These issues have been published in many areas and are readably available as public information.

Currently, the state codes and regulations of Connecticut allow the use of copper piping systems in various underground piping systems and applications, without any restriction on the depth at which they can be used, the amount that can be installed underground, their proximity to ground water sources, etc. As written, the current regulations arbitrarily restrict this use specifically for ground source (geothermal) heat pump systems, with no evidence of support for the anecdotal claims regarding the impact of the use of copper piping systems in underground environments.

With the long, and successful history of copper use here and throughout the world, and the energy efficiency improvements that can be realized by consumers using the copper-based direct exchange ground source heat pump systems we respectfully request that the proposed new sections 25-128-39b, Closed-Loop Geoexchange System Fluid and 25-128-39c, Closed-Loop Geoexchange System Piping either be removed from the regulation or be rewritten to properly address and allow the use of direct exchange systems.

We stand ready to assist the Department of Consumer Protection in addressing any concerns that they may have regarding this appropriate and responsible use of copper piping and/or drafting appropriate language to ensure fair and appropriate consideration of the use and installation of copper ground loops for direct exchange ground source heat pump systems.

Should you require further information or assistance you can contact me at the phone number or address listed on this letterhead.

Best regards,

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Water- and Soil-Side Corrosion of Copper Water Service Lines

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A study was conducted of the soil- and water-side corrosion of underground copper water service lines from various locations in Billings, Montana. The tubes had been in service from 10 to 70 years, and the extent of corrosion was directly related to the tubes' location in the city. The study showed that copper has excellent resistance to the indigenous soils and water.

When cast iron water mains in Billings, Montana, failed and had to be replaced, the original copper water service lines also were replaced. This provided the opportunity to study the soil- and water-side corrosion of the copper lines, which had been in service from 10 to 70 years with no failures.

The study was conducted to correlate the degree of corrosion with the service life of tubes from various locations and with the characteristics of the soil and water at those locations.

There is little written about the behavior of copper in underground applications because experience clearly shows copper has excellent resistance to soil-side corrosion. Gilbert reported that corrosion of copper in British soils for periods of up to 10 years varied considerably depending on soil corrosiveness.[1] The most severe attacks were found where sulfate-reducing bacteria (SRB) were present. In moist acid clay and wet acid peat, wall thickness losses ranged from 0.000024 to 0.0042 in. (0.00061 to 0.11 mm) while pit depths ranged up to 0.019 in. (0.5 mm).

Logan and Romanoff exposed copper samples for nine years in 14 different soils in the United States.[2] The greatest attack occurred in soils where the backfill contained cinders or had high organic or inorganic acidity. Losses in wall thickness ranged from 0.0002 to 0.002 in. (0.0051 to 0.051 mm), in good accord with the observations of Gilbert. Pit depths ranged up to 0.051 in. (1.3 mm).

Based on these studies and that of Denison,[3] Myers and Cohen described the conditions that can render soils corrosive to copper.[4] They are:

- Elevated sulfate or chloride contents together with poor drainage, retained moisture, and an annual rainfall exceeding 30 in. (76 cm);
- Very low resistivity (below 100 to 500 ohm-cm);
- Large quantities of organic matter, particularly organic acids;
- Moist cinder fills, either because of the sulfides present in the cinders or because of galvanic action between the copper tubes and the cinders;
- Anaerobic SRB, which produce sulfides and are aggressive to copper;
- Inorganic acids; and
- Appreciable amounts of ammonia or ammoniac compounds, which may be introduced in lawn fertilizers.

Other factors that could promote underground corrosion of copper include:[4]

- **Oxygen differential concentration cells.** Preferential corrosion is sometimes found on the underside of copper tubes because they often are in contact with undisturbed soil where the oxygen content is reduced, in contrast to the upper portion of the tube which may be exposed to aerated backfill.
- **Variable aeration characteristics.** These depend on particle size and distribution, degree of packing, and drainage characteristics of the soil.
- **Deicing practices.** If the chloride content of the soil is elevated

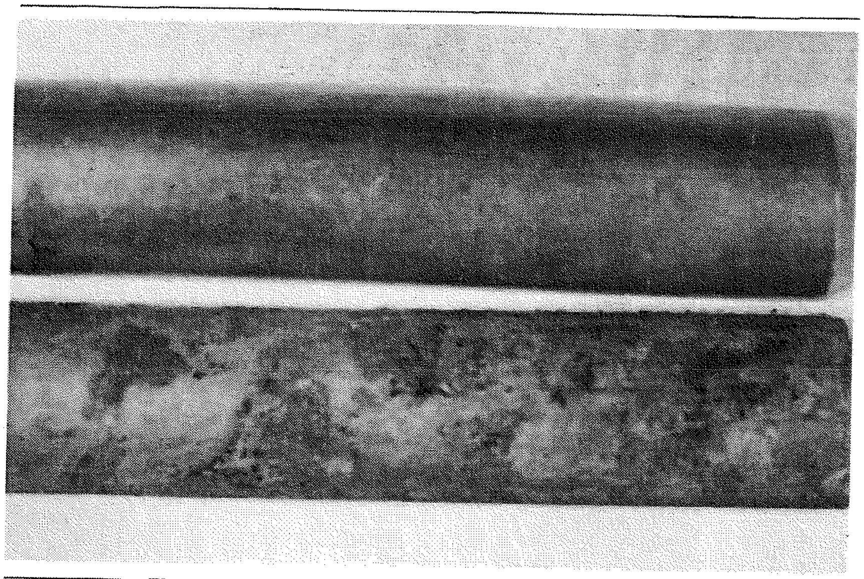

FIGURE 1
Typical outside surface condition of as-excavated tubes after up to 70 years' soil-side exposure.

because of deicing, the metal becomes more anodic than in regions where the chloride content is lower.

- **Stray currents.** Direct current from impressed cathodic protection systems or from the grounding of AC systems to underground copper service lines can be detrimental.
- **Cinders.** Although connections of copper tube to steel water mains can be favorable to the underground copper tube, the copper still can be attacked if it is embedded in a backfill composed of cinders.

Tube Samples

A total of 110 samples of annealed-temper seamless copper water tube produced to the types K and L wall-thickness schedules of ASTM B 88[5] from eight locations were visually examined at magnifications up to 40x. Figure 1 shows the surface condition of as-excavated tubes after up to 70 years of soil-side exposure.

Soil Analysis

Soil from the Billings, Montana, area is alluvial, having been deposited from water. The class of soil is related to the particle size as follows:[6]

Gravel and stones	>2 mm
Fine gravel	1 to 2 mm
Sand	0.05 to 1 mm
Silt	0.002 to 0.05 mm
Clay	< 0.002 mm

Moisture content, minimum resistivity, pH, water-soluble sulfate content, and chloride are shown in Table 1 for each site from which copper tubes were removed for examination.

Phase I—Soil Side

Detailed descriptions of the tubes examined in their as-excavated and cleaned conditions, together with their maximum and average depths of pitting and surface roughness, are described in Table 2. The maximum depths of pitting as a function of exposure time are plotted in Figure 2. The graph shows that even with a maximum soil-side pit depth of 0.011 in. (0.28 mm) after 35 years' exposure, the service life of the underground water lines at these locations would extend into the hundreds of years.

TABLE 1
Soil Properties

Property	Location							
	Alderson Ave.	Avenue B	Delphinium Drive	Frances Ave.	Harvard Ave.	McArthur Ave.	Mountain View Blvd.	Parkhill Drive
Soil classification	Lean clay	Lean clay	Graded gravel with sand	Lean clay with sand	Lean clay	Silty sand	Sandstone	Lean clay with gravel
Moisture content (%)	22	23	2	19	6	27	9	12
Minimum resistivity (ohm-cm)	288	352	5,440	730	1,600	205	832	2,304
pH	7.9	7.5	8.9	7.6	7.7	7.6	7.8	7.7
Water-soluble sulfate (%)	2.1	1.94	0.03	0.04	0.02	0.54	0.13	0.09
Water-soluble chloride (ppm)	20.8	3.1	1.14	5.2	3.1	11	5.1	14.2

TABLE 2
Description of Tube Specimens—Soil Side

Location (No. of Samples) Years Installed	Appearance As Excavated	Appearance After Cleaning	Depth of Pitting in. (mm)	Roughness (μm)
Alderson Ave. (22) 1936-1949	Negligible corrosion; varying amounts of residual soil films—light blue tint; orange deposits—high iron content.	Negligible corrosion	Maximum 0.0072 (0.18) Average <0.001 (<0.025)	Maximum 82.9 Typical 5.3-11.5
Avenue B (12) 1922-1941	Negligible corrosion; surface tarnish; some attached residual soil	Negligible corrosion	Maximum 0.011 (0.28) Average 0-0.006 (0-0.15)	Maximum 63.2 Typical 3.5-14.6
Delphinium Drive (11) 1949-1961	General corrosion; dark orange-brown appearance; attached residual soil; blue due to presence of basic copper sulfate corrosion products	Most samples heavily roughened; high frequency of small pits	Maximum 0.011 (0.28) Average 0.004-0.008 (0.10-0.20)	Maximum 58.4 Typical 12.6-36.8
Frances Ave. (9) 1948-1962	Negligible corrosion; reddish-brown tarnished appearance; some with blue-green corrosion products	Essentially free from attack	Maximum 0.004 (0.10) Average 0-0.002 (0-0.05)	Maximum 13.8 Typical 4.2-7.4
Harvard Ave. (18) 1946-1985	Negligible corrosion; light brown tarnish; trace of blue-green corrosion products	Essentially free from attack	Maximum 0.0015 (0.04) Average <0.001 (<0.025)	Maximum 12.7 Typical 5-10.2
MacArthur Ave. (11) 1946-1980	Gray-black film over entire surface; heavy tarnish; heavy corrosion/rough appearance	Substantial general corrosion; surface roughened	Maximum 0.008 (0.020) Average 0.005-0.007 (0.13-0.18)	Maximum 54.5 Typical 14.9-38.5
Mountain View Blvd. (10) 1947-1955	Minimal corrosion; light brown tarnish film; some blue-green corrosion products	Generally lustrous appearance	Maximum 0.003 (0.08) Average <0.001 (<0.025)	Maximum 22.7 Typical 6.2-15.4
Park Hill Drive (13) 1951-1957	Some samples displayed relatively high corrosion; dark brown tarnish with some green corrosion products	Roughened surface with some metal loss but no discrete pits	Maximum 0.0085 (0.22) Average <0.001 (<0.025)	Maximum 41.1 Typical 5.7-29.0

The results show that the degree of underground corrosion of the copper tubes is related to their location. At five of the eight streets from which samples were taken, average pit depths for the sets of tubes from each street ranged up to only 0.002 in. (0.05 mm).

Nonaggressive soils (lean clay and sandstone) were all slightly alkaline, with a pH in the range 7.5 to 7.9 and moisture content ranging from 6 to 23%. Resistivity ranged from 288 to 1,600 ohm-cm, soluble sulfate from 0.02 to 2.1%, and soluble chloride from 3.1 to 20.8 ppm. There was no consistency of a single property or of any combination of these properties which would indicate why they were nonaggressive.

For the tubes embedded in the corrosive soils, the degree of corrosion was more extensive, with typical pit depths of 0.006 to 0.007 in. (0.15 to 0.18 mm). They also had considerable general corrosion, which led to significant increases in their measured surface roughness. The properties of the corrosive soils in terms of resistivity, moisture content, and amounts of soluble sulfate and chloride were similar to those of the lean clays, and no correlation could be made between these properties and the extent of corrosion.

Because larger particle size per-

TABLE 3
Description of Tube Specimens—Water Side

Location (No. of Samples), Years Installed	Color of Water-Side Deposit	Percentage of Water Side Severely Roughened	Maximum Depth µm (mil)
Alderson Ave. (22) 1936-1949	Orange-yellow to creamy white	20-100	86 (3.4)
Avenue B (12) 1922-1941	Yellow-brown to gray-black	15-75	72 (2.8)
Delphinium Drive (11) 1949-1961	Yellow-white	5-100	112 (4.4)
Frances Ave. (9) 1948-1962	Yellow-brown	10-45	70 (2.8)
Harvard Ave. (18) 1946-1985	Sandy-brown to gray	15-90	76 (3.0)
MacArthur Ave. (11) 1946-1980	Creamy yellow	5-60	68 (2.7)
Mountain View Blvd. (10) 1947-1955	Off-white to orange-brown	5-50	106 (4.2)
Park Hill Drive (13) 1951-1957	Creamy white	5-80	84 (3.3)

TABLE 4
Analysis of Billings Municipal Water Supply (July 1, 1981, to June 30, 1982)

Property	Monthly Average (ppm)	Maximum Daily Extreme (ppm)	Minimum Daily Extreme (ppm)
Total dissolved solids	290	442	75
Total alkalinity (as $CaCO_3$)	102	188	33
Total hardness (as $CaCO_3$)	160	206	53
Saturation index (Langelier)	−0.84	−2.17	−0.1
Calcium (as $CaCO_3$)	44.6	57.7	16.5
Free carbon dioxide	8.92	—	—
Aluminum (Al)	0.03	0.25	0.01
Iron (Fe)	0.02	0.06	0.04
Nitrate (NO_3)	0.34	0.62	0.00
Sulfate (SO_4)	98	155	32
Total phosphorus (P)	0.04	—	—
Fluoride (F)	0.57	1.5	0.15
pH	7.32	7.65	6.41
Specific conductance (micromhos)	290	—	—
Temperature (°F)	52	72	35

mits soils to be more readily aerated and allows more aerated water to reach the tube surfaces, greater soil-side corrosion can be expected, as occurred on samples from Delphinium and Park Hill Drives.

Silty sand, with the lowest water drainage rate of any soil evaluated, had the highest moisture content and lowest resistivity, which are characteristics of an aggressive soil (McArthur Avenue).

Results

The degree of soil-side corrosion varies from street to street within the city. At five of the eight streets from which samples were taken, the corrosion was generally very low. No single or combination of soil properties indicated why soils were nonaggressive.

At three of the streets that had nonaggressive soils, occasional samples had been more severely attacked in terms of both the depth of pitting and the degree of general corrosion. This suggests that the increased attack resulted from local contamination or from a different class of soil.

In the three other streets, slightly deeper pitting had occurred, and corrosion on the tube surface was more apparent. Generally, this manifested itself in increased surface roughness, particularly on the specimens from Alderson Avenue, Avenue B, and Delphinium Drive (Table 2). The extent of corrosion could not be correlated to the properties of resistivity, moisture content, or the amounts of soluble sulfates or chlorides.

Even in the most aggressive soils, it was evident the tubes could have endured exposures for multiples of their present service lives without failing. Clearly, copper has excellent resistance to underground corrosion in the soils indigenous to this community.

Phase II—Water Side

Evaluation of the water-side surfaces was conducted on the same tube samples evaluated for the Phase I study.

Results

Deposit Characterization

All tube interiors were covered with a rippled deposit, the color of which ranged from almost white through yellow and orange to brown. Analysis of the deposits suggested they were predominantly aluminates and silicates with various amounts of hydrated iron oxides.

Cleaned Tube Surfaces

After acid cleaning and sectioning lengthwise, evidence of corrosive attack from the water became apparent, although there was no correlation between the nature of the overlying deposit and the extent of attack.

Surface Roughening

The water-side surface of some tube specimens exhibited more corrosion than others. These regions were rougher and, in some cases, extended over the entire specimen length. The percentage of water-side surface that had suffered more severe attack varied (Table 3), but was unrelated to the tube's service life. Irregular corrosion penetration into tube walls was noted on some specimens. In some cases, the porous metal appeared as needle-shaped crystallites.

Depth of Pitting Attack

The inside tube surface area on which pitting occurred was quite variable, as was the pitting depth. The maximum depth of water-side attack reported in Table 3 is 0.0044 in. (0.11 mm). Pit depths showed no relationship to the tube's years of service in any location.

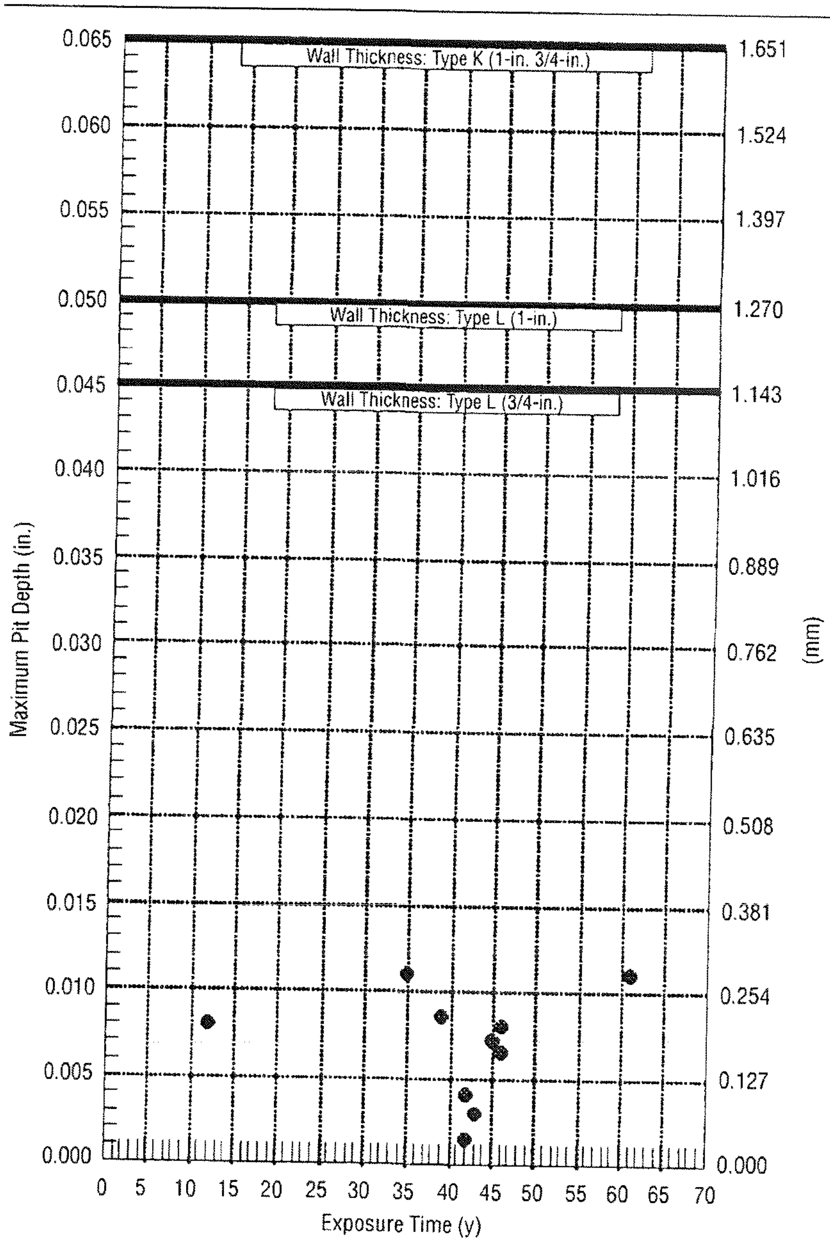

FIGURE 2

Maximum pit depth as a function of exposure time to the various soil conditions (points). Dark horizontal lines represent the original pipe wall thicknesses.

Tube Hardness

The Billings water department was concerned that tube hardening after years of service had caused difficulty in connecting the copper service lines to the water mains by means of traditional compression or flared (mechanical) fittings. Rockwell F hardness measurements were plotted as a function of service life for the tube samples from one excavated street.

ASTM B 88 specifies a maximum Rockwell hardness (HRF) of 55 for seamless copper water tube.[5] The measured values ranged from a low of HRF 45 to a high of HRF 80, with

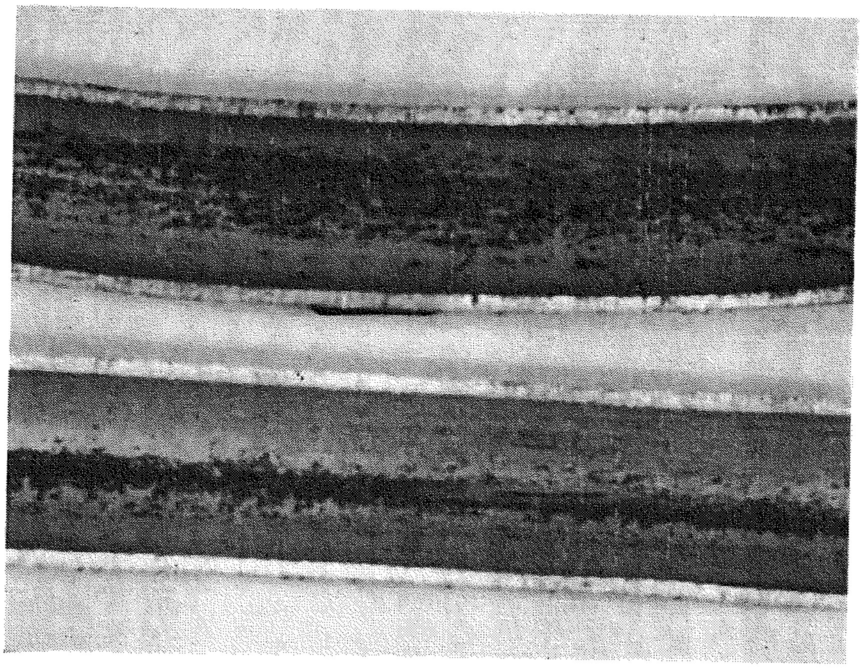

FIGURE 3
Typical inside surface of as-cleaned tubes from Harvard Avenue after up to 48 years' service (top: installed 1949; bottom: installed 1946).

most in the range of HRF 55 to 70. Hardness values exceeding HRF 55 were probably due to cold working as a result of coil unwinding or other tube handling during installation. There is no evidence to demonstrate any relationship between tube service life and its hardness.

Discussion

Various degrees of underdeposit corrosion were observed on the water side of tube specimens from Billings. The deposit color ranged from off-white through yellow, orange, and brown to almost black (Table 3). This iron-rich layer most likely precipitated from the water as an iron oxide from corrosion in the water mains. There was no relationship between the color of the deposits and the service lives of the tubes.

The rippling of the deposits was probably caused by turbulence generated from nonflowing to flowing conditions within the tubes.

The cleaned surfaces of some tubes exhibited more severe corrosion than others (Figure 3). This attack probably was caused by the deposit and the differential aeration cells produced by the deposits.

Irregular penetration of the tube wall also occurred. Corrosion products inside the pits were predominantly cuprous oxide. The maximum depth of the pits is less than 5% of the wall thickness after 29 years' service. As demonstrated by the data plotted in Figure 4, anticipated tube service lives would be many times those of the exposures represented. The figure clearly shows that, even with a maximum water-side pit depth of 0.0044 in. (0.11 mm) after 41 years' exposure, service lives of underground water lines would extend to hundreds of years.

No correlation could be made between the service life and the percentage of water-side surface that suffered pitting attack. This result implies that the water composition did not change in the first few years of the tubes' service and that little if any corrosion occurred in subsequent years. Many tubes from three streets, which had been exposed to the Billings water supply for up to 70 years, actually exhibited pit-free surfaces.

Water analyses for July 1981 to June 1982 are shown in Table 4. Chemical treatment of the water supply consists of alum flocculation to remove suspended and colloidal material, lime, and phosphate softening. Precipitates are removed by filtration. Chlorination and copper sulfate additions prevent scum and algae formation.

The average Langelier saturation index was –0.84, confirming that the water is nonscaling in terms of its ability to deposit calcium carbonate. Total dissolved solids averaged 290 ppm; aluminum- and silicon-rich particulates were deposited in all the tubes.

The iron content of the water is very low; therefore, iron-rich areas observed in the outer regions of the deposits probably came from corrosion of the cast iron water mains. Total hardness (as calcium carbonate) averaged 160 ppm, which classifies Billings' water as moderately hard.[7]

In the absence of a protective calcium carbonate scale, tube surfaces protected by a film of cuprous oxide would promote only a very slow general dissolution of copper. The rate of attack would depend on the water's oxygen content and temperature. The water flow rate and the ratio of the time the water is flowing to the time it is stagnant would also play roles. A high ratio would result in a higher oxygen replenishment rate to the copper-water interface, leading to a higher corrosion rate.

The observed pitting corrosion was due mostly to differential aeration concentration cells. Over time, the entire tube bore had become covered with a deposit, and such concentration cells essentially disappeared.

Summary

The water side of the tubes was covered with a rippled deposit whose color varied from off-white through yellow, orange, and brown to almost black. The outer layers of the deposits were composed of iron, calcium, phosphorus, and oxygen; the darker deposits were associated with higher

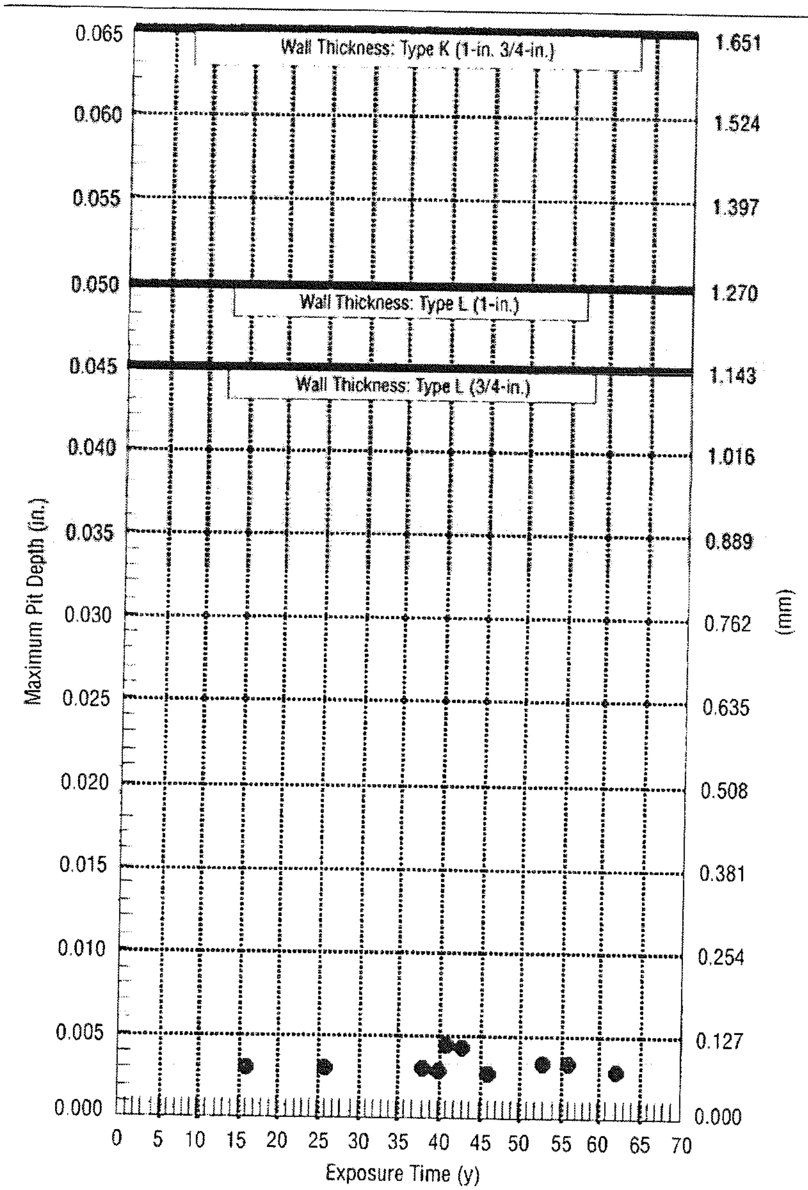

FIGURE 4
Maximum pit depth as a function of exposure time to the municipal water supply (points). Dark horizontal lines represent the original pipe wall thicknesses.

iron contents. Under the deposits, the corrosion product was predominantly cuprous oxide.

After removal of the deposits, some of the tubes were found to be pitted; the extent of the attack was less than 5% of the wall thickness after 29 years' exposure.

Depth of attack varied among tube samples, but the maximum pit depth of 0.0044 in. (0.11 mm) was associated with a shorter service life.

Although Billings' water is non-calcium carbonate scaling, the corrosion experienced by the tubes was due to deposit or concentration cell attack just after they had been placed in service.

When deposits entirely covered tube surfaces, local concentration cells were no longer present, and the rates of attack were substantially decreased.

The Billings water supply is not aggressive to copper by either general or pitting attack mechanisms. Based on the examination of the service lines studied, copper plumbing tube could be used successfully for far longer periods with no danger of failure from corrosion.

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