



ETATM
EARTH TO AIR SYSTEMS
ADVANCED GEOTHERMAL HEATING AND COOLING

JUN 08 2009

123 SE Parkway Court, Suite 160

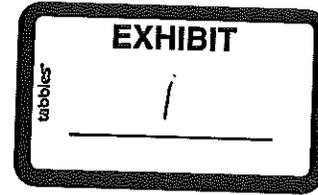
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June 4, 2009



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DEPT OF CONSUMER PROTECTION
OFFICE OF THE COMMISSIONER

Mr. Jerry Farrell, Jr., Commissioner
State of Connecticut
Department of Consumer Protection
165 Capitol Avenue
Hartford, Connecticut 06106

Re: DX Geothermal Informational Session

Dear Mr. Farrell:

Thank you for including me in your request for comments pertaining to issues of concern regarding Direct Exchange ("DX") geothermal heating/cooling system ground loops.

In specific reply to the three primary issues raised, please be advised as follows:

Heat Transfer Media:

The concern expressed herein is that DX system refrigerants could pose a safety/contamination threat to groundwater.

An example is cited via the use of ethylene dibromide, which, when applied as a pesticide on tobacco fields resulted in ground water contamination. Initially, please be advised that ethylene is listed by the U.S. Environmental Protection Agency ("USEPA") as a "colorless, heavy organic liquid with a mildly sweet chloroform-like odor (that is) mainly used in anti-knock gasoline mixtures, particularly in aviation fuel."

Please be advised that a refrigerant, such as R-410A, as utilized by Earth To Air Systems, LLC ("ETA") in its DX systems, is not a liquid at normal temperature ranges, is not a dangerous contaminant to groundwater, and is environmentally safe, as evidenced via the attached R-410A Material Safety Data Sheet page and May 15, 2005 letter to ETA from the USEPA.

I would further respectfully point out that:

- (1) Connecticut presently allows water-source geothermal systems to be installed.
- (2) If a leak in the refrigerant to water heat exchanger of a water-source system develops, refrigerant can easily be transported along with the water throughout the sub-surface polyethylene pipe loop, which plastic loop has a higher likelihood of leaking than a silver-soldered DX system copper loop.
- (3) Polyethylene pipe couplings are butt-fused together, meaning the plastic pipe is heated/melted and stuck together. The fused pipe is typically pressure

tested at only about 100 psi. Pressure testing may not always evidence tiny leaks, which may worsen over time.

- (4) A DX system has silver soldered joints, secured by an acetylene/oxygen torch. The joints can be tested via a 250 micron vacuum, which is superior to pressure testing, or, alternatively, can be pressure tested at about 400 psi because HVAC grade copper tubing is much stronger than typical 1/8 inch wall plastic polyethylene tubing.

As a supplement to the above, I have additionally attached a Consumer Factsheet for ethylene dibromide, as published by the USEPA, which evidences what I have referenced regarding ethylene dibromide.

Construction Materials:

The concern that appropriate construction materials be utilized is clearly appropriate. In this regard, I will address the stated concerns.

First, there is a concern that copper is susceptible to corrosion over time when buried in the ground, and therefore might eventually leak refrigerant into the soil or ground water. Factually, a general assertion that copper will corrode over time in the ground is incorrect. Copper is a naturally occurring element that has been in the ground ever since the earth was created. If copper deteriorated over time, there would be no copper to be mined today, as the earth is very old. Copper is reported not to be adversely affected by ground soil/water conditions unless the ph is below 5.5 or above 11, or unless there are certain other infrequent and generally unnatural sub-surface conditions. Copper pipes, fully intact, have reported to have been unearthed in the Middle East that were believed to have been installed before Noah's Flood over 5,000 years ago.

In the very infrequent geographic areas where copper could be subject to corrosive elements, the copper tubing can be protected by encasing same in a cementitious grout, such as Grout 111, as developed by the USA's Brookhaven National Laboratory, and/or by coating the sub-surface copper tubing with a protective plastic coating of polyethylene, or equivalent, that is at least 0.01 inches thick.

The comment that "it is known that a rust inhibitor can be used to prevent copper from corroding" is likely referencing the use of cathodic protection to protect copper in soil conditions where the ph is below 5.5. Technically, copper does not rust, as does steel, (hence, a rust inhibitor is unnecessary) but the copper integrity can be compromised in rare corrosive environments absent the use of a sacrificial anode, such as zinc, magnesium, or even steel. However, since any sacrificial anode has a certain lifespan, when copper tubing is installed within a corrosive sub-surface environment, it would be recommended to require the use of Grout 111, or the like, and/or to require coating all of the sub-surface copper tubing with a protective plastic coating of polyethylene, or equivalent, that is at least 0.01 inches thick.

As noted above, even if a leak should ever develop, which is highly unlikely, the escaping refrigerant would pose no health threat to the ground or water.

In those rare areas of Connecticut that may have sub-surface conditions that could be corrosive to copper, such as a ph level below 5.5 or above 11, I am respectfully suggesting that DX system sub-surface copper ground loops be permitted, subject to the following protective measures:

- (A) The sub-surface copper ground loops must be sealed by the manufacturer of the loops by means of brazing with at least 15% silver solder, or equivalent.
- (B) The sub-surface copper ground loops must be leak tested by the manufacturer of the loops so as to hold at least a 250 micron vacuum for at least two minutes; the loops next must be filled with at least 50 psi of dry nitrogen prior to shipping; and the actual shipping charge must be clearly marked by the manufacturer.
- (C) The recipient of the loops, both before and after field installation, must inspect the psi pressure of the loops to insure the original manufacturer's marked shipping psi has remained unchanged. If a pressure drop is observed, the loop must be removed from the well, and the problem must be resolved prior to re-insertion of the loop into the well. Any new repair coupling must be fully coated and sealed with polyethylene, or equivalent, by plastic shrink wrap, and/or by protective plastic coating, the thickness of which is at least 0.01 inches thick. The repaired loop must then be evacuated to at least a 250 micron vacuum, which must be held for at least two minutes prior to grouting.
- (D) The installed sub-surface ground loops must be surrounded by cementitious Grout 111, as developed by Brookhaven National Laboratory, USA, or equivalent cementitious grout.
- (E) The copper sub-surface ground loop lines themselves must be surrounded by at least a 0.01 inch thick polyethylene coating, or equivalent.
- (F) Any and all sub-surface field couplings to the sub-surface copper lines must be completely surrounded by polyethylene, or equivalent, by plastic shrink wrap, and/or by protective plastic coating, the thickness of which is at least 0.01 inches thick.
- (G) Only a non-ozone depleting refrigerant, approved for use under the Montreal Protocol, may be used as a heat transfer fluid within the sub-surface loops. Specifically, R-410A, and equally safe refrigerants, are permitted.

Permitting and Licensing Issues

Clearly, as stated, "Drilling any type of borehole can cause a problem if the drill strikes an underground structure."

In this regard, there is no difference in an ETA system vertical borehole than in an already permitted water-source geothermal system vertical borehole, or even in a water-well for that matter. ETA systems utilize vertical boreholes within which to

install its closed loop geothermal heat transfer tubing. While ETA understands some DX systems utilize angled boreholes, ETA does not, and the use of angled boreholes is not at issue with ETA.

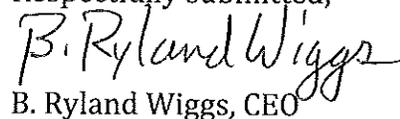
Further, regarding potential damage resulting from drilling into some underground structure, and a DX system's installer's obligation to make the homeowner "whole", I would not understand why a DX system installer should be treated any differently than a water-source system installer, or than a water-well driller, or than a utility pole driller, in this regard. Typically, many jurisdictions have a "one call" number when one anticipates excavating or drilling, so as to help insure underground utility lines, etc., are located and avoided.

Factually, I would venture that existing regulations pertaining to the drilling of water-wells (permitting requirements and drilling safe-guards) within Connecticut would adequately cover all ETA DX system boreholes, if such regulations were simply extended to DX system borehole applications.

In conclusion, please be advised that DX geothermal system requires only two primary heat exchange steps and requires no water circulation pump, unlike a conventional water-source geothermal system that requires three primary heat exchange steps and a water pump. Hence, a DX system is generally more efficient under analogous conditions, which saves the home-owner/business-owner money, which can reduce power generation requirements, which can reduce greenhouse gas emissions. Thus:

- (1) The citizens of Connecticut will be better served via permitting the above-outlined safe conditional use of DX system ground loops, which provide the potential of: reducing heating/cooling energy costs by about 50% over conventional system designs; enhancing interior comfort levels; enhancing humidity removal abilities in the cooling mode (thereby reducing mold/mildew concerns); reducing power production requirements; reducing greenhouse gas emissions; and reducing dependency on foreign fuel supplies.
- (2) The citizens of Connecticut will be better served via permitting the above-outlined safe conditional use of DX system ground loops, which reduce utility company peaking concerns, which assist in avoiding potential brownouts and blackouts, and which assist in further reducing consumer utility costs.

Respectfully submitted,


B. Ryland Wiggs, CEO

PS: Two articles regarding copper in the ground are attached for your reference.

This is Google's cache of http://www.epa.gov/OGWDW/contaminants/dw_contamfs/ethylene.html. It is a snapshot of the page as it appeared on May 23, 2009 09:58:40 GMT. The current page could have changed in the meantime. [Learn more](#)

These search terms are highlighted: **ethylene dibromide**

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Consumer Factsheet on: ETHYLENE DIBROMIDE

[List of Contaminants](#)

As part of the Drinking Water and Health pages, this fact sheet is part of a larger publication:

National Primary Drinking Water Regulations

This is a factsheet about a chemical that may be found in some public or private drinking water supplies. It may cause health problems if found in amounts greater than the health standard set by the United States Environmental Protection Agency (EPA).

What is EDB and how is it used?

Ethylene dibromide (EDB) is a colorless, heavy organic liquid with a mildly sweet chloroform-like odor. **Ethylene dibromide** is mainly used in anti-knock gasoline mixtures, particularly in aviation fuel. Other uses include: as a solvent for resins, gums, and waxes; in waterproofing preparations; in making dyes and drugs; and as a pesticide for grains and fruit.

The list of trade names given below may help you find out whether you are using this chemical at home or work.

Trade Names and Synonyms:

EDB
Glycol dibromide
Bromofume
Dowfume W 85
Aadibroom
Iscombrome-D
Nefis
Pestmaster
EDB-85
Soilbrom
Soilfume



Kopfume

Why is EDB being Regulated?

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine safe levels of chemicals in drinking water which do or may cause health problems. These non-enforceable levels, based solely on possible health risks and exposure, are called Maximum Contaminant Level Goals.

The MCLG for EDB has been set at zero because EPA believes this level of protection would not cause any of the potential health problems described below.

Based on this MCLG, EPA has set an enforceable standard called a Maximum Contaminant Level (MCL). MCLs are set as close to the MCLGs as possible, considering the ability of public water systems to detect and remove contaminants using suitable treatment technologies.

The MCL has been set at 0.05 parts per billion (ppb) because EPA believes, given present technology and resources, this is the lowest level to which water systems can reasonably be required to remove this contaminant should it occur in drinking water.

These drinking water standards and the regulations for ensuring these standards are met, are called National Primary Drinking Water Regulations. All public water supplies must abide by these regulations.

What are the Health Effects?

Short-term: EPA has found EDB to potentially cause the following health effects when people are exposed to it at levels above the MCL for relatively short periods of time: damage to the liver, stomach, and adrenal glands, along with significant reproductive system toxicity, particularly the testes.

Long-term: EDB has the potential to cause the following effects from a lifetime exposure at levels above the MCL: damage to the respiratory system, nervous system, liver, heart, and kidneys; cancer.

How much EDB is produced and released to the environment?

EDB is released during the use, storage, and transport of leaded gasoline, as well as during any spills; from its former use as a pesticide; wastewater and emissions from processes and waste waters of the chemical industries that use it.

From 1987 to 1993, according to the Toxics Release Inventory EDB releases to land and water totalled over 3,000 lbs. These releases were primarily from petroleum refineries. The largest of these releases occurred in California and Missouri.

What happens to EDB when it is released to the environment?

When spilled on land or applied to land during soil fumigation, **ethylene dibromide** may leach to groundwater. Its persistence can vary greatly from soil to soil, from a few weeks to as much as 19 years.

EDB released to water will mainly evaporate. It can be degraded by microbes and chemical reaction in some types of groundwater. It does not tend to accumulate in aquatic life.

How will EDB be Detected in and Removed from My Drinking Water?

The regulation for EDB became effective in 1992. Between 1993 and 1995, EPA required your water supplier to collect water samples every 3 months for one year and analyze them to find out if EDB is present above 0.01 ppb. If it is present above this level, the system must continue to monitor this contaminant.

If contaminant levels are found to be consistently above the MCL, your water supplier must take steps to reduce the amount of EDB so that it is consistently below that level. The following treatment methods have been approved by EPA for removing EDB: Granular activated charcoal.

How will I know if EDB is in my drinking water?

If the levels of EDB exceed the MCL, 0.05 ppb, the system must notify the public via newspapers, radio, TV and other means. Additional actions, such as providing alternative drinking water supplies, may be required to prevent serious risks to public health.

Drinking Water Standards:

Mclg: zero

Mcl: 0.05 ppb

EDB Releases to Water and Land, 1987 to 1993 (in pounds):

	Water	Land
TOTALS (in pounds)	2,554	2,670

Top Six States		
CA	500	
MS	500	
HI	750	
NJ	700	
TX	466	
PR	500	

Top Industrial Sources		
Petroleum refining		1,716
Industrial organic		700
chemicals, fertilizers		

Learn more about your drinking water!

EPA strongly encourages people to learn more about their drinking water, and to support local efforts to protect and upgrade the supply of safe drinking water. Your water bill or telephone book's government listings are a good starting point.

Your local water supplier can give you a list of the chemicals they test for in your water, as well as how your water is treated.

Your state Department of Health/Environment is also a valuable source of information.

For help in locating these agencies or for information on drinking water in general, call: EPA's Safe Drinking Water Hotline: (800) 426-4791.

For additional information on the uses and releases of chemicals in your state, contact the: Community Right-to-Know Hotline: (800) 424-9346

List of Contaminants

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URL: http://74.125.47.132/search

MATERIAL SAFETY DATA SHEET Genetron[?] AZ-20 (R-410A)

% VOLATILES: 100
FLASH POINT: Not applicable
(Flash point method and additional flammability data are found in Section 5.)

10. STABILITY AND REACTIVITY

NORMALLY STABLE? (CONDITIONS TO AVOID):

The product is stable.
Do not mix with oxygen or air above atmospheric pressure. Any source of high temperature, such as lighted cigarettes, flames, hot spots or welding may yield toxic and/or corrosive decomposition products.

INCOMPATIBILITIES:

(Under specific conditions: e.g. very high temperatures and/or appropriate pressures) – Freshly abraded aluminum surfaces (may cause strong exothermic reaction). Chemically active metals: potassium, calcium, and powdered aluminum, magnesium and zinc.

HAZARDOUS DECOMPOSITION PRODUCTS:

Halogens, halogen acids and possibly carbonyl halides.

HAZARDOUS POLYMERIZATION:

Will not occur.

11. TOXICOLOGICAL INFORMATION

IMMEDIATE (ACUTE) EFFECTS:

LC₅₀ : 4 hr. (rat) - ≥520,000 ppm (difluoromethane)
Cardiac Sensitization threshold (dog) ≥100,000 ppm (pentafluoroethane)

DELAYED (SUBCHRONIC AND CHRONIC) EFFECTS:

Teratology - negative
Subchronic inhalation (rat) NOEL - 50,000 ppm

OTHER DATA:

Not active in four genetic studies

12. ECOLOGICAL INFORMATION

Degradability (BOD): Genetron AZ-20 (R-410A) is a gas at room temperature; therefore, it is unlikely to remain in water.

Octanol Water Partition Coefficient: Log P_{ow} = 1.48 (pentafluoroethane), 0.21 (difluoromethane)

13. DISPOSAL CONSIDERATIONS

RCRA

Is the unused product a RCRA hazardous waste if discarded? Not a hazardous waste
If yes, the RCRA ID number is: Not applicable



May 15, 2005

Earth To Air Systems, Inc.
123 Southeast Parkway Court, Suite 160
Franklin, TN 37064:

Please find below the text of a letter I wrote several years ago. The information in this letter is still valid.

I understand that your company is a manufacturer of Direct-Exchange (DX) geothermal heat pumps (GHPs). I also understand that you often encounter confusion about environmental issues related to this technology. I hope this letter will help to clarify some of these issues.

As you may know, EPA recognized GHPs as the most cost-effective and environmentally friendly technology for heating and cooling homes in most climates in its 1993 report, Space Conditioning: The Next Frontier. We at the Atmospheric Pollution Prevention Division (APPD) at the Environmental Protection Agency (EPA) look quite positively on the potential of DX GHPs. The use of refrigerant in copper pipes as a heat exchanger appears to have an inherent efficiency advantage over antifreeze solutions in plastic pipe, making them even more attractive from an energy-efficiency standpoint than traditional GHPs.

Our only potential concern with DX GHPs is that they use R-22, as do virtually all other large-scale heat pump technologies on the market. Since R-22 contributes to ozone depletion, it is being phased out over the next three decades in accordance with the Montreal Protocol. DX GHPs do not appear to use appreciably more R-22 than air-source heat pumps, and EPA is not discouraging their use either. One of the key reasons R-22 has been such a widely used refrigerant for more than 50 years is that it is a nontoxic inert gas that poses no direct health dangers to humans, and therefore could be used with confidence by HVAC manufacturers and installers. Since R-22 poses no direct health threat to humans—nor to ground water—there is no reason why it cannot also be used with confidence in underground heat exchangers as part of a DX system.

EPA does regulate the use of R-22, however. Only licensed persons may install and service systems that use the refrigerant, and they must follow EPA guidelines regarding reclamation and recycling of the refrigerant. For more information about R-22 regulations, please call 1-800-296-1996.

I hope this information is helpful to you. Please call me if you have any questions or if I can be of any further assistance.

Sincerely,

Stephen J. Offutt
Atmospheric Pollution Prevention Division

Since the time of that letter, the use of other refrigerants, specifically R-410A, have come into use. R-410A is also a nontoxic, inert gas, posing no direct health threat to humans—nor to ground water—and it can be used with confidence in underground heat exchangers as part of a DX system. Even better is the fact that, unlike R-22, R-410A is not an ozone-depleting chemical.

Signed,

Stephen J. Offutt
Environmental Protection Specialist



ETA

EARTH TO AIR SYSTEMS
ADVANCED GEOTHERMAL HEATING AND COOLING

Underground Tubing and Refrigerant Information

Two common questions are;

"How long will the underground tubing last?"
and

"Is the underground system environmentally safe?"

Underground Tubing

The first question is generally answered via a treatise by James R. Myers, a Corrosion Consultant, of Franklin, Ohio, and by Arthur Cohen, Manager of Standards and Safety Engineering for Copper Development Association, Inc., of New York, New York.

The first introductory paragraph of the treatise written by these gentlemen reads as follows: "The belief by knowledgeable engineers, architects, and water works personnel that copper is not adversely affected by the vast majority of worldwide soils is well-founded. Unusually well preserved copper artifacts continue to be recovered in Mesopotamia from beneath the clay deposited by the "Great Flood," which is believed to have occurred about 4,000 B.C. Many of the underground copper pipes used to convey water in Egypt nearly 5,000 years ago are still in existence. Further, copper is one of the few metals which exist naturally as an element. There is also the outstanding history of copper water tube's performance as a highly corrosion resistant material in most underground environments."

Several potential corrosive situations are outlined, such as soils with high sulfate and/or chloride content in combination with poor drainage and more than 30 inches of rainfall per year; soils containing organic or inorganic acids; soils containing appreciable amounts of ammonia; and soils subject to stray electric currents (principally direct currents as opposed to alternating currents) and/or galvanic action. However, these conditions are generally rare and infrequent. Soils such as clay, sand, gravel, loam, and chalk are usually completely safe.

When rare corrosive sub-surface environments are present, Earth To Air Systems, Inc.'s ("ETA") in-ground copper lines are either completely encased in a protective solid cement type Grout 111, or are enclosed in a watertight, environmentally safe, protective polyethylene plastic coating. Consequently, rare, but potential, underground corrosive elements are totally prevented from reaching and affecting the system's copper refrigerant transport tubing.

Even if the copper tubing was installed directly into the ground without a protective grout encasement, or without a sealed plastic protective encasement, the copper tubing would still generally not be subject to danger from acidic or basic elements so long as the surrounding soil's pH level was above 5.5 or below 10, which is typically the case.

The said treatise also explains: "Copper is essentially immune to corrosion in that it behaves like a noble metal in most underground environments because of the naturally protective film which forms on the metal's surface. If this film, which often consists of reddish-brown cuprous oxide (CU₂O) is destroyed and cannot be repaired, copper can be expected to corrode (when situated within a corrosive sub-surface environment is implied). Fortunately, the protective film on copper remains intact or is readily repaired under most soil conditions."

Former, and older generation, direct expansion/exchange heating/cooling systems often required the in-ground copper tubing system components to be located as close to the home or business as possible, due to operational design limitations, taking care not to go too close to a septic system, or too close to trees and shrubs, all while keeping the sub-surface tubing at least 15 feet away from the foundation to avoid freezing damage. Further, if corrosive soils were encountered, an additional expense to provide cathodic protection for the in-ground copper became necessary. The new generation ETA design, with the copper tubing encased within a watertight protective plastic piping or cementitious

grout, overcomes all of these prior limitations and concerns when and if rarely applicable.

ETA includes its underground tubing in its standard system limited warranty. Extended warranty provisions can be purchased from ETA.

Refrigerant Fluid vs. Earth’s Ozone and Sub-Surface Environment

The second question, “Is the underground system environmentally safe?”, primarily concerns the system’s refrigerant fluid, as some refrigerant fluids/gases can affect the earth’s upper ozone environment. To a lesser extent, the second question involves the affect of propylene glycol and of the system’s compressor lubricant oil (which mixes with the system’s refrigerant) upon the sub-surface environment.

Former, and older generation, direct expansion/direct exchange (“DX”) heating/cooling systems generally utilized a refrigerant fluid known as a hydrochlorofluorocarbon (HCFC), specifically HCFC-22, or R-22 (“Freon” being a common trade name), circulated within sub-surface copper tubing that typically was never more than 5 to 100 feet deep (a near-surface system design).

Since most refrigerant fluids are stable chemicals, the U.S.E.P.A. issued a letter confirming that the U.S.E.P.A. was not aware of any soil or groundwater toxicity issues that would discourage the use of R-22 in direct expansion heat pumps. The compressor lubricant oil, which was mixed and circulated with the refrigerant, was typically an environmentally safe, refined mineral oil, such as Suniso Refrigeration Oil 3GS. Thus, the only cause for concern was the use of a refrigerant, such as R-22, containing a chlorofluorocarbon because of its upper atmosphere ozone depletion potential.

In March of 1988, a report of the Ozone Trends Panel (a global group of scientists led by NASA) concluded that chlorofluorocarbons (CFC’s) are most likely the primary cause of the Antarctic Hole phenomenon, whereby stratospheric ozone is depleted. Subsequently, sufficient international support was received by at least eleven nations,

representing a combined minimum of 2/3 of global CFC consumption, to implement the “Montreal Protocol on Substances that Deplete the Ozone Layer.”

Ozone Depletion Potential (ODP) of Select Chemicals

Chemical	ODP
CFC - 11	1.0
CFC - 12	1.0
CFC - 113	0.8
CFC - 114	1.0
CFC - 115	0.6
CFC - 502	0.3
HCFC - 22	0.05
HCFC - 123	0.02
HFC - 134A	0.00
HFC - 410A	0.00

The Montreal Protocol dictated an orderly schedule to reduce global consumption of CFCs 11, 12, 113, 114, and 115 (plus certain halons unrelated to refrigeration) over the subsequent ten years, and called for a ban on imports of these chemicals, and products containing them, from non-participant nations. In August of 1988, the U.S. Environmental Protection Agency (EPA), issued certain regulations which directly follow the Montreal Protocol provisions and identified a system of production quotas as the preferred means of plan implementation.

HCFC-22, the refrigerant fluid primarily, and virtually exclusively, utilized in all older generation direct expansion/direct exchange geothermal Heating/cooling systems, was neither banned nor scheduled for phase out within the subject first 10 year period.

This is because HCFCs, such as R-22, contained hydrogen, as opposed to chlorofluorocarbons (CFCs), which do not contain hydrogen. The addition of hydrogen makes the chemical unstable in the troposphere, where most of it is removed through conversion into water, carbon dioxide, and other water-soluble compounds.

Scientific evidence demonstrated it was the chlorine in refrigerant gases which reacted with, and depleted, ozone. Consequently, because of its instability in the troposphere, very little of the chlorine in HCFCs had an opportunity to reach the stratosphere, where ozone depletion occurs.

The following chart identifies the potential effects on ozone depletion of various, and previously common, refrigerant fluids. While the potential ozone depletion effect of HCFC-22, or R-22 ("Freon"), is relatively low in comparison to other refrigerant fluids, the ozone depletion potential is still there. Consequently, current EPA guidelines are reported to call for the phase-out of HCFC-22 production commencing in 2006, the ban of HCFC-22 production for new equipment in 2010, and the total ban of HCFC-22 production in 2020.

All of the new generation ETA direct expansion/direct exchange heating/cooling systems are designed to operate with a refrigerant fluid known as R-410A (the refrigerant identification number assigned by ASHRAE). R-410A is a non-ozone depleting HFC (hydrofluorocarbon) refrigerant, containing absolutely no chlorine. Besides having no potential adverse effect upon the earth's ozone, R-410A is a stable chemical, is not subject to hazardous polymerization, and is not a hazardous waste. It is a fact that refrigerant fluids are typically stable, non-poisonous, inert, and harmless in their natural state (except for potential frostbite when discharged under pressure, and except when displacing oxygen in a confined area). This is why refrigerant fluids are safely and commonly used in home refrigerators and freezers. Further, the compressor lubricating oil used with R-410A is Polyol Ester. Polyol Ester is a non-hazardous product according to OSHA (1910.1200).

Consequently, the owner of a state-of-the-art geothermal ETA system does not have to worry about his unit's R-410A refrigerant having any adverse impact upon the earth's upper ozone layer, does not have to worry about older R-22 design components soon becoming obsolete, does not have to worry about his sub-surface copper tubing being affected by corrosive elements, and

may rest assured that his/her system will not harm our environment.

Note: The above information is based upon data and reports believed to be accurate and prepared by credible sources, but which data and reports have not been independently verified by ETA.

MFP

MATERIALS
PERFORMANCE

An Official NACE International Publication

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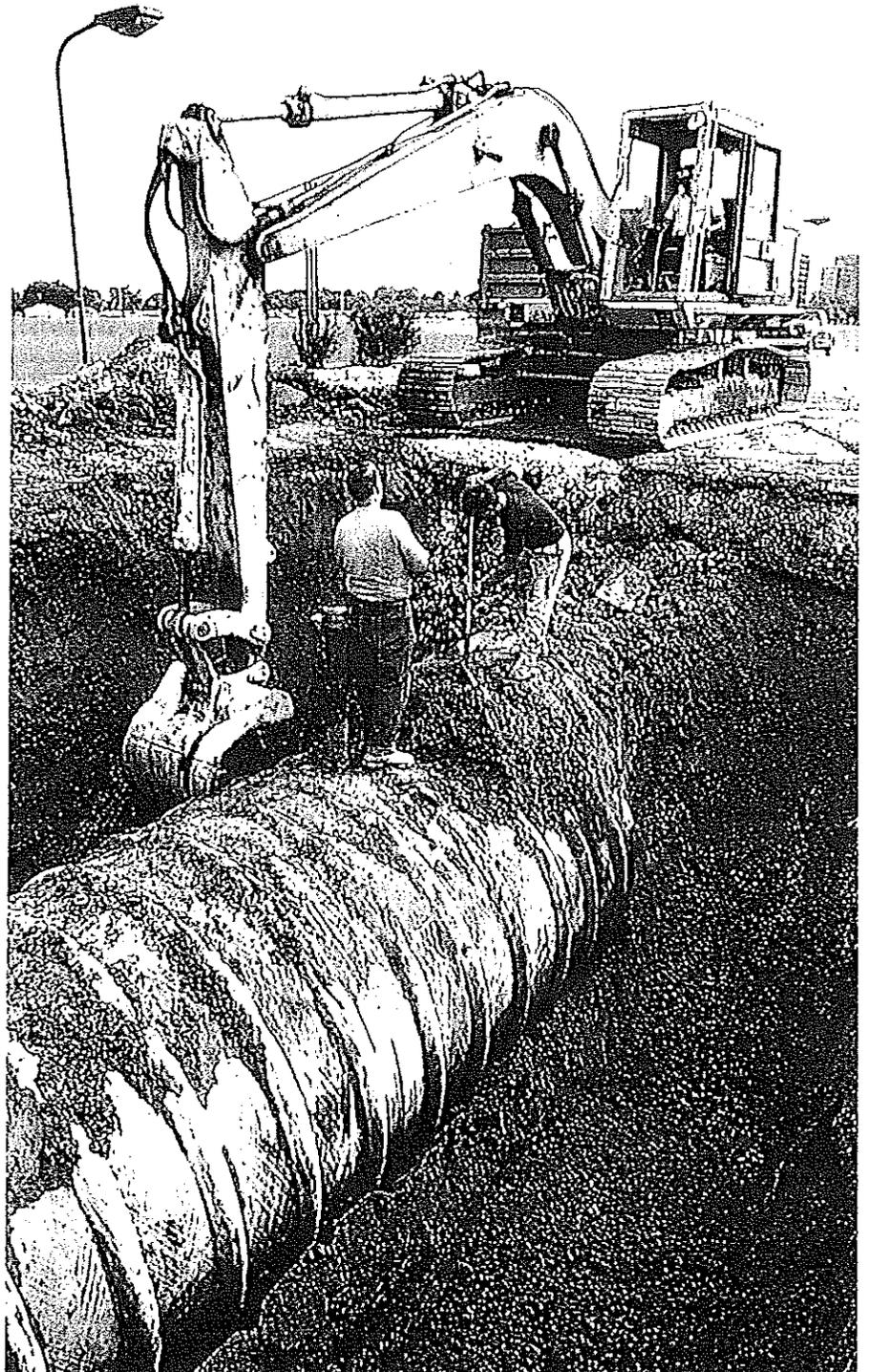
Focus on

Underground Corrosion

**Stray Current Control
on Water Mains**

**Corrosion
of Copper
Water Service Lines**

*Wake-Up Call
for UST Owners*



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

Arthur Cohen

Copper Development Association Inc., 260 Madison Ave., New York, NY 10016

Andrew J. Brock

Olin Metals Research Laboratories, 91 Shelton Ave., New Haven, CT 06511

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

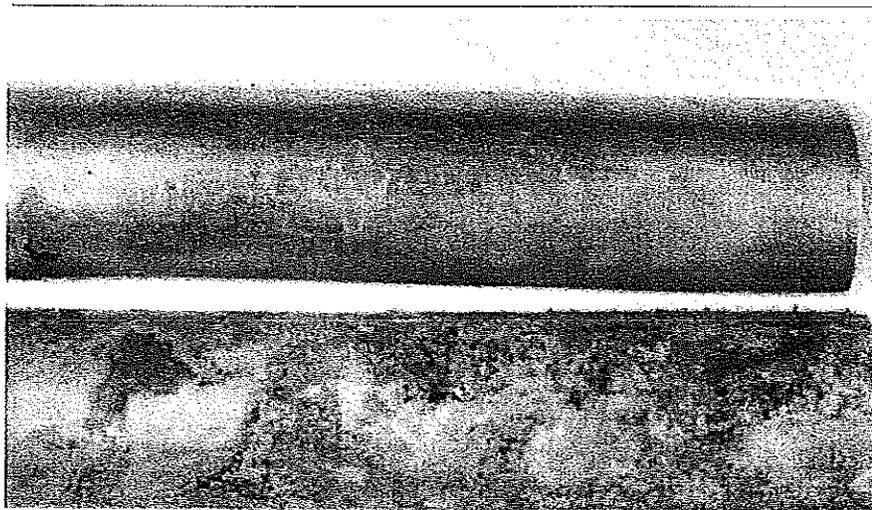


FIGURE 1

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

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.

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 88⁵ from eight locations were visually examined at magnifications up to 40x. Figure 1 shows the surface condition of as-excavated tubes after

TABLE 1
Soil Properties

Property	Location							
	Alderson Ave.	Avenue B	Dolphinium 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 56.4 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. (10) 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 14.9-36.5
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 5.2-15.4
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 (Langlier)	-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 non-aggressive.

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 ex-

tent 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 vari-

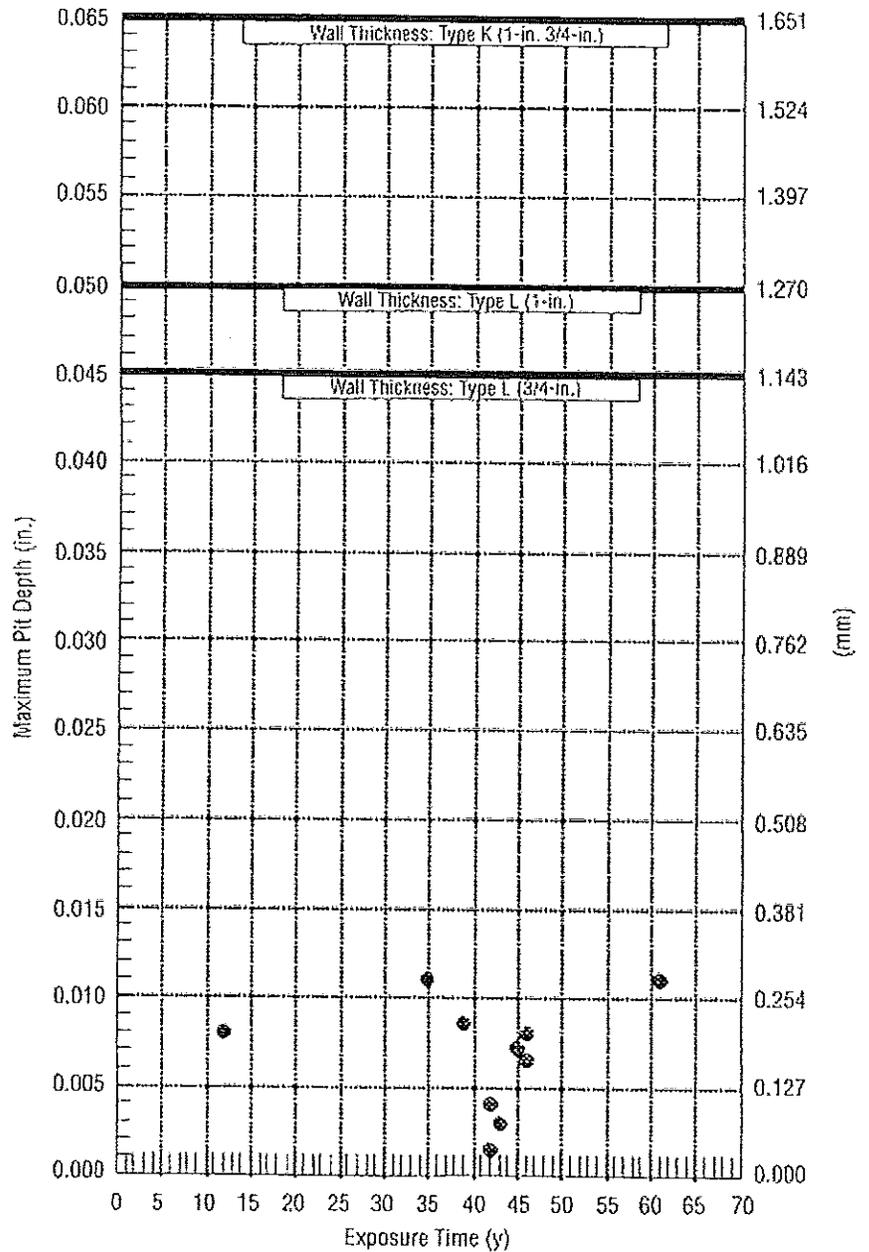


FIGURE 2
Maximum pit depth as a function of exposure time to the various soil conditions (points). Dark horizontal lines represent the original pipe wall thicknesses.

able, 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.

Tube Hardness

The Billings water department was concerned that tube hardening after years of service had caused difficulty in connecting the copper ser-

vice 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

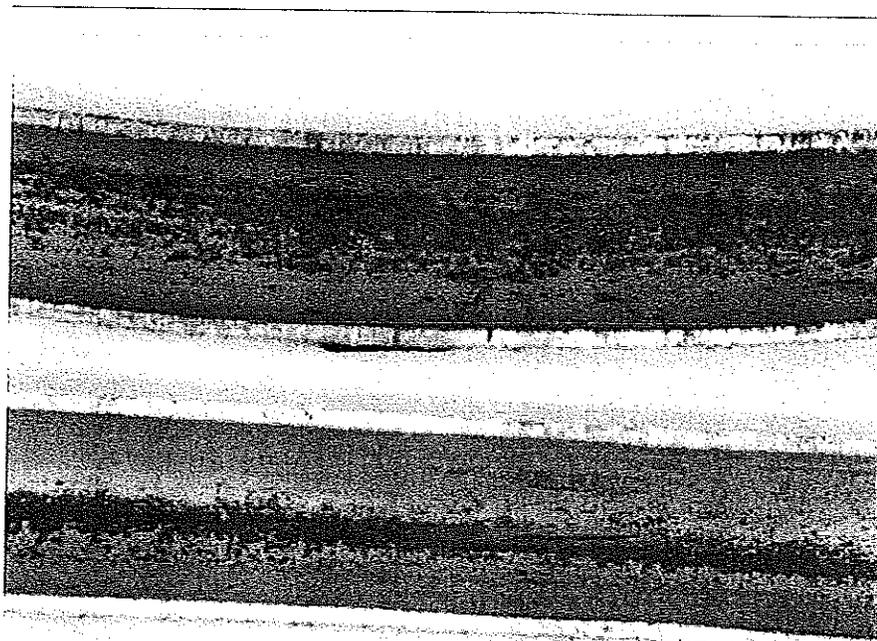


FIGURE 3

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

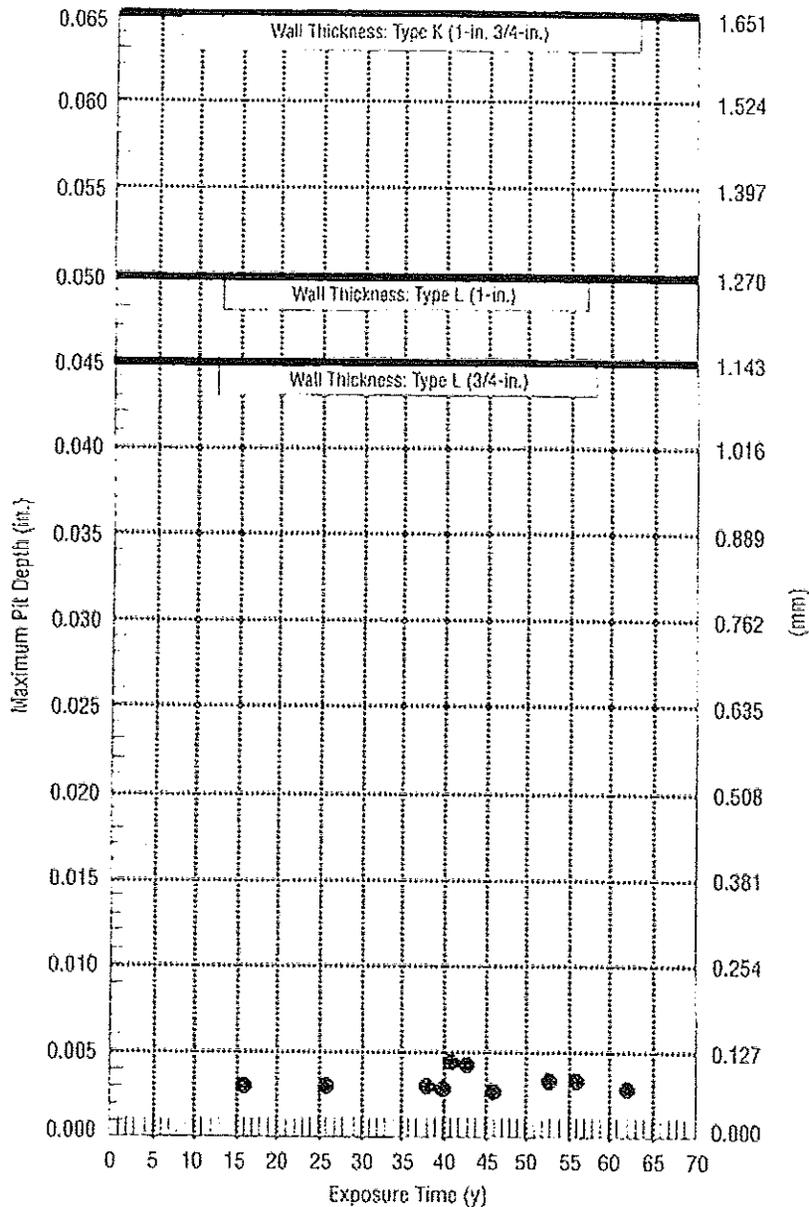


FIGURE 4

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

tube could be used successfully for far longer periods with no danger of failure from corrosion.

References

1. P.T. Gilbert, J. Inst. Metals 73, 139 (1917): p. 100.
2. K.H. Logan, M. Romanoff, J. Research NBS 33, 172 (1944).
3. I.A. Demison, Trans. Electrochem. Soc. 81, 235 (1942): p. 111.
4. J.R. Myers, A. Cohen, JAWWA 76, 8 (1964): p. 68.
5. ASTM B 88, "Specification for Seamless Copper Water Tube," Annual Book of ASTM Standards, Vol. 02.01 (Philadelphia, PA: ASTM).
6. M. Romanoff, Underground Corrosion, NBS Circular 579 (Gaithersburg, MD: NIST, April 1957).
7. G. Butler, H.C.K. Ison, Corrosion and Its Prevention in Waters (New York, NY: Reinhold, 1966).

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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 corro-

sion 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