ADAMS AND REESE LLP®

Attorneys at Law
Baton Rouge
Birmingham
Houston
Jackson
Memphis
Mobile
Nashville
New Orleans
Washington, DC

Brad A. Lampley
Direct (615) 259-1310
E-Fax (615) 687-1538
brad.lampley@arlaw.com

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DEPT OF CONSUMER PROTECTION
OFFICE OF THE COMMISSIONER

April 16, 2008

EXHIBIT
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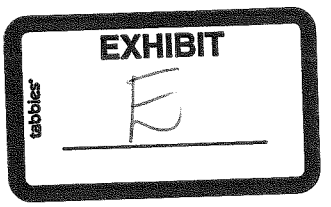


By FedEx
Jerry Farrell, Jr.
Commissioner, Connecticut Department of Consumer Protection
Room 103, State Office Building
165 Capitol Avenue
Hartford, CT 06106

Dear Commissioner Farrell:

This firm represents Earth To Air, Inc. ("ETA"), a geothermal heating and cooling company based in Franklin, Tennessee. ETA is in receipt of the proposed changes to the Connecticut state regulations concerning well drilling, and wishes to comment and suggest revisions to the same.

The products ETA utilizes in its systems are somewhat unique as compared to others commonly found in the industry. First, ETA utilizes a direct exchange geothermal heating and cooling technology that circulates the environmentally-friendly R410A refrigerant instead of water, antifreeze, and other potentially dangerous chemicals. R410A is approved by the United States Environmental Protection Agency as an underground heat exchanger that poses no direct threat to the ground and/or to the ground water.

Second, instead of utilizing plastic ground loops for purposes of circulating water, antifreeze, and rust inhibitors in a sub-surface environment, ETA uses copper loops to circulate solely the environmentally friendly refrigerant. Copper has a superior level of heat conductivity, is a naturally occurring element, and naturally forms a protective greenish copper oxide coating. Copper lines have been found in-tact that were installed in Egypt before Noah's Flood.

The copper tubing, with only several silver braze joints, is evacuated to a 250 micron level at the factory to insure there are no leaks. In comparison, the black plastic polyethylene loops installed with a water-source system have joints that are melted together in the field, and are only typically pressure tested to 100 psi. Pulling a 250 micron vacuum is a superior leak detection method.

Finally, the ETA copper loops themselves are protected in the wells by cementitious Grout 111, which was specially developed for geothermal installations by Brookhaven National

Laboratory, at the request of the United States Department of Energy ("DOE"). Grout 111 is shrink and crack resistant, is virtually water impermeable, and has the highest known heat conductivity of any grout in existence. Since Grout 111is a cementitious grout, it prevents any possibility of surface contaminants leaching into the water table from the surface, and it prevents any cross contamination among differing sub-surface aquifers.

The end result is a geothermal heating and cooling system that has been shown to be more efficient than various other, older technology, geothermal heating/cooling designs. As a practical, in-field example, the ETA systems in a 20,000 sq. ft. home near Harrisburg, PA, were separately monitored for power consumption during January, 2007. The cost to heat the 20,000 sq. ft. home, during the entire 32 day billing cycle, when the average outdoor temperature was 18 degrees Fahrenheit, was reported to be $206.

The comments below stem from ETA's belief that the breadth of some of the proposed regulations should be expanded to allow for the installation of the newer and more efficient technologies, such as ETA's, that are now being commonly used in the geothermal industry both within the USA and on an international basis. For example, 60% savings in bills have been reported via ETA system installations in schools in Australia. Moreover, ETA's suggested revisions are designed to make the proposed regulations consistent with widely-held industry standards and/or federal government standards as they relate to the type of products utilized by ETA and others.

Specifically, ETA's comments to the proposed regulations are as follows:

1. **Sec. 25-128-39b.** This proposed regulation lists fluids permitted for use in closed-loop geoexchange systems, but does not include the R-410A refrigerant used by ETA. R-410A has been evaluated by the United States Environmental Protection Agency ("USEPA"), and has been deemed safe for sub-surface installation. It poses no threat to the ozone layer and has been shown to be one of the most environmentally friendly and safest refrigerants to utilize. In that regard, I have attached as Exhibit 1 a self-explanatory May 15, 2005 letter form Stephen J. Offutt, of the USEP, for your ready reference. Further, a copy of the material safety data sheet for R-410A is attached as Exhibit 2, showing R-410a is not hazardous. The only indirect danger posed by R-410A is that of most any other pressurized gas (including nitrogen, which comprises about 60% of the air we breath), in that if all of the oxygen is displaced with in a closed environment, one could be harmed by lack of oxygen.

Accordingly, ETA proposes that the regulation be revised to read in pertinent part as follows, with ETA's suggested revision in bold:

> Closed-loop geoexchange system fluids permitted for the use in closed-loop geoexchange systems include potable water, heat transfer fluids containing potable water combined with a maximum of twenty (20) percent food grade propylene glycol or potassium acetate, **R-410A refrigerant, or other heat transfer fluids approved by the United**

States Environmental Protection Agency and/or the Department of Consumer Protection in consultation with the Department of Public Health. All chemicals used or added to potable water circulating through a closed-loop geoexchange system shall meet NSF/ANSI Standard Sixty (60) or be approved by the Department of Consumer Protection in consultation with the Department of Public Health.

2. **Sec. 25-128-39c(a).** This proposed regulation lists the materials approved for use in the underground portion of a closed-loop geoexchange system, as (1) high density polyethylene extrusion compound; and (2) any other material approved by the Department of Consumer Protection in consultation with the Department of Public Health and the Department of Environmental Protection. As stated, ETA uses copper ground loops. While it has been demonstrated that copper will not corrode in most soil types (see Treatise and ETA Informational Guide, attached as Exhibit 3), ETA has solved any potential problems by either completely encasing its in-ground copper lines in the cementious Grout 111, and/or by utilizing copper lines coated with a safe polyethylene ("PE") plastic coating. Either scenario prevents corrosion of ETA's in-ground copper lines in sub-surface geologies that are otherwise corrosive to copper.

Accordingly, ETA proposes that a new subpart (2) be added to the regulation, set forth below in bold:

(a) The only acceptable materials for the underground portion of a closed-loop geoexchange system are as follows:

1. High density, polyethylene extrusion compound having a cell classification of PE 345434c or PE 355434c with an Ultraviolet ("UV") Stabilizer of C, D or E as specified in ASTM D-3350 with the following exception: This material shall exhibit zero (0) failures ("FO") when tested for one hundred ninety two (192) hours or more under ASTM D-1693, Condition C, as required in ASTM D-3350. This material shall maintain a one hundred sixty pound per square inch ("psi") hydrostatic design basis at 73.4 degrees Fahrenheit per ASTM D-2837, and shall be listed in PPI TR4 as a PE 3408 piping formulation; or

2. Refrigerant-grade copper tubing, wither fully encased in a grout described at 25-128-48a(c) or (d) and/or fully coated with a protective polyethylene ("PE") coating.

3. Those materials approved by the Department of Consumer Protection in consultation with the Department of Public Health and the Department of Environmental Protection.

3. **Sec. 25-128-39c(b).** In the event that the Department accepts ETA's proposed change relating to the addition of copper as a material permitted for use in the underground portion of a

closed-loop geoexchange system, ETA respectfully requests that the foregoing subpart be revised to read as follows, with the ETA's suggested additions in bold:

> (b) The only acceptable method for joining sections of buried polyethylene pipe is by the heat of the fusion process in accordance with the pipe manufacturer's specification, or by use of mechanical stab fitting approved by the IGSHPA. **The only acceptable method for joining sections of buried copper tubing is by brazing with at least 15% silver solder or other materials generally accepted for the leak-free joining of copper pipe utilized for refrigerant containment.** The only acceptable methods for joining sections of piping made of materials approved pursuant to subsection (h)(2) of Section 25-128-40 of the Regulations of Connecticut State Agencies shall be those methods approved by the Department of Consumer Protection in consultation with the Department of Public Health and the Department of Environmental Protection. All resultant piping assemblies shall be leak proof as determined by pressure testing **and/or as determined by the ability to maintain at least a 250 micron vacuum.**

4. **Sec. 25-128-39(c).** ETA tests for leaks by pulling a 250 micron vacuum, which vacuum is impossible to maintain if a leak is present. It is respectfully submitted that the pulling of a 250 micron vacuum is a better leak test than an actual pressure test over a period of time. ETA can additionally pressure test its geoexchange system with a dry nitrogen charge at 400 psi, but such a pressure test is not as accurate as pulling a 250 micron vacuum. Accordingly, ETA requests that the proposed subpart be revised to read as follows, with ETA's suggestion in bold:

> (c) All geoexchange systems shall be pressure tested with water, air, or an inert gas to a minimum of one hundred fifty (150) percent above the heat pump manufacturer's operating specifications for a minimum period of thirty (30) minutes before being put into service. **In the alternative, geoexhange systems operating with copper sub-surface heat exchange tubing may be pressure tested with a charge of dry nitrogen, at a pressure not lesser than 400 pounds per square inch for 30 minutes, or, in the alternative, may be leak tested via the ability to sustain a 250 micron vacuum for 5 minutes.** Any system found to leak shall be repaired or replaced and then retested before being put into service.

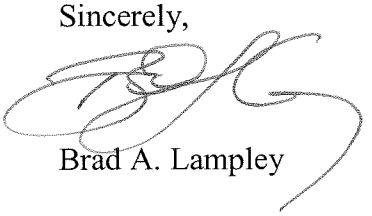
5. **Sec. 25-128-48a(d).** As stated, ETA utilizes the cementitious Grout 111, which was specially formulated for the DOE to be utilized in geothermal installations. While it could be argued that Grout 111 falls within one or more of the categories of gout set forth at 25-128-48a(d), out of an abundance of caution ETA respectfully suggest that a new subpart be added to 25-128-48a(d), to read as follows:

> **9. Grout 111, as formulated with the guidelines specified by the Office of Science for the Untied States Department of Energy's Brookhaven National Laboratory, of Upton, New York.**

In conjunction with this proposal we are also attaching the subject guidelines as Exhibit 4.

Thank you for your consideration of the foregoing comments. While our firm is not licensed to practice law in Connecticut and therefore will not be present at your April 22, 2008 hearing, the CEO of ETA, Mr. B. Ryland Wiggs, does plan to personally attend to present this letter into evidence and to answer any questions. Of course, if you have any questions in the meantime, please do not hesitate to contact Mr. Wiggs or myself.

Sincerely,



Brad A. Lampley

BAL/blk

cc: B. Ryland Wiggs
David Wiggs

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

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% 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, 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:
LC_{50} : 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

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ETA
EARTH TO AIR SYSTEMS
ADVANCED GEOTHERMAL HEATING AND COOLING

Underground Tubing and Refrigerant Information

Two common questions are;
"How long will the underground copper 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 under- ground 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, polyethylene plastic pipe, which, after insertion of the copper refrigerant tubing, is filled with water and propylene glycol (a harmless, food grade, anti-freeze). Consequently, rare, but potential, underground corrosive elements are totally prevented from reaching and affecting the system's copper refrigerant transport tubing. Further, the copper tubing installed within protective plastic piping is accessible for servicing without having to re-drill a deep well, and without having to re-excavate.

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

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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

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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.

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GUIDELINES FOR MIXING AND PLACING THERMALLY CONDUCTIVE CEMENTITIOUS GROUT (Mix 111) FOR GEOTHERMAL HEAT PUMP APPLICATIONS

M.L. Berndt
Department of Energy Sciences and Technology
Brookhaven National Laboratory
Upton, New York
(631) 344 3060; allan@bnl.gov

BACKGROUND

Mix 111 is a cement-sand grout developed and tested at Brookhaven National Laboratory for use with vertical ground loops for geothermal heat pumps. The grout was primarily designed to have improved thermal conductivity and sealing capability compared with neat cement and bentonite grouts. Development of Mix 111 involved extensive laboratory testing, modelling and field trials in which the performance was verified. The grout was also approved by the New Jersey Department of Environmental Protection. Mix 111 was intended to be mixed and placed on site by suitably experienced and equipped grouting contractors and has been used independently on numerous commercial projects. The grout consists of cement, water, silica sand of a particular gradation and small amounts of superplasticizer and bentonite. The superplasticizer is an additive commonly used in the concrete industry and improves the pumpability of cementitious grout while enabling the water/cement ratio to be kept low.

Research has determined that the mix proportions and sand gradation are critical to achieving pumpability and hardened properties such as thermal conductivity, coefficient of permeability, bonding to U-loop, shrinkage resistance and durability. Therefore, any alterations to the mix proportions and materials as given in the following specifications can be expected to change the resultant grout properties and will not conform to Mix 111. Technical information is available in the reports indicated below.

1.0 Materials

1.1 Cement

The cement used shall conform to ASTM C 150-Type I. If the site conditions require that sulfate resistant cement is necessary then Type II or Type V cement can be used. Cement that already contains a waterproofing additive should not be used as this has been found to cause slight foaming of the grout and reduce the thermal conductivity.

Cement should be kept dry at all times, stored on pallets and covered with a tarpaulin or plastic sheet. Any bags of cement that are damaged (e.g., torn) or that have been exposed to water should be discarded. The cement should be fresh and free from any hard lumps.

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1.2 Bentonite

The decision to use to bentonite will depend on the mixing equipment used. For low shear (e.g., paddle) mixers it is recommended that a small amount of bentonite be used to aid grout stability and reduce segregation of sand. The bentonite used shall be 200-mesh unadulterated sodium montmorillonite. The viscosity of the grout will increase with increasing proportion of bentonite.

1.3 Water

The mixing water shall be potable. Water with excessive impurities may affect the final properties of the grout.

1.4 Silica Sand

The silica sand shall conform to ASTM C 33 in terms of soundness and absence of deleterious substances only. The sand shall have a silica content > 98%. The particle size gradation shall conform to that in Table 1 below (not that given in ASTM C 33). This gradation of sand is the same as that used for preplaced aggregate concrete as discussed in ACI 304.1R (Guide for the Use of Preplaced Aggregate Concrete for Structural and Mass Concrete Applications, ACI Materials Journal, V. 88, No. 6, 1991).

The sand has been selected on the basis of grout pumpability, thermal conductivity of hardened grout and other grout properties. Other sands that do not meet the specifications may cause pumpability problems or reduce thermal conductivity. The sand used in this work was purchased from New Jersey Pulverizing Co. (516 921 9595; Reference Test Card 3343-97). However, other sand suppliers should be able to blend sand to meet the specified gradation.

The bags of sand should be kept dry at all times and stored on a pallet. Sand that contains moisture should not be used as this will increase the water/cement ratio of the grout.

Table 1. Specification for Particle Size Gradation of Silica Sand

Sieve No. (Size, μm)	Percentage Passing (%)
8 (2360)	100
16 (1180)	95-100
30 (595)	55-80
50 (297)	30-55
100 (149)	10-30
200 (75)	0-10

1.5 Superplasticizer

The superplasticizer shall be ~42% sodium naphthalene sulfonate conforming to ASTM C 494 Type F. The product used in this work was Rheobuild 1000 from Master Builders Technologies (216 831 5500). Other manufacturers supply equivalent products. Superplasticizer can often be obtained from local concrete ready mixed companies.

2.0 Equipment

The grout can be mixed in either a low shear (paddle) or high shear (colloidal) grout mixer. Mix 111 in the proportions given below has been designed for compatibility with a paddle mixer. Improved sand carrying capacity, decreased water requirement, reduced bleeding and greater flowability of grouts is usually achieved with grouts mixed in colloidal mixers.

It is preferable to use a grout mixer in conjunction with a larger capacity agitator in which the grout is stored and agitated until use. This is necessary to keep the particles in suspension, and, in the case of thixotropic grouts, keep the grout mobile and fluid. As discussed previously, the grout can be pumped continuously from the agitator tank while the next batch is mixed. Thus, pumping is not interrupted and the risk of plugging the tremie tube is reduced. It is critical that a proper grout mixer suited to cement-sand grouts be used. Mixing of the grout by hand, pumps or concrete ready mix trucks is not acceptable.

Piston pumps are recommended for pumping the cement-sand grouts. Excessive wear may be encountered when using a helical rotor (progressing cavity/Moyno) pump. Based on the field trials a minimum 1.25-inch diameter tremie tube with an open end and several side discharge outlets is recommended.

3.0 Grout Mix Proportions

The basic mix is given in Table 2. The amount of grout that can be mixed at once will depend on the capacity of the grout mixer. It is preferable to mix as much as possible per batch.

Depending on the mixing equipment and actual particle size gradation of sand used, the rheology of the grout may vary. Irrespective of the mixer used, it is recommended that trial mixes are performed and water, bentonite and/or superplasticizer adjusted so that suitable pumpability is achieved. However, use of excessive water will be detrimental to the hardened grout properties (e.g., shrinkage, permeability, durability, thermal conductivity) and probably induce segregation of the sand. Superplasticizer should be limited to a maximum of 20 ml/kg cement. This is equivalent to 851 ml (29 fluid ounces) per 94 lb. bag of cement.

Since the grout properties are very sensitive to water/cement ratio and superplasticizer dosage, it is critical that the amounts of water and superplasticizer required for a grout batch are measured accurately. This can be achieved through use of graduated containers or, in the case of water, with a water meter.

Table 2. Mix Proportions and Yield for Batch of Mix 111 Based on One Bag of Cement.

Cement	1 x 94 lb. bag
Water	23.5 litres (6.19 U.S. gallons)
Sand (conforming to spec.)	2 x 100 lb. bags
Superplasticizer	639 ml (21 fl. oz) (approximately, not to exceed 851 ml)
Bentonite (optional)	470 g (1.04 lb)
Yield	72.2 litres (19.1 U.S. gallons)

4.0 Recommended Grout Mixing Procedure

The recommended procedure for mixing the cement-sand grout in a paddle mixer is as follows:

1. Pre-mix bentonite with the required, measured quantity of water until bentonite is uniformly dispersed. (A Jiffy mixer may suffice).
2. Place water-bentonite mix in grout mixer.
3. Place required measured quantity of liquid superplasticizer in mixer.
4. Start mixer at low speed.
5. Mix water-bentonite and superplasticizer for approximately 10 seconds. Care should be to avoid air entrainment by mixing at excessively high speed.
6. Gradually add required quantity of cement in mixer and increase mixer speed. Mix for approximately one to two minutes or until cement is well dispersed.
7. Gradually add required quantity of sand in mixer and increase mixer speed if necessary.
8. Mix grout for specified time (Maximum of 5 minutes should be adequate).
9. Transfer grout to agitator. If agitator is not used then transfer grout to hopper. Grout in hopper should be agitated occasionally with Jiffy mixer or similar.

5.0 Quality Control

Every batch of freshly mixed grout should be measured for specific gravity prior to pumping. This requires use of a mud balance available from companies such as Baroid and the test procedure is given in ASTM D 854-83. The specific gravity is sensitive to water/cement ratio, sand/cement ratio and uniformity of mixing. Mix 111 with the proportions given above has a specific gravity of 2.18 (Density = 18.2 lb./gal). As a guide, the specific gravity should be 2.18 ± 0.02. Measuring flow time in accordance with ASTM C 939 can also be performed to check for grout pumpability and uniformity. All data and any changes in grout mix proportions or mixing procedure should be documented by the grouting contractor.

Samples should also be taken for future laboratory thermal conductivity testing. In this case, the grout should be poured into a suitable leakproof mould, the dimensions of which depend on the equipment that will be used to measure thermal conductivity. The grout samples should be

sealed or covered with plastic for 24 hours and maintained at temperature as close as possible to 20-25°C. After 24 hours the samples should be demoulded and immersed in a water bath at 20-25°C to cure for at least 7 days prior to testing.

FURTHER INFORMATION

M.L. Allan, Thermal Conductivity of Cementitious Grouts for Geothermal Heat Pumps, FY 97 Progress Report, BNL 65129, November, 1997.

M.L. Allan and A.J. Philippacopoulos, Thermally Conductive Cementitious Grouts for Geothermal Heat Pumps: FY 98 Progress Report, BNL 66103, November 1998.

M.L. Allan and A.J. Philippacopoulos, Properties and Performance of Thermally Conductive Cement-Based Grouts for Geothermal Heat Pumps: FY 99 Final Report, BNL 67006, November 1999.

M.L. Allan, Materials Characterization of Superplasticized Cement-Sand Grout, Cement and Concrete Research, Vol. 30, No. 6, 937-942, 2000.

DISCLAIMER

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