INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1970-TRP, Study of Grout for Ground Heat Exchangers

Attached is a Request-for-Proposal (RFP) for a project dealing with a subject in which you, or your institution have expressed interest. Should you decide not to submit a proposal, please circulate it to any colleague who might have interest in this subject.

Sponsoring Committee: TC 6.8 Geothermal Heat Pump and Energy Recovery Applications

Budget Range: $100,000. May be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **September 1, 2025** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EDT, May 30th, 2025. NO EXCEPTIONS, NO EXTENSIONS. Electronic copies must be sent to rpbids@ashrae.org. Electronic signatures must be scanned and added to the file before submitting. The submission title line should read: 1970-TRP, *Study of Grout for Ground Heat Exchangers*, and *"Bidding Institutions Name"* (electronic pdf format, ASHRAE's server will accept up to 10MB)

If you have questions concerning the Project, we suggest you contact one of the individuals listed below:

For Technical Matters
Technical Contact
Matt Mitchell
NREL
Littleton, CO 80127
Phone:208-351-9922
E-Mail: Matt.Mitchell@nrel.gov

For Administrative or Procedural Matters:
Manager Research & Technical Service
Steve Hammerling
ASHRAE, Inc.
180 Technology Parkway, NW
Peachtree Corners, GA 30092
Phone: 404-636-8400
E-Mail: Shammerling@ashrae.org

Contractors intending to submit a proposal should notify, by mail or e-mail, the Research Administrator by May 1st, 2025 in order that any late or additional information on the RFP may be furnished to them prior to the bid due date.

All proposals must be submitted electronically. Electronic submissions require a PDF file containing the complete proposal preceded by signed copies of the two forms listed below in the order listed below. **ALL electronic proposals are to be sent to rpbids@ashrae.org.**

All other correspondence must be sent to ddaniel@ashrae.org. Hardcopy submissions are not permitted. **In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EDT, May 30, 2025.**
NO EXCEPTIONS, NO EXTENSIONS.

The following forms (Application for Grant of Funds and the Additional Information form have been combined) must accompany the proposal:

(1) ASHRAE Application for Grant of Funds (electronic signature required) and
(2) Additional Information for Contractors (electronic signature required) ASHRAE Application for Grant of Funds (signed) and

ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)

Grout is used to seal the entire borehole by filling the cavity between the ground loop pipe, typically made of high-density polyethylene (HDPE) or copper, and the ground formation. The grout seal prevents water permeation (i.e., migration along the borehole) thereby avoiding (1) the mixing of water from aquifers at different depths and (2) infiltration of surface contaminants into the groundwater. The important properties for groundwater protection are density, percent solids, and permeability (i.e., hydraulic conductivity). The key grout properties for ground heat exchanger (GHX) thermal performance are thermal conductivity and density. Grout includes (1) a sealing component which is typically either cement or bentonite, (2) an optional thermal enhancement compound which is typically sand or graphite, and (3) potable water. Grouts used in GHXs are specially formulated to be flexible and thereby accommodate thermal expansion and contraction of pipes. This prevents grout-pipe separation, which can occur with conventional grouts that set rigid, especially at colder temperatures. Grout flexibility is particularly important for GHXs, since they are exposed to the wide variation in operating temperatures, ±50°F (±28 °C), and the commonly used HDPE pipe has a relatively large coefficient of expansion. Further, grout ensures good thermal contact between the ground loop pipe and the surrounding formation. Thermally enhanced grout can further improve the heat transfer, though the impact is modest because generally the greatest resistance to heat transfer from the GHX working fluid to the ground is in the conduction through the formation. Grout thermal property data are generally provided by the manufacturers and are an important design input for GHX installation. A summary of typical grout types and 18 formation types and the drilling practices used for each is given in (Kavanaugh and Rafferty, 2014, pp. 63-64, 370-373, 398).

The "Nebraska Grout Study" (NGS, Lackey 2009) is currently being considered as the basis for new standards for grouting GHXs, but the study has questionable applicability for GHXs and may result in unnecessarily expensive and restrictive requirements. The NGS focus was on grouts used for constructing water wells (i.e., not GHX boreholes) in different formations throughout Nebraska. In the 11th hour, the researchers decided to add several permeation tests for grout applied to vertical-bore GHXs. While the researchers did their best to replicate and monitor the in-situ performance of the grout, the resulting experiment likely did not fairly represent a GHX. For example, page 18 of the NGS document stated that the cement grouts may have detached from the casing in many of the wells assessed with this grout type. But these cement-based grouts were not representative of the more flexible grouts typically used in GHXs to accommodate the tube expansion and contraction. Further the study documents that the detachment was difficult to assess visually due to the design of the experiment, so the ratings of the grouts as applied to GHXs are in question. Therefore, while this study helped clarify how grouts perform in different geological formations, it is not conclusive.

Nebraska is currently the only state that uses the NGS as a basis for their GHX standard. However, due to the limited research information on grouts used for GHXs, California regulators are considering new and restrictive standards based on the NGS. The resulting requirement would be that all ground loop pipe and u-bend loops are to be sealed into the borehole with a minimum of a 2-inch annular seal. This represents a significant increase in grout volume compared to current industry practice and might require installers to add centralizers to keep the pipe in the center of the borehole. Both measures add cost to the GHX, but their necessity is not supported by any cited cases of groundwater contamination for GHXs designed and constructed per ANSI/CSA/IGSHPA C448 (which doesn't require the 2-inch annual seal or the centralizers). Further, because of the NGS and results comparing the dye penetration rate (not leakage) of grouts with varying %-solids specified as silica sand, CA is considering a requirement (CADWR, 2024) that all GHX systems use Mix 111 (Allen, 1999). This particular grout mix has high %-solids and it is perceived that this will address potential leakage of GHX during California's frequent years of drought that result in dry formations. However, Mix 111 may not actually be the best sealing material in all formations, and it is a cement-based grout where such products have been proven to separate from the GHX piping due to the seasonal expansion and contraction of the pipe (Paul, et al, 1996, and EPRI, 1997). Further, the high solids content makes the mix difficult to pump, and as such, GHX installers are reluctant to work with it. An additional problem is that Mix 111 specifies very particular materials that may not be locally available or of the quality required. Finally, Mix 111 is a recipe, rather than a product with manufacturing quality controls and established laboratories for verification of permeability and thermal property targets. For these reasons, requiring the use of Mix 111 for GHXs may not be practical or in the best interest of water protection.

Justification
The proposed changes to the GHX grouting standards in California (and Utah) are an early warning sign that regulating bodies are considering using the NGS as the basis for the standards, which could result in unnecessarily restrictive rules requiring prohibitively expensive solutions. There is a need for ASHRAE to provide authoritative grout performance data that all states can use to make evidence based GHX grout standards that protect the groundwater while minimizing costs and embracing new technology. Further, the information will help ground source heat pump (GSHP) system designers and installers to stay current on grout technology and practices, and confidently select the appropriate grout for each GHX.

Objectives
The primary objective is to provide authoritative grout performance data in varied formations. This data will be used to formulate evidence-based GHX grout standards that protect the groundwater while minimizing costs and embracing new technology.

Scope:
A literature survey report shall be created to capture the state of the art of grouts applied to GHXs in the USA and abroad. Particular attention must be given to the grout performance in protecting groundwater and subsurface formations (i.e., permeation), and in transferring heat to/from the formation. It is expected that this research effort will extend beyond searching scientific journals as the information provided there may be limited. Additional sources may include surveys, field tests, product laboratory tests, grout manufacturers, drillers, the oil, and gas industry (e.g., Halliburton, Schlumberger), and private and public research organizations such as the Electric Power Research Institute (EPRI). Information from available grout manufacturer reports shall be included as a reference about why particular grouts are recommended for different conditions.

The expected approach includes, but is not limited to:

1. **Task**: Research and gather information about grouts that are currently available and/or under development for sealing HDPE, PEX, and copper pipes in GHXs. Grout types must at include at least the 9 types from (Kavanaugh and Rafferty, 2014, pp. 63-64). For each grout the information must include at least:
   a. Recipe and application information
      i. Constituents and recipes where permission to share is given by manufacturers.
      ii. Percent solids and percent active solids.
      iii. Mixing instructions or other notes on combining constituents.
      iv. Guidance on grout sealing thickness (i.e., "annular seal" for GHXs, water-wells, and other applications).
      v. Manufacturer guidance for other grout installation parameters and techniques needed to properly seal the borehole.
      vi. State of final product as described by manufacturer (e.g. flexible, semi-rigid, rigid).
   b. Properties
      i. Permeability
      ii. Thermal conductivity
      iii. Density
      iv. Viscosity or pumpability
      v. Biodegradability (yes/no)
      vi. Heat of hydration (cementitious grouts only)
   c. Performance in varied geological formations (e.g., dry formations, brackish water, contaminated sites) and temperature profiles. The formation types must include at least the 18 listed in (Kavanaugh and Rafferty, 2014, p. 398).
      i. Degradation of the thermal conductivity, permeability, and density as required by CSA C448-Series 16, Clause 5.8.3.1.4.
      ii. How long the grout remains flexible.

   Deliverable: Presentation given to PMS providing summary of initial data collection results.

   Delivery date: 3 months from contract execution

2. **Task**: Summarize all available research studies of in-situ or laboratory tests of grout materials for GHXs. Describe how the grout seal and thermal properties vary with respect to temperature variation, formation type and moisture content, and percent solids.

   Deliverable: Provide a draft section of the final report for PMS review. The section shall discuss research gathered on currently available grouts and grouts under development. Include all references, data, or other information collected. Provide a log of all attempted and successful avenues for data collection.

   Delivery date: 5 months from contract execution.

3. **Task**: Identify and summarize any documented failures of a GHX due to the grout and its ability to seal the borehole for groundwater contamination and/or thermal contact with the ground. Document any system failures due to improper grouting practices or failed due to issues attributed to grouting.

   Deliverable: Provide a draft section of the final report for PMS review. The section shall include documentation of GHX failures due to grout failure, with a minimum 10 instances. If less than 10 are found, also provide a justification. Provide a log of all contacts attempted for data collection.

   Delivery date: 6 months from contract execution.

4. **Task**: Provide a critical assessment of the NGS to confirm, refute, or augment its conclusions for use and applicability to GHXs (grouted boreholes).

   Deliverable: Provide a draft section of the final report for PMS review. The section shall assess the NGS conclusions, implications, etc. and how the results compare to current research and previous data collection. Provide any updated report sections for PMS review.

   Delivery date: 8 months from contract execution.

5. **Task**: Identify key information gaps in grout permeability and thermal performance. Make recommendations as to which of the research studies identified in Task 2 (i.e., in-situ or laboratory tests of grout materials for GHXs) could be used as the basis for a follow-on ASHRAE research project to measure performance of existing and new grout materials as they are applied to GHXs.

   Deliverable: Provide a draft section of the final report for PMS review. The section shall identified gaps in the data and providing recommendations for follow-on ASHRAE research.

   Delivery date: 9 months from contract execution.

6. **Task**: Provide drafts of all documentation
   a. Final report.
   b. A 1–2-page ASHRAE Technical Bulletin for practitioners that summarizes key findings of the final report. The bulletin shall include (but is not limited to): recommendations of how to apply the results of the study to protect the groundwater and achieve good thermal performance for various subsurface formations, temperatures, and groundwater conditions.
   c. Concise summary of the key findings that can be included in the ASHRAE handbook chapter on Ground-source Heat Pumps and Geothermal Energy.

   Deliverable: Draft of final report, ASHRAE Technical Bulletin, and summary for ASHRAE handbook chapter.

   Delivery date: 11 months from contract execution.

7. **Task**: Provide final versions of the documentation from Task 6. The documents shall address the comments from the Project Monitoring Subcommittee (PMS).

   Deliverable: Final report, ASHRAE Technical Bulletin, and summary for ASHRAE handbook chapter.

Delivery date: 12 months from contract execution.

Deliverables:
The following deliverables shall be provided to the Project Monitoring Subcommittee (PMS) as described in the Scope/Technical Approach section above, as they are available:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically on or before each January 1, April 1, June 10, and October 1 of the contract period.

Furthermore, the Institution's Principal Investigator, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically for review by the Society's Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

- An executive summary in a form suitable for wide distribution to the industry and to the public.
- Two copies; one in PDF format and one in Microsoft Word.

c. Technical Bulletin

A 1–2-page ASHRAE technical bulletin for practitioners that summarizes key findings of the final report. The bulletin shall include (but is not limited to): recommendations of how to apply the results of the study to protect the groundwater and achieve good thermal performance for various subsurface formations, temperatures, and groundwater conditions. For example, the bulletin could include a decision matrix which can help practitioners select grout types based on subsurface formation, application, etc.

d. ASHRAE Handbook text

Concise summary of the key findings that can be included in the ASHRAE handbook chapter on Ground-source Heat Pumps and Geothermal Energy.

e. Data

Data is defined in General Condition VI, "DATA"

f. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights

The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort
The level of effort is expected to be approximately 3-professional months for the principal investigator, and 12-professional months for a research associate. Total estimated cost for the project is $100,000.

This project is expected to include a comprehensive literature review, and require efforts to connect with researchers, practitioners, and manufacturers to collect data and information. It will also include documenting the current research across all collected data and providing assessments of the current state-of-the-art and recommendations based on the results of the project. Final deliverables include proposed updates to the ASHRAE Handbook, a Technical Bulletin, and a comprehensive final report.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Contractor's understanding of Work Statement as revealed in proposal.	**20%**
2	Quality of methodology proposed for conducting research.	**15%**
3	Contractor's capability in terms of having or being able access multiple sources of information and willingness to contact grout companies and other research entities for information.	**20%**
4	Qualifications of personnel for this project	**20%**
5	Graduate student involvement	**5%**
6	Probability of contractor's research plan meeting the objectives of Work Statement.	**20%**

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Presentation given to PMS providing summary of initial data collection results	3
2	Draft section of the final report for PMS review outlining research gathered on currently available grouts and grouts under development. Include all references, data, or other information collected. Provide a log of all attempted and successful avenues for data collection.	5
3	Draft section of the final report for PMS review which includes a documentation of GHX failures due to grout failure, with a minimum 10 instances. If less than 10 are found, also provide a justification. Provide a log of all contacts attempted for data collection.	6
4	Draft section of the final report assessing NGS conclusions, implications, etc. and how the results compare to current research and previous data collection. Provide any updated report sections for PMS review.	8
5	Draft section of the final report for PMS review providing identified gaps in the data and providing recommendations for follow-on ASHRAE research.	9
6	Draft documentation, including draft project report, draft ASHRAE technical bulletin summarizing the findings of the literature survey and resulting report which may be used by practitioners, and draft updates to the ASHRAE handbook chapter.	11
7	Final documentation, including final project report, final ASHRAE technical bulletin summarizing the findings of the literature survey and resulting report which may be used by practitioners, and final recommended updates to the ASHRAE handbook chapter.	12

References

1. M. L. Allen and A.J. Philippacopoulos, *Properties and Performance of Cement-Based Grouts for Geothermal Heat Pump Applications*, BNL-67006 Informal Report, Office of Geothermal Technologies, US DOE, Washington, DC, November 1999.
2. ANSI/CSA/IGSHPA C448 Series-16(R2021) *Design and installation of ground source heat pump systems for commercial and residential buildings.* Toronto: CSA.
3. CADWR, Well Standards, California Department of Water Resources, https://water.ca.gov/wellstandards, accessed Jan. 19, 2024.
4. EPRI, *Grouting for Vertical Geothermal Heat Pumps Systems – Engineering Design and Field Procedures Manual*, Final Report, EPRI TR-109169, December 1997.
5. Lackey, S., W. Myers, T. Christopherson, J. Gotulla, *In-Situ Study of Grout materials 2001-2006 and 2007 Dye Tests*, Education Circular EC-20, University of Nebraska, Lincoln, October 2009.
6. Kavanaugh, S. Rafferty, K. *Geothermal Heating and Cooling: Design of Ground-Source Heat Pump Systems*, ISBN:9781936504855, ASHRAE, Peachtree Corners, GA, 440 2014
7. Paul, Ned. D., *The Effect of Grout Thermal Conductivity on Vertical Geothermal Heat Exchanger Design and Performance*, South Dakota State University, Masters Thesis, 1996.
8. Remund, C., and G. Streich, *PSSL Building Documentation*. Mechanical Engineering Department South Dakota State University, Brookings, SD. August 2000.