INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1890-TRP, "Minimum flow velocities for purging air and debris from hydronic piping systems"

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: TC6.8 Geothermal Heat Pump and Energy Recovery Applications
Co-sponsored by: TC6.1, Hydronic and Steam Equipment and Systems & TC6.2, District Energy

Budget Range: $150,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2022,** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, Thursday, December 1, 2022. 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: 1890-TRP, "Minimum flow velocities for purging air and debris from hydronic piping systems", 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
Harrison Skye
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For Administrative or Procedural Matters:
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Contractors intending to submit a proposal should so notify, by mail or e-mail, the Manager of Research and Technical Services, (MORTS) by December 1, 2022, 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 and mvaughn@ashrae.org.** Hardcopy submissions are not permitted. **In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 15th, 2022.**
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)

Current hydronic installation standards for geothermal systems recommend that fluid piping systems be purged at a velocity of 2 ft/s (0.6 m/s) to remove air from the system (CSA 2016, IGSHPA 2017). It is known that greater velocities are required to remove denser debris from hydronic piping. However, current standards lack specific guidance to flush debris, and rather specify a flow rate between 2 ft/s (0.6 m/s) to remove air and maximum flow velocity recommended by the pipe and fitting manufacturer to remove debris (IAPMO, 2018). Some installers use higher flow rates when purging based on their own experience. There are currently no published guidelines for purging velocities to remove typical debris. There are many anecdotes from experienced engineers who report problems with debris remaining in hydronic systems that were thought to be properly purged as part of the installation.

For example, a middle school built in 2002 for the Tahoe-Truckee Unified School District in California experienced excess debris in their system, after reportedly being properly purged following construction. The vertical closed-loop ground heat exchanger was purged by the installing contractor to IGSHPA standards of 2 ft/s (0.6 m/s). Eleven years later, due to issues with water quality and heat pump failures, a second contractor was hired by the school district to re-purge the system. Contaminating debris including rocks, gravel, putty, and even an HDPE pipe fitting were purged from the 6-inch (15.24 cm) supply and return headers (Brower, 2013).

Transport velocity for slurries is a function of pipe diameter, particle size, particle-density, solids concentration, and fluid properties (Zanker, 1974). Slurry particle sizes would be comparable to debris such as sand, lime, and ash. However, there is a need to address larger particles often encountered during the construction of hydronic systems including pipe shavings, small steel parts, and rocks. A test apparatus consisting of a horizontal 8 inch diameter clear pipe flowing water demonstrated that 2 ft/s (0.6 m/s) is sufficient to move the debris; however, in the vertical direction it required 2.2 ft/s (0.7 m/s) to move a washer and 5 ft/s (1.5 m/s) to suspend a steel nut. (PurgeRite, 2016).

There has been some research related to mining where crushed granite, iron ore, and coal have been lifted in slurries. Sellgren concludes that the operating velocity needs to be 4 to 5 times the terminal settling velocity (Sellgren, 1982). Since slurry transport velocity depends on the solid particle concentration, correlations that are suitable for dense slurries will likely not apply to isolated solid debris in a hydronic system.

Justification and Value to ASHRAE

Hydronic systems are widely used in many HVAC applications in residential, commercial, and industrial applications. Ground source heat pumps (GSHP) are becoming more widely used in residential and commercial buildings as the industry moves to more energy efficient, and ultimately net-zero, systems. Having air or solid debris in the hydronic piping (including geothermal piping) can result in premature pump failures, inadequate or uneven flow rates, excessive pumping power consumption, or even system degradation due to changes in water system chemistry over time. The lack of definitive purging guidelines introduces uncertainties in the system installation. The results of this research project should enable design engineers and contractors to specify appropriate purging requirements that will ensure clean systems and proper operation. The data produced by this project will be placed in Chapter 35 (Geothermal Energy) and Chapter 12 (District Energy) of the ASHRAE Applications Handbook, Chapter 22 (Pipe Design) of the ASHRAE Fundamentals Handbook, and Chapter 46 (Pipe, Tubes, and Fittings) of the ASHRAE HVAC Systems and Equipment Handbook. It is likely that the results may also be introduced into installation standards for boilers, cooling towers, and other hydronic systems as well. Advancing the state-of-the-art for purging velocities is an important research activity for ASHRAE since responsibility for specifying the debris purging velocity typically resides with the design Architect/Engineer (A/E). For example, the state of Wisconsin's Master Specification for Hydronic Piping requires the (A/E) to review and approve flushing (purging) procedures specific to the project prior to the beginning of the flushing operations. This implies that the engineers know the appropriate criteria for properly flushing the hydronic system. Furthermore, the steps taken to commission a commercial GSHP system identifies flushing and purging as part of the prefunctional checklist (ASHRAE, SP-94) and requires that the A/E be included as part of the commissioning team. The engineer's responsibilities include developing specific equipment and system functional performance test procedures which also implies that appropriate criteria for flushing and purging the hydronic system are known.

Objectives

The objective of this research will be to experimentally determine the required purging velocities for removal of solid objects and air from hydronic piping. The results will be presented in one or more tables showing the minimum purge velocity required for various materials, various pipe sizes, and in both horizontal and vertical orientations, including testing of a u-bend loop for ground-source heat pump systems.

Scope:

Task 1 – Literature Survey

A comprehensive literature survey, including review and potential contact with video sources listed in the references, is required. The contractor shall deliver an annotated literature survey.

Task 2 – Experiment Development

The experimental apparatus will require a water pumping system capable of producing and measuring various flow rates through the different size pipes that will be used. For the larger pipe sizes, it may be advantageous to use an elevated storage tank rather than the very large pumps that would be required. Clear pipe, clear windows in the pipe, or cameras able to capture the flow and debris, or some other means, shall be used for visual observation of debris movement and each test shall be recorded on digital video. Different sizes of material shall be used, ranging from coarse sand particles to approximately 1 inch gravel. Metallic materials shall also be used, such as different size washers, screws, nails, and nuts. Long plastic shavings shall also be tested since they are sometimes present from heat fusing of plastic pipe and joining plastic pipe. Additionally, contaminants that may be prone to stick to the walls of the pipe such as clay, sludge, or joining compounds shall be included in the testing. Finally, the test shall also include purging of air to verify the current industry standard of 2 ft/s (0.6 m/s). An inventory of all debris injected into the test apparatus shall be compared to the fraction which emerges. All experiments are to be conducted with potable water.

Pipe materials selected shall be representative of materials specified for district heating and cooling systems, building hydronic systems, and buried ground loop heat exchanger systems (copper, steel, PE, PEX, etc.). As a minimum, the following nominal pipe sizes shall be experimentally tested in horizontal and vertical configuration: 3/4 inch (1.91 cm); 1 inch (2.54 cm); 2 inch (5.08 cm), 4 inch (10.16 cm); 6 inch (15.24 cm); 8 inch (20.32 cm), and 12 inch (30.48 cm). No more than three pipe materials may be used and pipe sizes must be contiguous for each material. For example, the proposer may choose to test the following materials and sizes: HDPE pipe in ¾ inch (1.91 cm); 1 inch (2.54 cfm); 2 inch (5.08 cm), 4 inch (10.16 cm); 6 inch (15.24 cfm) and steel pipe in 4 inch (10.16 cm); 6 inch (15.24 cm); 8 inch (20.32 cm), and 12 inch (30.48 cm). Bidders are encouraged to propose additional tests in these pipe sizes with elbows, tees, manifolds, valves, or other components typically found in hydronic systems. Finally, the tests shall also include a slinky ground heat exchanger configuration (36 inch/91.44cm pitch) using ¾ in (1.91 cm) SDR 11 HDPE and the testing of a vertical u-bend loop pipe of ¾ inch (1.91 cm), 1 inch (2.54cm) or 1-1/4 inch (3.17 cm).

The velocity required to move various solids is expected to be a function of the pipe orientation (vertical, horizontal, slinky-type ground heat exchanger), the inside diameter of the pipe, and the debris characteristics (density, size, shape, etc.). HDPE pipe in 1 inch (2.54 cm), 2 inch (5.08 cm), and 4 inch (10.16 cm) shall be tested with a small window/camera near the fused joint so that the effects of the fused connection on the debris movement may be observed during testing and documented. Because the double rollback bead extends beyond the interior pipe wall, it is expected that the velocity required to remove debris from HDPE pipe may vary from metal or other plastic pipe in the smaller diameter pipe sizes.

Proposers are to encouraged to provide additive bid line items for testing larger pipe sizes of 18 inch (45.72 cm) and 24 inch (60.96 cm) which are common sizes for district energy systems. If an additive bid item is not provided for the 18 inch (45.72 cm) and 24 inch (60.96 cm) sizes, the proposers may suggest a method of dimensionless analysis based on experimental results for smaller pipe sizes, that can be applied to predict required flushing velocities for the larger pipes sizes for various solids and pipe configurations. Modeling alone cannot be used for any portion of the project or for development of the dimensionless results.

All results shall be placed in tabular format by pipe material listing velocities required to move air and solids in the varying configurations. Proposers are encouraged to provide criteria for interpolation/extrapolation to pipe sizes not tested and to the extent possible nondimensionalize results.

An example of how a test apparatus of varying pipe diameters could be employed for this research may be viewed on-line (KSB Company, 2015), however the proposer is responsible for developing a device capable of meeting all project requirements. This device demonstrates the relationship between solids transport and minimum flow velocity in constant diameter horizontal and vertical pipe and is intended to simulate a standard size wastewater pipe.

Proposers shall detail and be prepared to provide current calibration records upon request of the Project Monitoring Subcommittee for the critical equipment they employ to perform the laboratory and field experiments.

Task 3 – Field Verification

It is desirable to verify the effectiveness of the laboratory experimental results from Task 2 through field verification, if possible. Opportunities may be available within reasonable distance from the research team to verify purge velocities for a hydronic system within a newly constructed building, a building about to be decommissioned or retrofitted, a thermal conductivity test borehole (after the thermal test is performed), or through a portion of a buried piping utility system. The field-testing site shall allow for positive confirmation of the flushing efficacy, i.e. the contractor will insert debris into the system and then verify the flushing procedure removed the debris.

Task 4 – Observations and Recommendations

In addition to the data table created as a result of this project, provide observations and recommendations for extrapolating data for pipe sizes not tested and materials that were not included in the experiment. There shall be recommended method(s) for flushing and time or volume necessary to ensure an acceptable level of cleanliness prior to connecting to building mechanical equipment.

Deliverables:

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

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.

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:

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. *Science & Technology for the Built Environment* or ASHRAE Transactions Technical Papers

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Papers for HVAC&R Research or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1890-RP) at the end of the title in parentheses, e.g., (1890-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

d. Data

Data is defined in General Condition VI, "DATA"

e. 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
24 months and a project value of $150k

Because this research could be accomplished through a Master Thesis project, a 24-month period is reasonable to complete this work. It should be sufficient time to develop the experiment, procure material, and perform the required laboratory experiments and field verification of the research results, and produce the reports and documents required.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Contractor's understanding of the Work Statement as revealed in proposal	20%
2	Quality of contractor's proposal meets or exceeds expectations with methodology proposed	25%
3	Qualifications of personnel for this project	20%
4	Engineering student involvement	5%
5	Probability of contractor's research plan meeting the objectives of the Work Statement	10%
6	Creativity of proposed approach to research plan	10%
7	Performance of contractor on prior ASHRAE projects (no penalty for new contractors)	10%

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Literature Survey	2
2	Experiment construction, preliminary testing	9
3	Laboratory Testing	15
4	Field Testing	19
5	Final Report	24

References

1. Brower 2013. Report of system flush for Tahoe Truckee Unified School District. Available online at: https://www.dropbox.com/s/wwofz10xkxrar7y/TRUCKEE%20REPORT%20AND%20PHOTOS.pdf?dl=0
2. CSA 2016. ANSI/CSA/IGSHPA C448 Series-16 Design and installation of ground source heat pump systems for commercial and residential buildings. CSA Group.
3. IAPMO 2018. Uniform Solar, Hydronics, and Geothermal Code. International Association of Plumbing and Mechanical Officials.
4. IGSHPA 2017.Closed-Loop/Geothermal Heat Pump Systems Design and Installation Standards
5. KSB 2015. https://www.youtube.com/watch?v=c1xX90ZfBj4&feature=youtu.be
6. PurgeRite2016. *2' Per Second Geo Flush Is NOT Enough*, https://www.youtube.com/watch?v=c_Nj-vDt-3w
7. Sellgren, A. 1982. *CHOICE OF OPERATING VELOCITY IN VERTICAL SOLID-WATER PIPELINE SYSTEMS*. Hydrotransport 8, Papers Presented at the 8th International Conference on the Hydraulic Transport of Solids in Pipes., Johannesburg, S Afr, BHRA Fluid Engineering. 211-226.
8. Zanker, A. 1974. *Nomograph for calculation of transport velocities in solids/water suspensions*. Chemical Engineer(291): 727-728.
9. State of Wisconsin department of Administration Division 23 – HVAC - Master Specifications Section 23 21 13 Hydronic Piping
10. https://doa.wi.gov/Pages/DoingBusiness/MasterSpec_Div23.aspx
11. ASHRAE SP-94, 2002, Commissioning, Preventative Maintenance, and Troubleshooting Guide for Commercial Ground-Source Heat Pump Systems.
12. Siegenthaler 2020, personal communication with Lance MacNevin, Plastic Pipe Institute, March 24, 2020.