Conf-9

ANL/CP--74875

DE92 015226

ICE SLURRY COOLING DEVELOPMENT AND FIELD TESTING

by

Dr. K. E. Kasza, Senior Engineer, Argonne National Laboratory
Mr. J. Hietala, Project Leader, Northern States Power
Mr. R. D. Wendland, Senior Program Manager, Electric Power Research Institute
Mr. F. Collins, Program Manager, U.S. Department of Energy, Utility Systems

To be presented at the 83rd Annual Conference of the Int. District Heating and Cooling Association, Boston, MA, June 14–17, 1992.

ICE SLURRY COOLING DEVELOPMENT AND FIELD TESTING

by

Dr. K. E. Kasza, Senior Engineer, Argonne National Laboratory
Mr. J. Hietala, Project Leader, Northern States Power
Mr. R. D. Wendland, Senior Program Manager, Electric Power Research Institute
Mr. F. Collins, Program Manager, U.S. Department of Energy, Utility Systems

ABSTRACT

A new advanced cooling technology collaborative program is underway involving Argonne National Laboratory (ANL), Northern States Power (NSP) and the Electric Power Research Institute (EPRI). The program will conduct field tests of an ice slurry distributed load network cooling concept at a Northern States Power utility service center to further develop and prove the technology and to facilitate technology transfer to the private sector. The program will further develop at Argonne National Laboratory through laboratory research key components of hardware needed in the field testing and develop an engineering data base needed to support the implementation of the technology. This program will sharply focus and culminate research and development funded by both the U.S. Department of Energy and the Electric Power Research Institute on advanced cooling and load management technology over the last several years.

Key Words: Ice, Slurry, Cooling, Storage, Transmission

INTRODUCTION

Improving cooling technology and fostering its use has been a targeted research objective of the U.S. Department of Energy (DOE) for the last five years. Argonne National Laboratory (ANL) has shown that pumpable phase-change slurries (i.e., an ice slush slurry) can be used to replace chilled-water delivery of cooling to a distributed load network. The use of ice slurries improves cooling system thermal hydraulics (for both primary coolant and HVAC), system operational characteristics and facilitates load management. EPRI's expertise on ice cool storage, load management, and on falling film ice slush generation equipment development, along with NSP's past experience with testing an ice storage cooling system, will greatly enhance the overall viability of this program. Potential system users and manufacturers of ice-making machines, heat exchangers, pumps, and piping have shown great interest in this technology. The collaborators have formulated and initiated a program to further develop and test this technology. Private-sector funding, amounting to approximately 50% of total program cost, has been secured.

This program is of four or five years duration. In the first two years, a suitable ice slush making machine will be identified by NSP and ANL and modified and tested at ANL, and a method will be developed for controlling slurry delivery to users. Also NSP, EPRI, and ANL will initiate detailed design and deployment of a field test system at NSP. In the first summer of field testing, at NSP the slurry will be utilized only within the NSP service center. In the second summer of field testing, piping will be installed to deliver slurry to a U.S. Post Office and a medical center, and the total system will be tested. In the third summer of field testing, additional hardware, such as other ice makers, pumps, etc., will be tested to achieve optimization of system performance. In the last year of this program, a design guide will be developed for use of the demonstrated technology. The completion of this program will have accomplished transfer of DOE- and EPRI-developed technology to the private sector.

BACKGROUND

Building space cooling, currently provided primarily by electrically driven equipment, represents a significant share of the total U.S. energy consumption. In 1985 for example, 1.2 quads (quadrillion BTUs) of energy in the residential sector and 1.3 quads of energy in the commercial sector were used for space cooling, compared to the total of non-transportation energy use of 53.8 quads (residential and commercial energy use totaled 9.8 quads in 1985). This cooling demand, even in northern climates, is contributing to peak loading problems for utility companies. The banning of chlorofluorocarbon (CFC) refrigerants because of environmental concern will likely cause a 5–8% increase in demand for space–cooling electricity resulting from less efficient refrigerants. In addition, chilled–water cooling systems in many large building complexes cannot satisfy demand due to utilization of large fixed windows and the increasing use of electrical equipment and computers. Furthermore, existing cooling technology, especially for large–scale distributed load systems associated with large building complexes or in the form of district cooling systems, is burdened by high capital costs, performance shortcomings and frequently by high electricity peak demand charges.

Improving cooling system technology is a targeted research area for both the U.S. DOE and EPRI. The work being funded is directed at improving the thermal–hydraulic performance of chilled–water cooling systems and utility load management. This current program will focus and culminate these past efforts by testing a complete ice slurry distributed load network cooling system in the field with involvement of equipment makers, engineers, and end users.

Specifically, ANL under DOE sponsorship, as part of its pioneering research with advanced energy transmission fluids, has shown that pumpable phase–change slurries (i.e., for this application an ice slush slurry) can be used to replace chilled–water delivery of cooling to a load. This permits pumping of energy transport fluids of higher energy density from a central ice slush generator to distributed loads which can use ice storage to shift peak electrical demand. In parallel, an advanced–concept ice slush generator has been under development under EPRI sponsorship to efficiently generate ice slush that can be used in storage for utility load management. Thus, all parties involved bring essential expertise and experience to ensure success of this program.

PROGRAM DESCRIPTION

The duration of this collaborative program which began in 1991 is expected to be four or five years. The combined expertise and resources of ANL, NSP and EPRI will be utilized to develop, design, install, and field test (at an NSP utility center in Minneapolis) an advanced cooling system involving ice slurry generation, storage, and piped transport to satellite users. This effort, in the first two and a half years, will involve equipment selection, modification, additional development and interface of critical components such as ice makers, water–ice mixing devices, control hardware, pumps, heat exchangers, and storage tanks. The hardware development, qualification testing and generation of design basis slurry flow and heat transfer correlations will be performed at the ANL Flow and Heat Transfer Test Facility. During this period, the field site test system will undergo detailed design (conceptual design already completed) and be installed and interfaced with an existing NSP heating, ventilating, and air-conditioning system for the first summer of testing. In this first phase of field testing, the ice slurry will only be used for cooling of the NSP service center. It should be noted that the design of this system is a first of its kind. During this period, it is also anticipated that considerable effort will go into establishing appropriate system controls and operational techniques.

The following describes the status of some of the important tasks which are underway in the first phase of this program.

1. The overall collaborative program objectives and work plan were mutually developed by ANL, NSP, and EPRI.
2. An agreement was reached by all parties as to the responsibilities and roles of each party.
3. Conceptual design of the field test system was established and commitment of two satellite users to participate as part of the distributed cooling system was obtained.
4. Various ice-maker machines were evaluated for use in the early stages of the program and the falling film binary solution method under development by EPRI was selected.
5. A joint EPRI/DOE-sponsored workshop on ice slurry cooling was conducted in May 1992 for power utilities and industry to achieve even broader interest and participation in the program.

The following two tasks are currently underway and will lead to field installation and startup of shakedown testing of the ice slurry system.

1. ANL is performing further testing and development on a reduced-scale (10-24 ton) falling film ice maker and will establish conditions to ensure operation without plate freezeup and best heat transfer performance and controllability. This information will allow specifications to be drawn up for purchase of the large 80 ton field unit. A technique and hardware for mixing of the ice slush with water to achieve desirable slurry loading compatible with pumping to the loads will be developed. Testing to obtain

design basis information for slurry ΔP in pipes and fittings and to establish guidelines for avoiding plugging in branch piping will be initiated.

2. ANL, NSP, and EPRI are performing detailed design of the field test system including establishment of operation and control methodology. The field ice generator will be purchased and the system installation implemented at NSP with startup.

With the successful completion of the first summer of field testing within the NSP service center, supply piping and interface equipment will be installed at the field site for slurry delivery to the satellite users, a U.S. Post Office and a health/medical center. Piping routes of $\approx$1/4 mile long have already been identified. The interface between slurry delivered and the user's existing cooling equipment will be designed to minimize disruption of the user's system and minimize his switchover costs. Each user will have an ice slurry storage tank, and will draw from the tank only cold liquid for utilization in his existing system. Testing of this distributed load cooling system (or district cooling system) will occur in the second summer and will involve considerable effort to develop a system operational plan and controls philosophy that optimally satisfies utility goals of managing electrical cooling loads and the user's goal of achieving reliable cooling at a reduced cost over conventional chilled water nonstorage systems. Developmental work may also be needed on instrumentation to monitor cooling BTUs delivered to the user so that he can be charged correctly.

In the third summer of testing, the field test site will be used to test other manufacturers' equipment designs for such things as ice slush makers, heat exchangers, pumps, storage tanks, and slurry control and monitoring instrumentation to achieve more optimum district cooling performance.

Finally, based on all the acquired field testing developmental experience and on fundamental ice slurry correlations to be developed at ANL, a design guide for ice slurry system design and operation will be developed by this program.

CONCLUSIONS

Upon successful completion, this collaborative program will have accomplished the following:

1. Demonstrated workability of ice slurry generation, transport, and storage in a field environment involving multiple loads and storage tanks;
2. Established ability to scale up an ice generator and identify a best ice generator;
3. Developed control and operation philosophy relative to space cooling, district cooling, and utility load management;
4. Accelerated the transfer of advanced cooling technology being developed by DOE and EPRI by bringing together in a sharply focused effort research and development groups, equipment manufacturers, and the end user in a collaborative research program;
5. Developed design information to enable the optimum application of ice slurry cooling in other situations.

The program will also have addressed the following specific design issues and developmental needs.

1. Established optimum falling film binary solution composition to maximize heat transfer and minimize ice adhesion;
2. Established an ice slush storage tank design that maximizes efficient cooling extraction and minimizes performance degrading phenomena such as ice crystal agglomeration and ice bridging above the liquid in the bottom of the storage tank;
3. Developed a method for obtaining a pumpable slurry of appropriate crystal size and void fraction from a storage tank;
4. Developed a method for splitting a slurry pipe flow in a controlled manner without pipe plugging and measuring energy delivered to user;
5. Established slurry system operation and control philosophy relative to optimum cooling and load management;
6. Developed slurry pipe flow pressure drop and heat transfer correlations as a function of pipe size, crystal size, loading fraction, carrier liquid type and flowrate.

ACKNOWLEDGMENT

This work was sponsored by the U.S. Department of Energy, Utility Systems Division, under Contract W-31-109-Eng-38.

DATE
FILMED
7/22/92