NATIONAL BUREAU OF STANDARDS REPORT

5283

PROGRESS REPORT FOR QUARTER ENDING APRIL 6, 1957

on

REFRIGERATION AND FIELD EQUIPMENT

by

C. W. Phillips
P. R. Achenbach

Report to
Quartermaster Research and Development Command
Department of the Army
Natick, Massachusetts

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Inquiries regarding the Bureau's reports should be addressed to the Office of Technical Information, National Bureau of Standards, Washington 25, D. C.

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Metering Heat Sink for Refrigerated Structures

The prototype metering heat sink apparatus for determining the over-allheat transfer, including both sensible and latent loads, of an insulated refrigerated structure was completed and put into operation early in January. A 21-foot insulated refrigerated Kentucky semi-trailer was used as the first item to be investigated with this apparatus because of its mobility, and because the comparison of heat transfer for this particular vehicle under the heat loss method and under the metering heat sink method was important in connection with possible investigation of current procurement of this item.

The metering heat sink apparatus developed under this program consisted of a refrigerated brine circuit, including a coil in the structure under investigation, a metered heat source, and a brine chiller, all connected in series, with the necessary instrumentation to compare the temperature rise of the brine in passing through the coil in the trailer, with the temperature rise of the brine in passing through the metered heat source. A simple schematic sketch of this circuit is attached.

The trailer under study was mounted on scales so that the gain in weight, due to the accumulation of moisture in the insulated space, or on the coil in the trailer, could be measured at regular intervals as the test progressed. The first phase of the test was expected to last only a few days, just long enough to show that without making specific effort to destroy the exterior

vapor seal, there would be a very slight gain in weight due to moisture. The actual rate of moisture accumulation, however, at the test conditions of 0F trailer temperature and 110F ambient temperature at 60 percent relative humidity, was much greater than expected, and amounted to more than one pound per hour. The test was continued from January 15 through March 28 without interruption.

The metering heat sink apparatus, which measures the heat transfer under conditions normal to intended use for a refrigerated structure, was capable of showing the difference in heat transfer due to changing the relative humidity of the ambient test space from 60 percent to 15 percent and back to 60 percent again without change in either interior or exterior temperature. The heat transfer rate of the structure did not increase sharply during the 73 days of the test, although more than 850 lbs of frost and ice accumulated in the insulated space. During the same period about 130 pounds of ice or frost accumulated on the coil in the structure.

On March 28, with representatives from QMR&D present, a number of openings were cut in the trailer exterior to permit inspection of the areas of ice accumulation. The test room ambient temperature was reduced to slightly below 32F to preclude any melting of the ice in the insulated walls during the inspection. The inspection showed that there was little ice or frost at or in the floor of the vehicle, little or no frost at the lower portion of the side walls, heavy frost at the top of the side walls, and little frost along the center line of the top. Several pictures were made of various openings made for inspection, and these will be included in the project report.

The heat transfer rate of the vehicle, by the reverse heat method, prior to the moisture accumulation test, was about 68 Btu per hour (°F). With the metering heat sink method, and with the room ambient relative humidity low, the heat transfer rate of the vehicle was about the same amount. As soon as the relative humidity in the test room was raised from a low value near 15 percent to 60 percent, the heat transfer rate showed an increase of about five Btu per hour (°F) or a heat transfer rate of about 73 Btu per hour (°F). After several days of operation at the 60 percent level, about 500 pounds of frost and ice

had accumulated in the vehicle, either in the insulated space or on the coil, the heat transfer rate had increased to about 76 Btu per hour (°F). At this point, the relative humidity in the test room was again lowered to about 15 percent and the heat transfer rate dropped to about 71 Btu per hour (°F), indicating that the heat surrendered by the moisture entering the insulated space caused an added increment to the heat transfer rate, that could be measured by the metering heat sink method. The reverse heat loss method, where the interior of the structure is heated, obviously would not indicate any such moisture effect unless the interior of the trailer were humidified.

After the March 28 inspection, all the openings made in the trailer exterior were patched with metal plates. About 45 three- or four-inch diameter round holes were drilled in the trailer exterior at various locations: ten in the roof; ten on each side wall, five near the top and five near the lower edge; four on each end, two near the top and two near the lower edge; seven in the bottom.

Without allowing any of the ice in the walls to melt, the test was continued at conditions of 0F trailer temperature and 110F ambient temperature at 60 percent relative humidity. The rate of frost and ice gain (by weight) was about 1.3 pounds per hour, as compared to about 1.2 pounds per hour at the start of the first test without any holes cut in the exterior, and as compared with about 0.7 pound per hour just before the March 28 inspection when 850 pounds of frost and ice had been accumulated in the insulating space.

The test was continued until about April 1, when the inspection patches were removed and the ice accumulation again observed. About 500 pounds more ice had accumulated in the insulated space, and the heat transfer rate with an ambient humidity of 60 percent had started to increase at a sharper rate, the rate being about 90 Btu per hour (°F) by April 1. Before the walls were opened for inspection, the humidity in the test room was lowered to 15 percent and a check of the heat transfer rate with the additional 500 pounds of ice, and at the lower humidity, was made. These data have not yet been analyzed, but appear to show the same decrease as for the previous tests when nothing other than the humidity was changed.

The significant comparison between the two phases is the little change in the rate of weight gain with no holes cut in the exterior and with many holes cut in the exterior. Careful examination of the vehicle body shows a few openings in the bottom exterior at the corners. Drops of water had been observed prior to this series of tests emerging around rivet heads and coming through seams, etc., when the exterior skin had been cooled suddenly, permitting condensation to form on the inside of the exterior skin and run down to such an opening at the lower edge of the exterior skin.

The examination of the walls on April 1 showed little increase of ice or frost in or at the floor or at the lower edge of the walls. There was some increase in the amount of frost at the top edge of the walls and a great increase in the frost along the center of the top, being heaviest at or near the holes cut into the top exterior surface. Photos of these areas were made and will be included in the project report.

Following the April 1 examination, the entire truck will be defrosted, then examined to see if the ice formation in the insulation had caused any structural changes in the skin, frame, or insulation placement. The heat transfer rate of the entire vehicle will then be checked with the reverse heat method to see how closely it compares with such a measurement before the vehicle had accumulated the ice in the insulated space. Following this, two additional tests will be made on this vehicle: first, the steady state heat transfer using the metering heat sink at conditions of 0F trailer temperature and 110F ambient temperature at 60 percent relative humidity will be measured with all of the exterior openings cut for test or examinations patched; then, second, the openings in the bottom exterior of the vehicle which were discovered by examination will be patched or plugged to determine if these openings were in fact the means by which the moisture entered the insulated space.

These tests have shown the metering heat sink method to be a useful research tool. Because the apparatus was a prototype, around-the-clock labor was necessary during the first month of operation, but as various parts were made more self-protecting, the labor required for operation was reduced.

Exhaust Gas to Refrigerant Heat Exchanger

Work was started during this quarter on the necessary modifications to permit the few test runs remaining at minus 40F to complete the evaluation of two systems for salvaging the waste heat from the gasoline engine used to drive the compressor of a refrigerating unit used as a heat pump. This setup has been idle for nearly two years, primarily because of priority of other investigations. It is believed that this series can be completed and reported in the near future.

Refrigerator Specification

Four current model, domestic refrigerators have been purchased on the open retail market for use in determining the adequacy of Federal Specification AA-R-00211d. The test setup has been started and the first of the four refrigerators to be tested has been prepared.

Refrigerated Structures

As reported under "Metering Heat Sink," the Kentucky 21-foot refrigerated semi-trailer has been under continuous test throughout this reporting quarter, and work with this trailer will be concluded in the next quarter. Work on preparation of the reports of the over-all series of investigations of several trailers and trailer or warehouse refrigerating units was continued during this quarter.

Project Cost Breakdown

The project costs for the reporting quarter are given in the accompanying invoice prepared by the Accounting Division. The figures given here are approximate and are shown as divided among the main four items under investigation during the quarter.

One expense for travel, included under Refrigerator Specification in the tabular itemization below, was about $160 for travel costs for two representatives from this Bureau to QMR&D at Natick on April 9. Although the actual travel occurred after the April 6 end of the reporting period, the travel costs were chargeable at the time of request prior to April 6.

Two items, development of the Metering Heat Sink, and performance of a refrigerated structure, were conducted simultaneously, and division of costs between these items was arbitrary. The only major item of material purchase was for the four domestic refrigerators procured from retail sources for study in relation to the Federal Specification AA-R-0021d, and this purchase amounted to about $1,210.

Tabular itemization:

Item	Metering Heat Sink	Refrig. Structures	Refrig. Spec.	Heat Exchngr.	Total
Labor	$ 6370	$ 3140	$ 630	$ 210	$10350
Material		550	360		910
Equipment	10		1210		1220
Misc. Services*	340	170	190	70	770
Bureau Supervision	2000	970	190	60	3220
Total	$ 8720	$ 4830	$2580	$ 340	$16470

*Travel, Shipping, Communications, Photos.

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major field laboratories in Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside front cover of this report.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Application Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering.

Radio Standards. Radio Frequencies. Microwave Frequencies. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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