NATIONAL BUREAU OF STANDARDS REPORT

3929

REFRIGERATION AND FIELD EQUIPMENT

PROGRESS REPORT
August 1, 1954 to December 31, 1954

To

HEADQUARTERS; QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND

NATICK, MASS.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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 is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in 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 of the back cover of this report.

Electricity. Resistance and Reactance Measurements. Electrical Instruments. Magnetic Measurements. Electrochemistry.

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

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels. Cryogenic Engineering.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Measurements. Infrared Spectroscopy. Nuclear Physics. Radioactivity. X-Ray. Betatron. Nucleonic Instrumentation. Radiological Equipment. Atomic Energy Commission Radiation Instruments Branch.

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 Control.

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.

Mineral Products. Porcelain and Pottery. 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.

Electronics. Engineering Electronics. Electron Tubes. Electronic Computers. Electronic Instrumentation. Process Technology.

Radio Propagation. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Frequency Utilization Research. Tropospheric Propagation Research. High Frequency Standards. Microwave Standards.

● Office of Basic Instrumentation

● Office of Weights and Measures.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
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REFRIGERATION AND FIELD EQUIPMENT

Progress Report
August 1, 1954 To December 31, 1954

by

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for

HEADQUARTERS, QUARTERMASTER RESEARCH & DEVELOPMENT COMMAND
NATICK, MASS.

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PROGRESS REPORT

REFRIGERATING AND FIELD EQUIPMENT

HEADQUARTERS:

QUARTERMASTER RESEARCH AND DEVELOPMENT COMMAND

August 1, 1954 Through December 31, 1954

1. INTRODUCTION

This report summarizes activities of the Heating and Air Conditioning Section, Building Technology Division, National Bureau of Standards in behalf of the Mechanical Engineering Division Headquarters, Quartermaster General Research and Development Command, U. S. Army. The report covers a five-month period, and includes a summary of the approximate expenditures for each project attached at the end, giving three figures; direct labor, supervision and services, and supplies and other expenses.

The specialized knowledge of nearly all members of the staff of the Heating and Air Conditioning Section has been utilized at times to further the work for QMR&D. Of these, ten have spent from 25% to 90% of their time during this reporting period to accomplish the work reported herein. The services and facilities of other sections at NBS have been drawn on as required. The principal activities on this program are itemized below, together with a discussion of the progress during the present reporting period or their status at the end of the reporting period. Items 1, 2, 3, 4 and 14 were completed during this reporting period.

Item 1. PREVIOUS PROGRESS REPORT

N.B.S. Report No. 3635, covering activities in the period from December 1, 1953 through July 31, 1954 was submitted on August 23, 1954.

Item 2. 1/3-TON THERMO KING REFRIGERATING UNIT

N.B.S. Report No. 3790, Effect of Engine and Fan Speeds on the Capacity of The 1/3-Ton Thermo King Refrigerating Unit, Model Q15G, was completed and submitted on November 12, 1954. It covered a study of the effect of various engine and fan speeds on the net refrigerating capacity of the 1/3-ton gasoline-driven warehouse unit, to permit determination of the possibility of reducing the number of models of such equipment

by using each model over a wider range of capacities. As designed the fan and engine speed proportions were fixed by pulley sizes. Optimum speeds for engine and fans, when varied independently, were determined. The fact that the design engine and fan speeds did not achieve the maximum net refrigerating capacity indicated the need for study of other items of similar nature and for further study of the application of fans and blowers for low-temperature refrigerating service generally.

A request for more detailed information concerning the various tests has been received and this material is currently being assembled.

Item 3. DEFROSTING CHARACTERISTICS OF THE 1-TON REFRIGERATING UNIT

N.B.S. Report No. 3735, Defrosting Characteristics of the Thermo King 1-Ton Warehouse Refrigerating Unit, Model MQ51, was completed and submitted on October 12, 1954. Defrosting performance of both the gasoline-driven and electric motor-driven models of this important item was outlined. Quantities of frost required to block the refrigerating coil, and the effect on internal warehouse temperatures during the periods required for defrosting were reported, for conditions of empty warehouse and with the warehouse loaded with simulated frozen food. The studies were also divided between operation under manual selection of defrosting time and automatic defrost timing as provided originally by the equipment manufacturer.

This study of defrosting characteristics is directly related to the problem of heating (full or partial reverse cycle) by means of refrigerating equipment. For portable equipment, the warehouse might be exposed to temperatures both above and below the desired product temperature and in such cases, the ability of a single piece of apparatus to both heat and cool is needed. Possible applications of refrigerating equipment as space heating apparatus, using it as a heat pump, or salvaging waste heat from the exhaust gases of the gasoline engine is currently under study in a separate portion of this project, and is reported under Item 5.

Item 4. REVISION OF FEDERAL SPECIFICATION AA-R-211c

The Federal Specification covering Refrigerators, Electric, Self-Contained, has been under revision during this and the previous reporting period. The draft for AA-R-211d has been completed and will be submitted before January 15, 1955. Although the previous specification, AA-R-211c, covered domestic, shipboard, and commercial refrigerators up to 100 cu.ft., the pro-

posed draft for AA-R-211d covers only domestic refrigerators up to 15 cu.ft. It is hoped that the Heating and Air Conditioning Section can revise the specification for commercial refrigerators, since much of the information gathered on domestic refrigerators, in reference to use of plastics, metals, methods for defrosting, methods for testing, etc., can be applied to this portion of the specification. Shipboard refrigerators will probably be covered in a separate specification which can either be included in or patterned after an applicable Navy specification.

The proposed draft recognizes that domestic refrigerators are divided into types determined first, by whether a compartment suitable for storage of frozen foods is provided, and second, whether the defrosting process is started manually or by means of an automatic device.

The use of plastics was covered in some detail in the light of experience gained during field trips to manufacturing plants during the first phase of this work. Test procedures were generally made to agree with NEMA recommendations as outlined in proposed ASA Standards within the scope covered by these standards. Several conferences were held with Mr. Joe V. Davidson, QMR&D representative, during the period in which the proposed draft was being prepared.

Item 5. DEVELOPMENT OF EXHAUST GAS TO REFRIGERANT HEAT EXCHANGERS

Since all low-temperature refrigerating apparatus must be defrosted, the importance of improving the defrosting characteristics of the various items of portable gasoline-driven refrigerating units was recognized early in the research and development program of QMR&D. During this reporting period, studies were continued of two methods of utilizing some of the waste heat in the exhaust gases of the gasoline engine. For each of these methods, the normal cooling coil in the conditioned or refrigerated space is used as a heating surface during defrosting or heating. In the method proposed by QMR&D, a heat exchanger is provided in the exhaust line from the engine which is refrigerated by vaporizing refrigerant, with the flow controlled by a thermostatic expansion valve, and the normal evaporator is employed as a condenser. In a second method proposed by NBS a heat exchanger is also installed in the exhaust line from the engine. The discharge gas from the refrigerating compressor is forced through this exchanger and superheated to the highest practical temperature, not over 350 to 400 F, then permitted to flow through the normal evaporator. In this system little, if any, of the refrigerant is condensed during heating or defrosting. There appears to be advantages for each system,

and the first phase of the investigation in ambient temperatures of 35 F and above has demonstrated that each is feasible. The second phase of the investigation which is now in progress is expected to provide further data on the two when operated in ambient temperatures approaching -30 F. Attempts to operate this equipment at lower ambient temperatures have brought to light many difficulties, primarily connected with malfunctioning of the gasoline engine. Failure of oil lines, distributor points, fouling of spark plugs, failure of water jacket gaskets, contamination of lubrication oil, sticking of governor linkage, freeze-out of water in gas lines, blocking of the engine breather with ice, blocking of the exhaust line with condensate and other waste material, are representative of the sort of mechanical difficulties present in low-temperature investigations.

One item noted particularly with the commercial heat exchanger used for the first method with the vaporizing refrigerant circuit was the rapidity with which foreign material in the exhaust gas plugged the exhaust vapor passages through the heat exchanger. Other designs for the heat exchanger to be used will probably improve this characteristic.

Using the vaporizing refrigerant system incorporated in the first method and the commercial heat exchanger, a heating capacity of approximately 7000 to 8000 Btu/hr has been observed when the warehouse temperature was at 15 F and the ambient temperature of the engine was minus 20 F. Values have been observed at lower ambient temperatures and other warehouse temperatures, but the runs have been interrupted by mechanical failures before steady state conditions have been attained. This series will be concluded in the near future, and this same system will be observed using another type of heat exchanger, before both types of heat exchangers are tested in low ambient temperatures with the superheated refrigerant system incorporated in the second method.

It is anticipated that the Wisconsin VE4 air-cooled gasoline engine will be used for the tests of the superheated refrigerant system, since this type of engine may be used for the one-ton warehouse unit in future production.

Item 6. MODIFICATION OF CONTROLS FOR THE ONE-TON REFRIGERATING UNIT

Work has been continued during this reporting period on the general modification of the present complex electrical control system for the 1-ton gasoline-driven warehouse refrigerating unit. Manufacturers of control devices, such as thermo-mechanical

servo-mechanisms, engine governors, temperature limit devices, etc., have been consulted in regard to available controls, or their ability to modify present commercial items. It appears generally that the ability of these manufacturers to construct modified controls will be the solution of this problem.

In general the proposed system would operate in the following manner: A temperature-sensing thermo-mechanical device would determine the need for either cooling or heating, or neither, and regulate control valves for refrigerant flow, and regulate the speed of the gasoline engine from a minimum safe idling speed when neither heating or cooling is needed to a maximum safe engine speed when maximum cooling or heating is required. The gasoline engine would remain in operation except when being serviced, and consequently would require smaller capacity cranking facility, or manual cranking means for systems below 15 engine horsepower. No electrical controls, with the possible exception of engine over-temperature would be employed. Thermo-mechanical controls of a type familiar to both automotive and refrigeration personnel would generally be used for temperature regulation in the controlled space. The engine speed would be regulated by a governor, which is adjusted by need for varying capacity. In this way automatic governor protection against run-away speeds is assured, and variation of throttle position in response to varying loads, does not interfere with average engine speed which is determined by adjustment of the governor in direct relation to deviation of the temperature from desired control point in the controlled space. This work will be continued.

Item 7. 1/3-TON CARRIER REFRIGERATING UNIT

The first draft of a report of performance investigations on the 1/3-ton gasoline-driven warehouse refrigerating unit, Carrier Model D731 was completed during this reporting period and is currently being reviewed.

Item 8. 1/2-TON THERMO KING REFRIGERATING UNIT

The first draft of a report of a study of capacity and other performance characteristics of the 1/2-ton gasoline-driven Thermo-king warehouse refrigerating unit, Model K-10 was completed prior to this reporting period and is currently under review.

Item 9. COMPRESSOR STANDARDIZATION

Engineering assistance and recommendations on test methods and procedures were made to representatives of Consultants, Inc., under contract to QMR&D, during two conferences requested by

the contractor. A review of the apparatus required to perform the various performance, capacity, and general qualification tests referred to in the proposed compressor standardization program has been made to determine whether facilities of this section will meet the requirements. It is believed that a majority of the apparatus and trained personnel are currently available within the facilities of this section.

Item 10. INSULATED FOOD CONTAINERS

Three insulated food containers have been readied for test at ambient temperatures of minus 40 F and perhaps minus 70 F. Low temperature facilities at NBS are currently being readied for these tests.

Item 11. INSULATED REFRIGERATED TRAILER

Preparations have been made as requested for prompt testing of the thermal loss or gain characteristics of an insulated, refrigerated semi-trailer scheduled for delivery to this Bureau during January.

Item 12. REPORTS IN PROGRESS

At the end of this reporting period, final reports of tests or studies of several items are in progress. These include the Tent Heaters, Sectional Air Conditioner, Electric Conversion of the Thermo King Model MQ 51.

Item 13. AIR DISTRIBUTION IN REFRIGERATED TRAILERS

No work was done on this project during this reporting period. The trailer has been equipped with thermocouples and the type of air flow measuring devices to be used have been selected. A simulated food load consisting of 1.1 cu.ft. cases of combat food rations has been placed in the trailer and the trailer has been installed in a test area suitable for the tests proposed. Work can be resumed at any time.

A study of the behavior of moisture in refrigerated trailers, including its entrance into the insulated walls, entrapment, and passage into the refrigerated space, effect of steam cleaning, racking, wind velocities, etc., is contemplated by this section for another agency. This work can be of direct interest to QMR&D, and QMR&D participation in the project is invited.

Item 14. LANTERNS

Work was commenced during this reporting period on an intensive testing program for a better evaluation of the operating

characteristics of the Coleman Inverted Lantern, Gasoline, T-53-5. Under investigation were the pressures generated in the fuel tank in high ambient temperatures, the ability of the lanterns to operate satisfactorily on leaded gasoline, and the likelihood the lanterns exploding if the pressure regulator failed to function. NBS Report No. 3853, covering the results of these studies on operating characteristics was prepared and submitted under date of December 30, 1954.

Item 15. VAPOR TRANSMISSION STUDIES

Two tests were completed on the first insulated warehouse panel in the water vapor transmission apparatus without gaskets on the warm side of the panel. The temperature and relative-humidity averaged 110.2°F and 70% on the warm side and 36.6°F and 20% on the cold side, respectively, during the first test, whereas these quantities averaged 109.9°F and 62.4% on the warm side and -0.1°F and 70.8% on the cold side, respectively, during the second test.

Approximately a week's operation was required in each case to cause condensation or frost to occur on the interior side of the metal skin on the cold side of the panel. In the first test condensation was observed on the upper right plexiglas inspection window only. The wooden frame members were wetted on the upper half of the panel and free water was observed in the hook openings of the top and middle panel fasteners. The top hooks were badly rusted. In the second test frost was observed on all five plexiglas windows. Frost formed around some of the hooks in the upper and middle panel fasteners to a degree that made operation of the fasteners difficult. Frost was found between the mating wooden members at the panel joint on the upper half of the panel. There was frost on the insulation fibers at the upper two inspection windows on the cold side of the panel but the warm side of the panel was dry.

Item 16. INVENTORY OF QMR&D ITEMS ON HAND AT NBS

A list of the items on hand at the end of the previous reporting period was submitted with the previous progress report. With the exception of the 1/3-ton Thermo King Model Q15G, and four Inverted Coleman Gasoline Lanterns this equipment is still on hand. Three insulated food containers have been received for test during this reporting period, and two sets of artic clothing have been received for use in the low ambient temperature tests of the MQ51 heat exchangers. A Wisconsin air-cooled gasoline engine, Model VE4, was received for use in the modified 1-ton warehouse refrigerating unit. A Westinghouse home freezer

and a Frigidaire refrigerator were loaned to the section by their respective manufacturers for tests in connection with the revision of Federal Specification AA-R-211c. These last two items are, of course, still the property of the manufacturers and will be returned to them in accord with instructions.

2. EXPENDITURES

The total funds expended on work in behalf of QMR&D for the period August 1, 1954 through December 31, 1954 are summarized in the attached table. Three figures are given for each item for the entire period, the first is the amount expended on labor only, the second is the amount expended for supervision and services, and the third is the amount spent on all other items, such as materials, supplies, travel, photographs, printing, etc. The item numbers refer to item numbers in this progress report. The total expenditures reported at the bottom of the table for the period are the figures taken from the records of the Accounting Section; all other figures are the best approximations which can be made on the basis of records available.

TABLE 1

APPROXIMATE EXPENDITURES ON VARIOUS PROJECTS FOR QMR&D -- AUGUST 1 -- DECEMBER 31, 1954

ITEM	Labor	Supervision and Services	Materials And All Other Expenses	TOTAL
1,10,11,12,13,16. Progress Report, Food Containers, Trailers, Inventory, Other Reports	$ 670	$ 260	$130	$1060
2. 1/3-Ton Thermo-King	585	225	100	910
3. Defrosting 1-Ton Unit	230	90	70	390
4. Refrigerator Spec.	3650	1395	220	5265
5. Exhaust Gas Refrigerant Heat Exchangers	5130	1960	760	7850
6. Modification of Controls On 1-Ton Unit	3510	1340	360	5210
7. 1/3-Ton Carrier Unit	520	200	-	720
8. 1/2-Ton Thermo-King Unit	60	20	-	80
9. Compressor Standardization	135	50	-	185
14. Gasoline Lanterns	1890	720	290	2900
15. Vapor Transmission	710	270	350	1330
TOTALS	$17090	$6530	$2280	$25900

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 front 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 ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.


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