# NATIONAL BUREAU OF STANDARDS REPORT

6212

CAPACITY TESTS
OF
FOUR 3/4-TON GASOLINE-POWERED REFRIGERATING UNITS
THERMO KING, MODEL Q9

by

Clinton W. Phillips and Paul R. Achenbach

Report to
Mechanical Engineering Division
Headquarters, Quartermaster Research and Engineering Command
Natick, Massachusetts

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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**NBS PROJECT**
1003-20-4832

**NBS REPORT**
6212

November 7, 1958

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to

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Capacity Tests
of
Four 3/4-Ton Gasoline-Powered Refrigerating Units
Thermo King, Model Q9

## 1. Introduction

Capacity tests of four Thermo King, Model Q9 3/4-ton, gasoline-engine-driven refrigerating units were made at the request of the Mechanical Engineering Division of the Quartermaster Research and Engineering Command, United States Army, to determine their refrigerating capacity when used in conjunction with 21-foot military-type refrigerating semi-trailers. Figure 1 shows one of the four Model Q9 units.

Three military-type refrigerated semi-trailers, which had previously been tested for heat leakage by the reverse heat-flow method, were used as calorimeters for these tests. Figure 2 is a view of one of these trailers. The heat transmission coefficients, or "U" factors, determined for the three vehicles in the previous trailer tests, were used for computing the heat leakage of these same vehicles when each was used as a calorimeter during the capacity tests of the refrigerating units. These heat transmission factors ranged from 56.1 to 68.3 Btu/hr (F).

This report is a summary of nine refrigerating capacity tests, the results of which have previously been transmitted, either verbally or by letter, to representatives of the Quartermaster Research and Engineering Command. Tests numbered 4 and 8 were made at 110 F ambient temperature and the lowest obtainable trailer temperature. The other seven tests were made at 110 F ambient temperature and 0 F trailer temperature.

## 2. Test Procedure

Each of the gasoline-engine-driven refrigerating units was installed in a semi-trailer which was in a test chamber in which the desired ambient temperature could be maintained throughout the test. The engine exhaust was connected to an exhaust stack to conduct the fumes from the test chamber. All temperature measurements were made by means of thermocouples and potentiometers, and all temperatures used in computing the test results were corrected by the amount of the observed deviation of a typical thermocouple immersed in an ice bath.

In the tests at 110 F ambient temperature and 0 F interior temperature, a thermostatically-controlled heater, with shielded, resistance-type elements and a built-in blower, was placed inside the trailer to maintain the desired interior temperature. Electrical power supplying the heater, the blower, and circulating fans was measured by means of separate calibrated watt hour meters.

Each test was continued for a sufficient length of time to insure that steady rates of heat exchange between the interior and ambient air had been reached and for a six hour period thereafter. The tabulated test results were obtained from these six hour periods at steady state conditions.

The heat introduced into the interior of the trailer, as computed from the measured amount of electric power supplied to the resistance heater, the blower, and the fans, plus the computed heat leakage of the vehicle, was taken as the net refrigerating capacity of the Q9 refrigerating unit being tested.

## 3. Test Results

The conditions under which the refrigerating capacity of each of the four Thermo King, Model Q9, 3/4-ton refrigerating units was determined, and the results of these nine tests are shown in Table I.

The units bearing Serial Nos. 367 and 369 were tested as received, without adjustment. The unit bearing Serial No. 364 was received installed in Trailer B from the Field Evaluation Agency at Fort Lee. It had been tested there and the units were reported to be incapable of bringing the interior of the trailer down to a temperature of 0.0 F. In order to install the necessary thermocouple harness on the unit, to prepare it for the capacity tests, it was removed from the vehicle, and while it was being prepared, Tests 3 and 4 were made, with Model Q9 Serial No. 367 installed in Trailer B.

The important effect of suction pressure on net cooling capacity is indicated by comparing the results of Tests 1 and 2 on the unit with Serial No. 369 and of Tests 3 and 4 on the unit with Serial No. 367. In the first case, a change of 2 inches of vacuum in the suction pressure caused a vari-

ation of about 5% in net cooling capacity with virtually no difference in evaporator inlet temperature. In the second case, a decrease in evaporator inlet temperature of 9.3°F caused a decrease in suction pressure of about 2.7 psig and a decrease in net cooling capacity of 26 percent. In each comparison there was less than one percent change in compressor speed.

At the beginning of Test No. 5, with Model Q9 Serial No. 364 installed in Trailer B, it was found that this unit would not reduce the interior temperature of the vehicle to 0.0°F. It was found necessary to make several adjustments on the thermal expansion valve to establish a suitable super-heat condition and to adjust the engine speed of the unit to the design speed of 2800 rpm. Tests 5, 6, and 7 show the results of the capacity tests after these adjustments had been made.

Good consistency in results was obtained in Tests 5, 6, and 7 at the same operating conditions on this unit. There was only a half percent difference in net cooling capacity among the three tests.

Test 8 was made with the Model Q9 Serial No. 111 as received, and installed in Trailer C. Test No. 9 was made after several adjustments had been made to the thermal expansion valve to establish correct super-heat. Note the lower engine speed during Tests 8 and 9. A comparison of the results of Tests 8 and 9 made on the unit with Serial No. 111 shows that a reduction of 3.2°F in the evaporator inlet air temperature caused a decrease in suction pressure of 1.5 psig and a reduction in capacity of 9.5 percent.

Comparisons of the net cooling capacities of the four Q9 Thermo King refrigerating units of the same model provides some information on the tolerance to be expected in a group of such units. A comparison of Test 3 with Tests 5, 6, and 7 at the same evaporator inlet air temperature shows a variation in capacity of 6 to 7 percent for these two units. However, the net cooling capacity of the unit with Serial No. 369 as indicated by Tests 1 and 2 was 7 to 11 percent below that for the unit with Serial No. 364 and 13 to 17 percent below that for the unit with Serial No. 367.

The net cooling capacity of the unit with Serial No. 111, as shown in Test No. 9, at a compressor speed of 1750 rpm was about equal to that of the unit with Serial No. 369 at a compressor speed 300 rpm higher.

## 4. Discussion and Conclusions

The test results show that the Q9 unit, properly adjusted for super-heat and engine speed was capable of reducing the interior temperature of a stationary 21-foot military trailer, as typified by the three specimens used as a calorimeter, to a temperature below 0°F in an ambient temperature of 110 F. The margin of capacity above that required to produce a cargo space temperature of 0 F, ranged from 1500 to 3400 Btu/hr, representing from 20% to 50% excess capacity in the several trailers. It should be noted that the cooling loads of the three trailers ranged from 6200 Btu/hr to 7500 Btu/hr.

In two cases, an oil leak was observed at the front crankshaft oil seal of the gasoline engine after about 100 hours of operation. This leakage was apparently due to malfunctioning of a pressure-equalizing device intended to relieve crackcase pressure.

The heat transmission coefficients of the trailers, used as calorimeters for these tests, were measured using the reverse heat loss method. In this method, the interior temperature is raised above the ambient temperature, and the heat input is divided by the difference in temperature to determine the heat transmission coefficient.

More recent investigation has shown that the reverse heat flow method does not usually indicate as great a heat transmission coefficient as is observed when the refrigerated enclosure is tested with the interior temperature lower than the ambient dew point temperature. In most cases, the heat transmission coefficient will be greater when the interior of the trailer is refrigerated because of the latent heat transfer caused by condensation of water vapor entering with any leakage air which may penetrate the exterior skin.

Because of this, the computed trailer heat gains and also the refrigerating capacities reported in Table I for the four units may be slightly smaller than the actual values. It is probable that this error does not exceed five percent.

It should be noted that in all cases, the units tested, properly adjusted, and in an ambient temperature of 110 F, were of greater capacity than needed to reduce the trailer

temperature to 0 F when the trailers were stationary. Tests of commercial trailers on the road also indicate that the cooling load of such vehicles when in motion was greater than when tested in a stationary condition in the laboratory because additional air and moisture entered the trailer body under the impact of the air. This increment of additional heat gain amounted to 20 to 30% of the heat gain measured in the laboratory.

| | | | |
|---|---|---|---|
| Q9 Serial No. | | ..11 | 111 |
| Test No. | | 8 | 9 |
| Time | | ..-0500 | 1800-2400 |
| Date | | ..-23/56 | 7/3/56 |
| Trailer | | C | C |
| Head Pressure | Psig | ..75 | 179 |
| Suction Pressure | Psig or In.HgVac | ..3 | 2.8 |
| Ambient Temp. | °F | ..10.3 | 110.5 |
| Cargo Space Temp. | °F | ..2.7 | 0.7 |
| Evaporator Inlet Air Temp. | °F | ..2.7 | 0.5 |
| Engine Speed | RPM | ..388 | 2363 |
| Compressor Speed | RPM | ..765 | 1747 |
| Fan Speed | RPM | ..362 | 1347 |
| Trailer Heat Gain | Btu/hr | ..700 | 7500 |
| Electric Heat Input | Btu/hr | ..450 | 1500 |
| Net Cooling Capacity | Btu/hr | ..150 | 9000 |

Table I

CAPACITY TESTS OF THERMO KING Q9 3/4-TON REFRIGERATING UNITS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Q9 Serial No. | | 369 | 369 | 367 | 367 | 364 | 364 | 364 | 111 | 111 |
| Test No. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Time | | 1900-0100 | 0700-1300 | 1500-2100 | 1400-2000 | 2230-0430 | 1800-2400 | 0200-0800 | 2300-0500 | 1800-2400 |
| Date | | 1/6-7/56 | 2/24/56 | 3/23/56 | 3/24/56 | 4/5-6/56 | 4/6/56 | 4/7/56 | 6/22-23/56 | 7/3/56 |
| Trailer | | A | A | B | B | B | B | B | C | C |
| Head Pressure | Psig | 176 | 185 | 180 | 168 | 185 | 193 | 190 | 175 | 179 |
| Suction Pressure | Psig or In.HgVac | 2" Vac | 0.0 | 2.5 | 0.4 "Vac | 2.0 | 3.1 | 2.8 | 1.3 | 2.8 |
| Ambient Temp. | °F | 110.3 | 109.9 | 110.9 | 110.4 | 110.4 | 110.4 | 110.0 | 110.3 | 110.5 |
| Cargo Space Temp. | °F | 0.0 | -0.2 | 0.4 | -9.5 | 0.2 | 0.4 | -0.2 | -2.7 | 0.7 |
| Evaporator Inlet Air Temp. | °F | 1.4 | 1.9 | 0.6 | -9.9 | 0.3 | 0.4+ | -1.0 | -2.7 | 0.5 |
| Engine Speed | RPM | 2805 | 2796 | 2726 | *2737 | 2825 | 2794 | 2807 | 2388 | 2363 |
| Compressor Speed | RPM | 2054 | 2049 | 2014 | *2025 | 2038 | 2056 | 2063 | 1765 | 1747 |
| Fan Speed | RPM | 1543 | 1542 | 1544 | *1549 | 1609 | 1571 | 1583 | 1362 | 1347 |
| Trailer Heat Gain | Btu/hr | 6200 | 6200 | 7250 | 7050 | 7200 | 7200 | 7250 | 7700 | 7500 |
| Electric Heat Input | Btu/hr | 2650 | 3100 | 3400 | 0 | 2750 | 2750 | 2750 | 450 | 1500 |
| Net Cooling Capacity | Btu/hr | 8850 | 9300 | 10650 | 7050 | 9950 | 9950 | 10000 | 8150 | 9000 |

*Average
1500-2400 hrs.
3/24/56

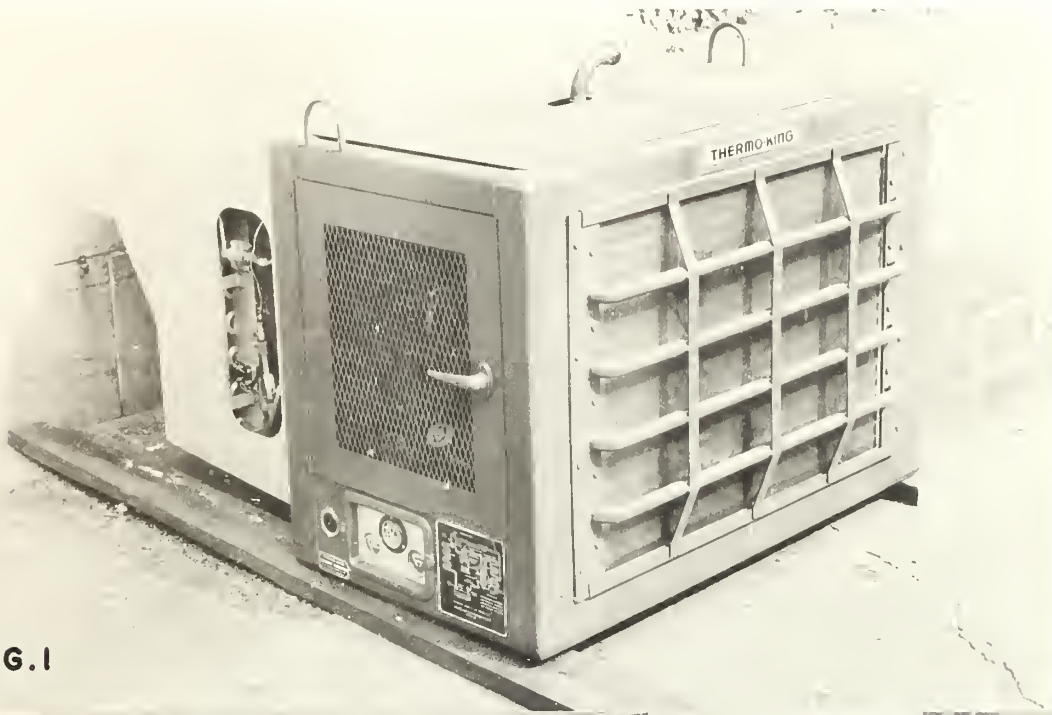


FIG. 1

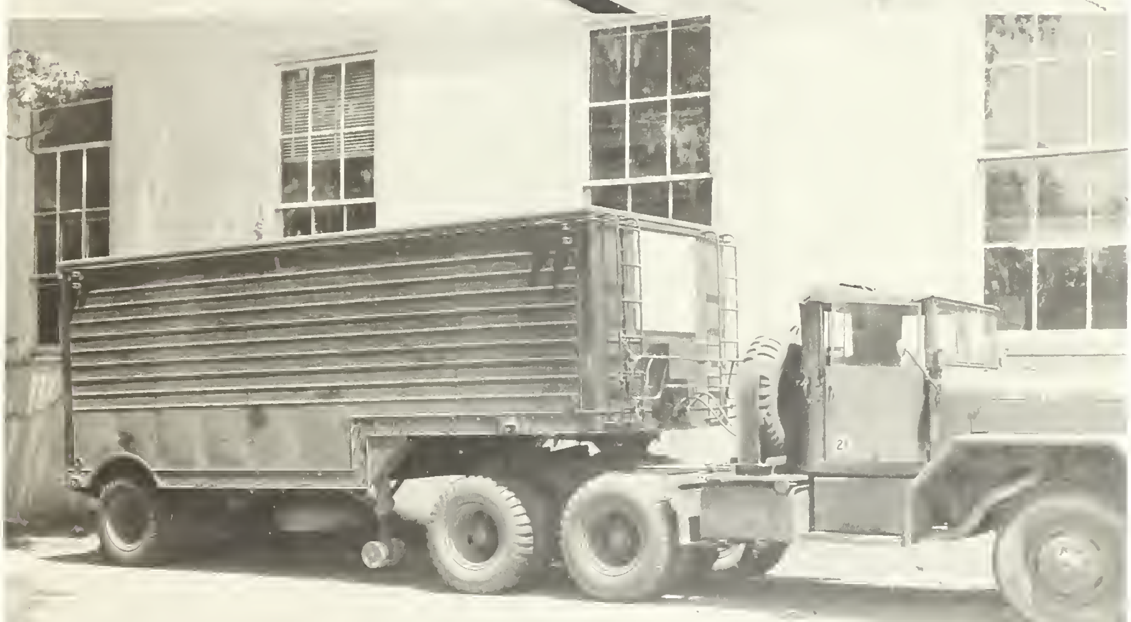

FIG. 2

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Sinclair Weeks, *Secretary*

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

# THE NATIONAL BUREAU OF STANDARDS

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## WASHINGTON, D. C.

**Electricity and Electronics.** Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.
**Optics and Metrology.** Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.
**Heat.** Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.
**Atomic and Radiation Physics.** Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.
**Chemistry.** Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. 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. 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. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.
**Applied Mathematics.** Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.
**Data Processing Systems.** SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog 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. VHF Research.
**Radio Propagation Engineering.** Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.
**Radio Standards.** High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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