Defrosting Characteristics of the Thermo-King One-Ton Warehouse Refrigerating Unit, Model R-51

R&D-1-54(013913)30 Apr 1954

by

C. W. Phillips
and
P. R. Achenbach

Heating and Air Conditioning Section
Building Technology Division

to

Headquarters, Quartermaster, Research
and Development Command
Natick, Mass.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Approved for public release by the
Director of the National Institute of
Standards and Technology (NIST)
on October 9, 2015.
Defrosting Characteristics of the Thermo-King 1-Ton Warehouse Refrigerating Unit, Model 151, with Gasoline and Electric Drives

1. INTRODUCTION

The potential usefulness of full reverse cycle operation of the gasoline engine driven refrigerating units for heating and defrosting was investigated by Headquarters, D, REB, and in this connection the Heating and Air Conditioning Section was requested to make a study of the defrosting characteristics of the 1-ton unit, being manufactured by U. S. Thermo Control Company at that time, and identified as Thermo King Model 151. A development contract for an improved defrosting system had been awarded by Headquarters, D, REB and it was desired to know the details of the present system to permit an evaluation of any modification.

Accordingly, tests of the defrosting characteristics of this unit were conducted, and have been completed. Conditions studied were:

a. With automatic control of defrosting cycle.

b. With manual control of defrosting cycle.

c. At 35°F refrigerator temperature.

d. At 0°F refrigerator temperature.

After investigating the variables listed above with the unit refrigerating an empty 600 cubic foot warehouse, other tests were made with the warehouse loaded with "O" rations to simulate a refrigerator in service, and tests were also run of the defrosting performance of this unit with the electric motor conversion drive apparatus.

2. TEST PROCEDURE

The tests with the empty warehouse were considered as the first phase. The heat transmission factor of the demountable prefabricated warehouse was determined by operating at a constant internal temperature for several days, and using the average outdoor temperature for the period involved. This method, while not as precise as similar tests conducted in a controlled temperature room, was considered sufficiently accurate for the purposes of these tests. In order to avoid the
direct effect of solar gains on the warehouse, it was shielded
with canvas mounted a foot or more about the roof.

The unit was installed in the normal panel provided at
one end of the warehouse. Measurements of ambient temperature,
refrigerator temperature, temperature of the stored product,
and many temperatures, pressures, etc., pertaining to the
operation of the refrigerating unit itself were observed dur-
ing the tests. Not all of the data recorded in these tests
are reported here but if additional information is desired it
can be summarized on request.

The Model K-51 Thermo-King unit was provided with a tim-
ing device, operated from the engine crankshaft, which at con-
stant speed of 2400 rpm provided an automatic defrosting approxi-
mately every 4-1/2 hours. The length of the defrost cycle was
controlled by a limit thermostat which restored the unit to
refrigerating service. It should be noted that the Model K-51
was not a reverse cycle unit in that it did not refrigerate
the condenser during the heating operation. The hot discharge
gas was introduced into the evaporator and the heating was
limited to the work performed on the gas by the compressor, with
the refrigerant condensing in the evaporator. All tests were
made with the refrigerator temperature at approximately 0°F
and a relative humidity of 60%. During extended operation at
0°F, some difficulty was experienced with the humidifier freez-
ing up, but this did not occur as frequently as to disturb the
results significantly. During the tests that were terminated
when a temperature of 0°F could no longer be maintained because
of the frost accumulated on the evaporator coil, the refrigerator
temperature would sometimes rise above 0°F before the defrost
operations were begun.

During the tests with the refrigerator loaded, the com-
pressor (Thermo-King Model 4-R) failed and was replaced with
another of the same model borrowed from another K-51 unit on
hand. Tests of the unit with the electric conversion drive
apparatus were made with this second compressor and no compari-
on tests were made to determine the relative capacity of the
two compressors.

3. TEST RESULTS

At 35°F refrigerator temperature, in the first phase of
the tests, i.e., with the empty warehouse, the defrost cycles
occurred at intervals of approximately 4-1/2 hours, under
automatic control, lasted from 14 to 16 minutes and the amount
of water obtained from each defrost was between 1/4 and 36 pounds.

The refrigerator temperature rose on the average from 35°F to 59°F during the defrost period. The rise in refrigerator temperature should be considered in the light of the manner of testing. To load the refrigerating unit to full capacity, internal heat was applied electrically with the largest amount supplied in the case of the tests under automatic control of defrosting. Then the refrigerator temperature rose above the control points, in this case 35°F, the controller turned off the principal internal heater. The rise in refrigerator temperature was then caused by other internal heaters (fans, humidifier, etc.), heat gain through the walls, and heat given off by the evaporator unit. In the case of the tests when the defrosting was under manual control, all of the internal heat was off during the defrost, and the rise in refrigerator temperature was due to heat gain through the walls and heat given off by the evaporator unit only. In both cases defrost tests were conducted at different ambient temperatures and this, of course, affected the amount of heat entering through the warehouse walls during the various defrost tests. The warehouse used for these tests had a heat transmission factor of approximately 56 Btu/hr/°F, so that in varying ambient temperatures, the heat gain through the walls might range from 2440 Btu/hr at a 40 degree F difference to 5040 Btu/hr at a 90 degree F difference. Since similar conditions would occur in service and it was not thought that these variations reduced the value of the test observations but must be considered in evaluating the results.

Under manual control at 35°F refrigerator temperature the time required for the coil to accumulate sufficient frost or ice to reduce the refrigerating capacity to approximately 65% of the rating was 36 hours, and the amount of water obtained from this defrost was nearly 49 pounds for the same refrigerator temperature. Fifty minutes were required to defrost and the warehouse temperature rose to 40°F during defrost.

At 0°F refrigerator temperature, the frequency of defrost cycles under automatic control was once every 4-1/2 hours, the defrost period varied from 14 to 17 minutes, and the water obtained from the defrost ranged from 2 to 2-3/4 pounds. The refrigerator air temperature rose from 0°F to 35°F during defrosting. Under manual control at the same refrigerator temperature, the time required to accumulate enough ice to reduce the capacity to approximately 7200 Btu/hr was in excess of 15 hours, and the amount of water obtained during defrost was 23-3/4 pounds. The refrigerator temperature rose to 50°F during
the defrost period, which lasted about 38 minutes. Under manual control, the refrigeration cycle was started after defrost by the same temperature-limit thermostat on the evaporator coil as used under automatic control.

Under the second phase, with the warehouse loaded, tests were made with the unit operated both with the gasoline engine drive and with the electric motor conversion drive. To simulate a product load the warehouse was loaded with 154 cartons of Army "C" Rations, the cases being 1.1 cubic feet in volume and weighing 39 pounds. These cases were arranged in four columns two cases wide, two cases deep and stacked approximately 9 cases high, with ventilating aisles or spaces between columns. Thermocouples were placed at numerous points in and on these columns; on the exterior carton surfaces facing the corners of the refrigerator; between two cartons and about 3" in from the outside of the column (referred to as "inside surface") and in the center of the mating surfaces between two cartons; (referred to as "center"). The temperature observations of the carton surfaces reported were all made from thermocouples mounted approximately midway from floor to ceiling.

The primary purpose of repeating these defrosting tests with the loaded warehouse was to determine the effect on general storage temperature when there was produce in the warehouse that would absorb heat as compared with our previous tests with the empty warehouse. Tests were made only at 0°F refrigerator temperature.

The test with the gasoline engine drive was terminated sooner than desired because of failure of the compressor. This failure did not prevent the compressor from handling refrigerant, but it would not retain sufficient oil for adequate lubrication. Frost was accumulated for five days, at refrigerator conditions of approximately 0°F and 60% r.h., with varying ambient temperatures from 46 to 52°F. The defrost required 50 minutes, the amount of water obtained was 37-1/2 pounds, and the average refrigerator air temperature rose from approximately 0°F to 20°F. The temperatures of the cases of rations rose as follows: outside surfaces, 16 degrees (from 6 to 22°F); inside surfaces, 6 degrees (from 4 to 8°F); and center, none (stayed at 4°F).
Following this test the compressor was removed and another installed. The replacement compressor was borrowed from another 6-51 on hand, and had been operated during tests of that unit. It retained its oil charge and trapped out the additional oil which had been added to keep the defective compressor operating. The unit was then placed in the test calorimeter in the controlled-temperature test room and comparative capacity tests were made with the gasoline engine drive versus the electric motor conversion drive. These tests were made with a refrigerator temperature of 0°F and in an ambient temperature of 110°F. Under these conditions the net refrigerating capacity with the gasoline drive was approximately 9760 Btu/hr and with the electric motor drive was approximately 5970 Btu/hr. The results of these comparison tests will be covered in more detail in another report, but are significant in connection with the defrosting tests in that one such test was made with the electric motor drive. It should be noted that the operating speed of the compressor was different for the two methods of drive, 2450 rpm with the gasoline engine and 1750 rpm with the electric motor. The fans, both evaporator and condenser, were operated at the same speed for the two cases, however, by means of suitable pulley sizes.

After placing the unit back in the loaded warehouse, a defrosting test was made with the electric motor drive. Frost was accumulated for about 35 days, when the unit was unable to hold the refrigerator temperature below 12°F in an ambient temperature of 75°F, corresponding to a refrigerating capacity of approximately 3500 Btu/hr. The defrost required 1 hour 30 minutes and the water obtained was 69 pounds. The refrigerator air temperature rose from 12°F to 32°F, and the stored produce rose in temperature as follows: outside surfaces, 10 degrees (from 12 to 32°F); inside surfaces, 7 degrees (from 10 to 17°F); and the center, none (stayed at 10°F). The temperature rise of the individual packages of "C" ration was undoubtedly less than that of the exterior surfaces of the cartons because of the insulating value of the cardboard carton.

No tests were made in the loaded refrigerator with the automatic defrosting control since it was clear that the internal temperature rise with the loaded refrigerator was materially less than with the empty warehouse, and suitable comparison data had already been obtained with the empty warehouse under manual control.
The rise in internal refrigerator temperature means that additional work can profitably be done in regard to improving the defrost rate and at the same time contain the defrosting heat within the unit. Separate investigations of the full reverse cycle operation of the unit are currently being made and will be reported separately. These developments can well be expected to improve defrosting operation of portable refrigerating equipment of this general type.