ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 1-20
430.3 GNOML

18 February 1944

1. PROJECT: No. 1 - Cold Weather Operations. Second partial report on: Sub-Project No. 1-20, Heat Retaining Capacities of Insulated Jugs.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose - To determine the heat-retaining capacity of an insulated food container constructed with Santocel, a new insulating material, instead of the cork employed in the containers previously tested.

2. DISCUSSION:

According to continued reports from combat areas there is need for special facilities for furnishing front line troops and casualties with hot food, since, in many cases, kitchen units have not been able to catch up with advance troops until late at night, if at all. This need applied especially to winter operations but exists also when only moderately low temperatures are encountered. The most feasible method for motorized troops is to carry the hot food with them in insulated containers. Vacuum jugs, while extremely effective, are too fragile for practical use. Other means of insulation are available, however, which will provide sturdy containers for the purpose. An 18-quart jug ~~similar to one previously~~ described and ~~recommended* but~~ with a new improved insulating material has been made available for test. The results of tests on this jug are to be found in the Appendix.

3. CONCLUSIONS:

a. Insulated jugs are effective in keeping food hot and provide an adequate means for the transportation of foods to front line areas.

b. The cooling rate of water in the subject container was found to be approximately 1.36 Btu/^{o}F/hr. At this rate, even under extreme environmental conditions (-40^{o}F and 12 mph), the "Santocel" insulated jug will keep food hot for periods up to eight (8) hours and warm for longer periods.

c. The shape and size of the subject food container are not suitable for use in armored vehicles and an improved design is suggested.

* See AMRL Report, Project No. 1-20 "Study of the Heat Retaining Capacities of Insulated Jugs," dated December 9, 1942.

4. RECOMMENDATIONS:

a. That food containers with "Santocel" insulation and improved design be subjected to field tests.

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3 Incls.
Incl. #1 - Appendix.
Incl. #2 - Tables 1 & 2.
Incl. #3 - Figures 1 & 2.

APPENDIX

The heat-retaining capacity of an 18.2 quart hot food container of improved construction from the standpoint of heat insulation* was measured under various combinations of environmental temperature and air movement. Before each test the container was pre-heated with boiling water for one half hour, at the end of which time the water was poured out and the container refilled to capacity with hot water for the test. The drop in temperature of the water was then determined over periods of from seven to twelve hours, the temperature being measured by means of three thermocouples placed respectively near the bottom, center and top of the jug. Air and floor temperatures in the immediate vicinity of the food container were also determined at intervals. Floor temperatures required some time before reaching equilibrium with air temperatures (See Table II). In certain experiments immediately after temperature readings were obtained the jug was shaken thoroughly and another set of measurements taken. No appreciable differences in temperature were observed.

In Table I and II are summarized the pertinent data obtained from observations made with environmental temperatures ranging from +92°F to -40°F, and with different degrees of air movement. In one pair of experiments, at an environmental temperature of approximately 90°, the rate of heat loss with the jug exposed to solar radiation was compared with the rate in the absence of sunshine.

Theoretical

For a given environmental condition, the rate of heat loss from an insulated food container varies with the resistance to heat flow through the insulated wall and with the heat capacity of the contents. The drop in temperature with time may be expressed by the exponential equation:-

$$T = T_o e^{-\frac{\Delta H}{WS} \cdot t}$$

Where:

T = temperature of contents above environmental temperature at anytime, t.

T_o = initial temperature of contents above environmental temperature.

t = time of observation in hours from initial observation.

ΔH = overall rate of heat flow through food container, Btu/°F/hr.

W = weight of contents in pounds.

S = specific heat of contents.

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* Employing "Santocel" insulation; manufactured by Landers, Frary & Clark.

Incl. #1

This equation plots as a straight line on semi-logarithmic paper and when the ratio, T/T_0, is plotted against time, the observations become independent of the initial temperature of the contents, and of the environmental temperature. Hence for a given jug, with constant ΔH, all observations should fall on a single straight line, the slope of which is a function of the insulating value of the container and of the heat capacity of the contents, as indicated in the equation above.

The temperature measurements obtained during several tests plotted as straight lines on semi-logarithmic paper as shown for two tests in Figure I. The rates of cooling per unit temperature difference, obtained from these lines were not constant, as shown in Table I, but did not, however, vary systematically with wind velocity or environmental temperature. The influence of floor temperature is much more important, Table II. The partial elimination of an avenue of heat loss by having floor temperatures higher than air temperatures results in a false impression of the insulative efficiency of the container. Experiments in which the jug was raised four inches off the floor so that temperatures were identical on all sides of the jug gave duplicate results on close agreement with the average of our series.

It is interesting to note that the rate of heat loss was not significantly changed at a given environmental temperature by increasing the wind velocity. This is a reflection of the high quality of insulation provided in the container. The overall resistance to heat flow from the inside of the jug to the surrounding atmosphere is a function of both the thermal resistance of the wall and of the surrounding air film, as indicated by the following equation:-

$$\Delta H = Ak. \frac{1}{\frac{1}{C} + \frac{1}{f}}$$

Where:

A = surface area of container, sq. ft.

C = thermal conductance of wall, Btu/$^{\circ}$F/sq.ft./hr.

f = surface air film conductance, Btu/$^{\circ}$F/sq.ft./hr.

k = constant

The value of f varies from 1.65 for still air to 6.0 for moving air at 15 mph, approximately a fourfold increase. The value of C is, for the subject food container, approximately 0.3. Entering this value of C and the two values of f in the equation results in the following values for ΔH:-

Still Air, $\Delta H = 0.256 \times Ak$

Moving Air, 15 mph, $\Delta H = 0.285 \times Ak$

Thus, the effect of increasing the air movement to 15 mph is to increase the rate of cooling over the rate in still air approximately 7 percent. This change could not be detected by the methods of measurement employed in these tests.

The average cooling rate for the subject food container was 1.36 Btu/°F/hr. At this rate it is capable of keeping foods above the minimum desired temperature for periods of eight hours or more under extreme conditions of outside temperature and wind velocity. For example, with an outside temperature of -40°F and 12 mph wind velocity and an initial temperature of the contents of the container of 190°F, the temperature at the end of seven hours will be 138°F, which is the maximum desirable temperature for coffee. The temperature will not drop below 120°F until approximately 12 hours. In Fig. 2, the rate of cooling of the insulated container's contents has been plotted for three environmental temperatures. It may be concluded from the tests that the heat-retaining capacity of this food container meets the practical requirements for field use by the Armored Command. The shape and overall design of the container, however, are not entirely acceptable. A food container which will be more suitable from the standpoint of conserving space and for general utility in armored vehicles have been developed by the Armored Medical Research Laboratory and the plans are available for consultation and use by interested parties. An important feature of the new design is that multiple containers are included which will permit separation of rations for five men. The design of the cover has also been improved to insure greater efficiency of insulation.

<u>APPENDIX</u>

TABLE I

Summary of Tests on Heat-Retaining Capacity

"Santocel" Insulated Food Container (18.2 Qt)

TEST CONDITIONS		TEMP. OF CONTENTS		ΔH Btu/°F/hr.
Air Temp. °F	Wind Velocity	Initial °F	After 10 hrs. °F	
+92 Sunshine	Irregular	178	158.0	1.060
+90 Cloudy	Irregular	194	160.5	1.568
+81 Laboratory	None	200	161.5	1.568
+71 Laboratory	None	192.5	158.0	1.356
+34	None	188	147	1.236
- 7	12 mph 1/12 of time	195	137	1.380
- 8	12 mph 1/12 of time	195	131	1.548
- 9	None	171	124	1.244
-18	12 mph Continuously	212	143	1.428
-23	12 mph 1/3 time	191	125	1.496
-29	12 mph Intermittent	202	149	1.060
-42	12 mph Continuously	199	130	1.356
Average				1.360

Incl. #2

TABLE II

Summary of Tests on Heat-Retaining Capacity
of
"Santocel" Insulated Food Container (18.2 Qt.)

TEST CONDITIONS				TEMP. OF CONTENTS		Δ H Btu/°F/hr.
Day of Test	Air Temp. °F	Δ °F (Air-Floor)	Wind Velocity	Initial °F	After 10 Hrs. °F	
1	- 8	21	12 mph Intermittent	194	138	1.220
2	-14	1	12 mph Intermittent	194	133	1.375
3	-14	2	12 mph Intermittent	194	132	1.400
5	-18	9	12 mph Intermittent	194	133	1.272
6	-18	0	12 mph Continuous	194	130	1.403
8	-19	0	5 mph Continuous	192	131	1.435
9	-16	0	12 mph Continuous	189	128	1.315

FIG. 1

COOLING RATE OF INSULATED FOOD CONTAINER
TYPICAL TEST RESULTS

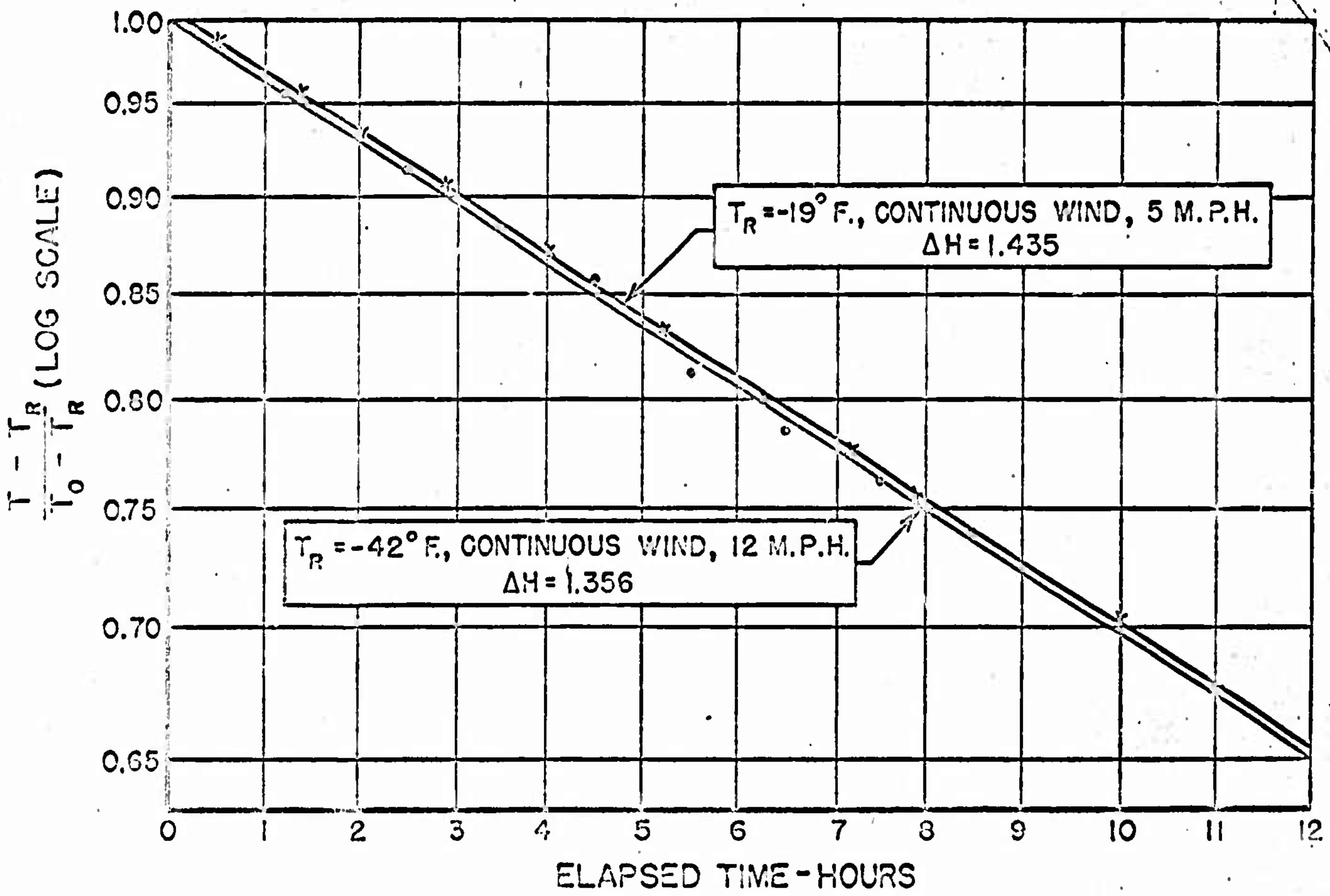

FIG. 2

RATE OF COOLING OF CONTENTS OF JUG
AT DIFFERENT AIR TEMPERATURES
(INITIAL TEMPERATURE OF CONTENTS 190° F)