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DEVELOPMENT OF A CONCEPT FOR A FIELD KITCHEN RECONSTITUTION SYSTEM

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Snell (Foster D.), Incorporated

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DEVELOPMENT OF A CONCEPT FOR A FIELD KITCHEN RECONSTITUTION SYSTEM

FINAL REPORT

By

Design and Development Division Of
Foster D. Snell, Inc.
8801 East Pleasant Valley Road
Cleveland, Ohio 44131

Contract No. DAAG17-73-C-0290

May 1974

UNITED STATES ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

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ABSTRACT

This project to develop a concept of a Field Kitchen Reconstitution System was authorized as part of a broad study of the field feeding practices of the U. S. Army and the Marine Corps. As an objective, the field practices study has the improvement of any and all aspects of field feeding. One aspect is the consideration of the many food preservation alternatives. This concept development project is directed toward one of the preservation alternatives; precooked frozen food.

During the concept development project, many commercial and institutional methods for reconstituting frozen foods were investigated. Methods currently in use as well as some still in the planning stage were investigated. Over thirty in-depth structured interviews were held with equipment manufacturers, food processors, institutional and commercial kitchen operators, and food development laboratories. The information obtained was analyzed and evaluated on the basis of the specific requirements of the field kitchen and its environment. Consideration was given to many aspects of the field kitchen operation, including package materials and configuration, the problems of supply and storage, kitchen mobility, reliability and durability, as well as the speed of reconstitution and food quality.

In all, twenty reconstitution system concepts were developed largely based upon or adapted from existing methods of reconstitution. Using weighted judgment criteria, developed jointly with NLABS personnel, the concepts were objectively evaluated by the contractor. The concept which emerged as meeting the field kitchen requirements best and which is recommended is a different approach than that found in commercial and institutional kitchens. The recommended concept consists of two elements which are:

- A special, multipurpose shipping case in which the frozen food is packed and sealed, shipped to the field, stored for up to five days, and heated to serving temperature. The case is also used to return the waste material to a rear area.

- A highly portable, diesel fired heating unit to which the cases are attached for food reconstitution. Air, at a temperature of 200° to 230°F is passed through the cases at a velocity of 40 to 50 feet per second to heat the food. The feasibility of this approach was demonstrated in the laboratory.

In addition to documenting the work done on the project, this report also contains recommendations for the next program steps.

I. BACKGROUND

I. BACKGROUND

The Operations Research and Systems Analysis Office of the U.S. Army Natick Laboratories is conducting a study of U.S. Army and Marine Corps field feeding practices. This is a broad study directed toward improving any or all aspects of field feeding of combat troops. Some of the goals are reduction in operating cost, fewer food service personnel, reduced subsistence supply weight and volume, water consumption, waste, etc. Many methods are being examined to achieve these goals.

One approach which has already been taken is the development of improved field kitchens to cook food using raw and canned ingredients. Some reductions in labor and improved food quality have been achieved with these improved cooking facilities. Nevertheless, the food quality is still dependent upon the skill and attitude of the cook working in a difficult environment.

An alternate to cooking raw food in the field is to use precooked foods. With this approach, the food is prepared and then preserved so that minimal field kitchen labor and facilities are needed to reconstitute the food for serving. ORSA is considering several methods of preservation, such as freezing, thermal processing, irradiation, and dehydration. This program, which deals with the use of frozen precooked foods, was authorized by the Army as a part of the ORSA study.

Experiments with garrison feeding have shown that the use of frozen precooked food can provide the desired quality with a reduction in the labor required at the serving site. Commercial and institutional feeding systems are also using precooked frozen foods successfully. One of the goals of this program is to identify and evaluate the technology developed in these situations in the context of a field feeding system. Specifically, this program is directed toward developing a design concept of a system to reconstitute precooked frozen food in the field and cook raw food in an emergency.

II. PROGRAM OBJECTIVE AND SCOPE

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The objective of this program is to produce a design concept for a system that will reconstitute (reheat) food which has already been cooked and then frozen, from the frozen state (0°F) to serving temperature (165°F).

The system shall be able to reconstitute enough individual portions, preplated meals, or bulk food from 0°F to 165°F in less than one hour to feed 200 men, and be capable of cooking raw food in emergencies. Typical quantities and varieties of food shall be based on Department of the Army Supply Bulletin SB10-261 "28 Day Master Menu" dated August 1969. Further the system shall be designed to:

- Achieve consistent food quality. The best combination of currently used heating methods or newly conceived devices may be used.
- Be compact and lightweight to allow for storage and transportation to and in the field by existing military equipment.
- Require minimum maintenance.
- Avoid safety hazards other than those normally associated with such equipment.
- Maximize the use of components with a previous history of high reliability.
- Take into account human engineering factors such as equipment layout, location and ease of operation of controls, and work flow.
- Be operated by one person who shall need no training or instruction other than that contained in a typical instruction manual issued for the equipment. All operations, from the removal of the frozen food from its storage container, to the transfer of the heated food to the serving area, are considered reconstitution system operations.

- Be sufficiently durable to withstand representative field operating conditions.
- Operate on existing Army field energy sources.
- Use disposable or recyclable food containers compatible with the equipment.

Subsystems to be considered in the selection of the best overall design concept shall include the following:

- The size of food containers in which to reconstitute the food, e.g., commercial (1/2 size steam table pans) size containers of individual food items, "TV" tray type containers holding all frozen components of a meal, or single serving containers holding a single portion of one food item.
- The method of serving the food, i.e., time and personnel required to serve, if food will be eaten from the reconstitution container or a different container.
- The method of disposing of food containers at the field kitchen site.
- The optimum thickness of frozen food components, to result in the highest quality level attainable.
- The specific energy source for the system.
- The specific transportation mode for the system.
- Any ancillary equipment required for better system performance, e.g., refrigerator or insulated storage space, food holding equipment.
- The logistical system, i.e., the amount of food to be handled by the reconstitution system, e.g., one day's supply or one meal's supply.

III. METHODOLOGY

III. METHODOLOGY

An extensive field survey of the current state-of-the-art of reconstitution was undertaken. Structured interviews were held with representative equipment manufacturers, frozen food processors, and operators of large commercial and institutional feeding operations. Natick Labs personnel working in the equipment, packaging, and food areas were also interviewed. The generous contribution of time and effort of all those interviewees listed in Appendix H provided the firm foundation of this study.

A decision matrix was developed to allow systematic evaluation of the relative advantages, disadvantages, versatility, and suitability of concepts in the field kitchen situation. All of the requirements and goals for the reconstitution system were used to formulate evaluation criteria. A judgment was made of the relative importance of these criteria by considering the field kitchen situation and the interaction of the reconstitution system with subsystems. Based on this judgment, numerical rating ranges were established for each of the criteria.

Reconstitution system concepts were developed based on currently available equipment. In addition, new methods based upon the application of heat transfer and food heating fundamentals were conceived. Using analysis, laboratory testing, and the findings of the field survey, it was determined how well each of the concepts met each of the criteria and a corresponding numerical rating was assigned. The total of the numerical ratings for each of the concepts were compared to objectively select the best field reconstitution system design concept.

IV. THE RECOMMENDED SYSTEM

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The recommended reconstitution system concept utilizes a multipurpose insulated shipping case and a special convection heating unit in a unique way to fulfill the field kitchen requirements for frozen food reconstitution better than any other approach. The principal components are:

- An insulated case which is packed at the ration breakdown point, used to store and ship the food, and in which the food is heated to serving temperature. The case is also used to return the waste to a central disposal point.

- A special diesel fuel fired heating unit to which the cases are connected to reconstitute the frozen food. The heating unit forces air heated to 200° to 230°F through the case and around the food packages at velocities of 40 to 50 feet per second.

The advantages of this concept are as follows:

- The low temperature food heating process will heat all foods to the serving temperature without overheating the more delicate foods. This also makes it unlikely for operator error to make the food inedible. One temperature heats all foods.

- Low temperature heating also allows the use of lower lower temperature plastics for disposable food containers which could be more aesthetically pleasing and less costly than aluminum foil.

- The insulated case approach provides several advantages:

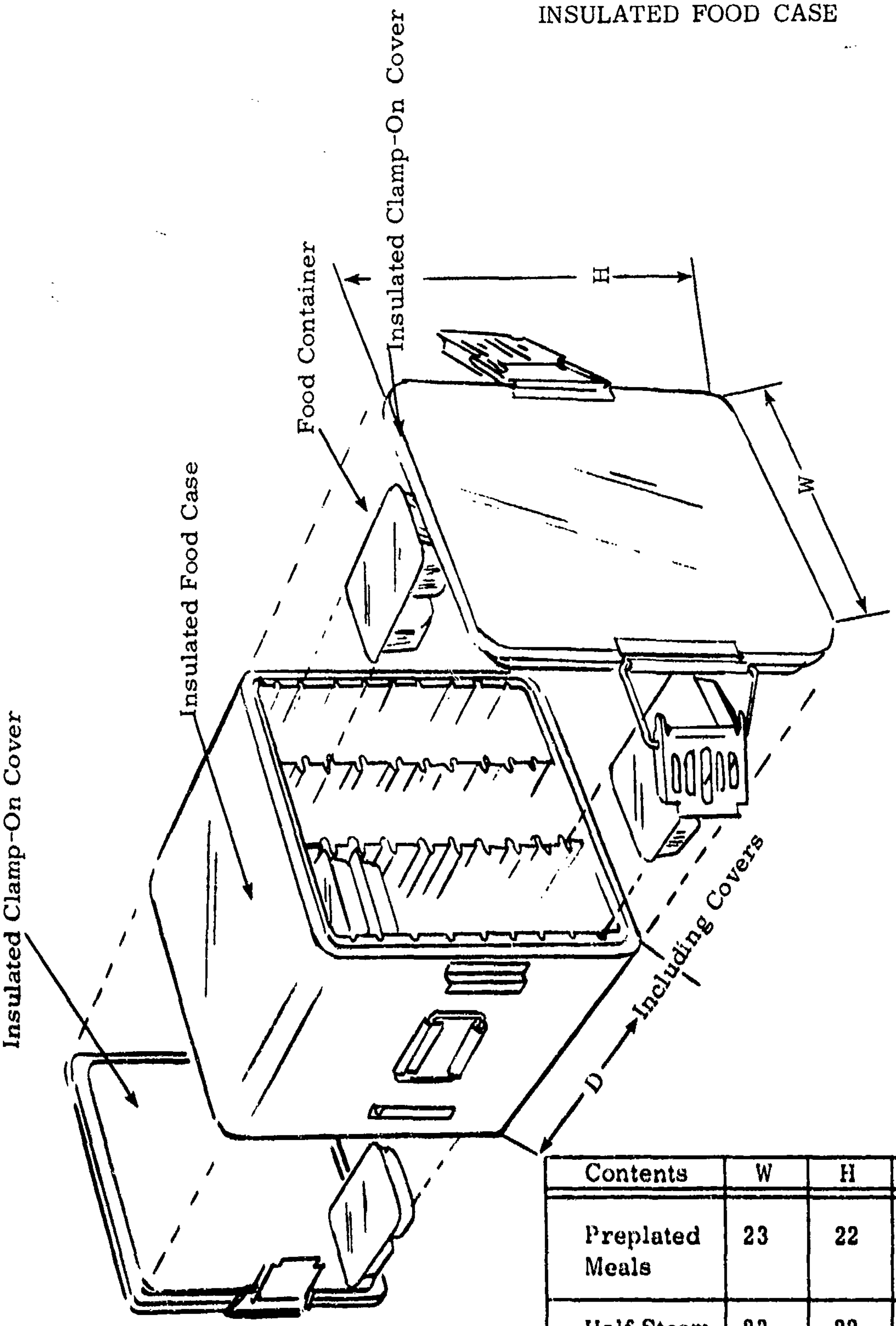
  - Minimum labor is required because the food is always handled in the standardized insulated cases.
  - The weight and volume of the heating system are reduced because the food heating compartment (the insulated case) is separate except when the system is heating food.
  - The need for an insulated truck body on the transport vehicle and a mechanically refrigerated storage unit at the field kitchen are eliminated.
- The use of the Bare Base diesel fuel fired burner reduces the quantity of fuel expended and the size of the diesel electric generator required.
- Operating flexibility is another major advantage. For example;
  - The heating units could be truck mounted and the food could be heated en route to an isolated group of men.
  - Preplated, and bulk packaged food as well as food in simple serving containers, can be heated with the same heating units.
- The insulated food cases could be closed after the food is heated and carried to an isolated group of men.
- The small insulated food cases allow supply by many different transport means.

The insulated food case is shown in Exhibit IV-1. The case would hold 54 hot or cold packs for dinner or supper, or 108 of the breakfast hot packs. A similar type of case would be used to hold trays of toast and juice. Assuming the case and its covers to be constructed of a .020" thick steel outer skin and a .060" thick polysulfone inner skin with 2" thick polyurethane insulation, foamed in place between them, the empty weight of the case would be approximately 30 pounds.

EXHIBIT IV-1

U.S. Army Natick Laboratories

INSULATED FOOD CASE



Contents	W	H	D
Preplated Meals	23	22	21
Half Steam Table Pans	23	22	18.5

The 2" thick insulated walls would allow five days storage of the closed case in a 100°F environment, assuming that the food packages are at 0°F when loaded into the case. Food temperature would be maintained below 40°F throughout the storage period. This allows a three day supply cycle with some margin of safety without the requirement for supplemental refrigeration.

Two heating units used to heat the food in the insulated cases are shown in Exhibit IV-2. One unit is shown with two insulated cases in position for heating. The other unit shows the transport configuration with the hot air bypass cover in place to close the unit. These units are sized to supply hot air at 40 to 50 feet per second. Diesel fuel burners are used to supply the heat energy. The combustion products are vented to the atmosphere and kept separate from the food heating air by sealed heat exchanger walls. An electric motor driven 16" diameter fan which may be reversed periodically, if necessary, to reverse the air flow to improve temperature uniformity of the food is included. Guided flow passages would increase the effectiveness of the air velocity. All air would be forced by the fan to flow through the food packages in one case, through the hot air bypass cover, through the food packages in the other case, and back to the fan, as shown in Exhibit IV-3, following Exhibit IV-2. Heat exchanger area, control system volume, and burner space have been provided in accordance with that used in the Bare Base oven design.

An electric power supply is required for operation of the fan motor and controls. A 5.5 KW diesel electric generator is included in the system. A power pack is also required to supply compressed air and pump the diesel fuel to the burner.

Emergency raw food cooking will require a covered or key locked switch which would activate a high temperature mode of operation. This switch might also reduce the fan speed if tests show it is necessary. Special 3" x 6.5" x 18" covered roasting pans would be carried by the field kitchen for emergency cooking.

Bulk packed food may be heated with the same heating unit using insulated cases similar to those used for prepleated meals. The bulk food cases would have the same air flow cross-section but they would be sized for half size steam table pans. It would be possible to furnish the food in preplated meal packages on some days and bulk packaged food on other days to provide variety and alleviate the monotony which might result from using the same package form over a period of time.

EXHIBIT IV-2
U.S. Army Natick Laboratories
HEATING UNITS
(2 Shown Side By Side)

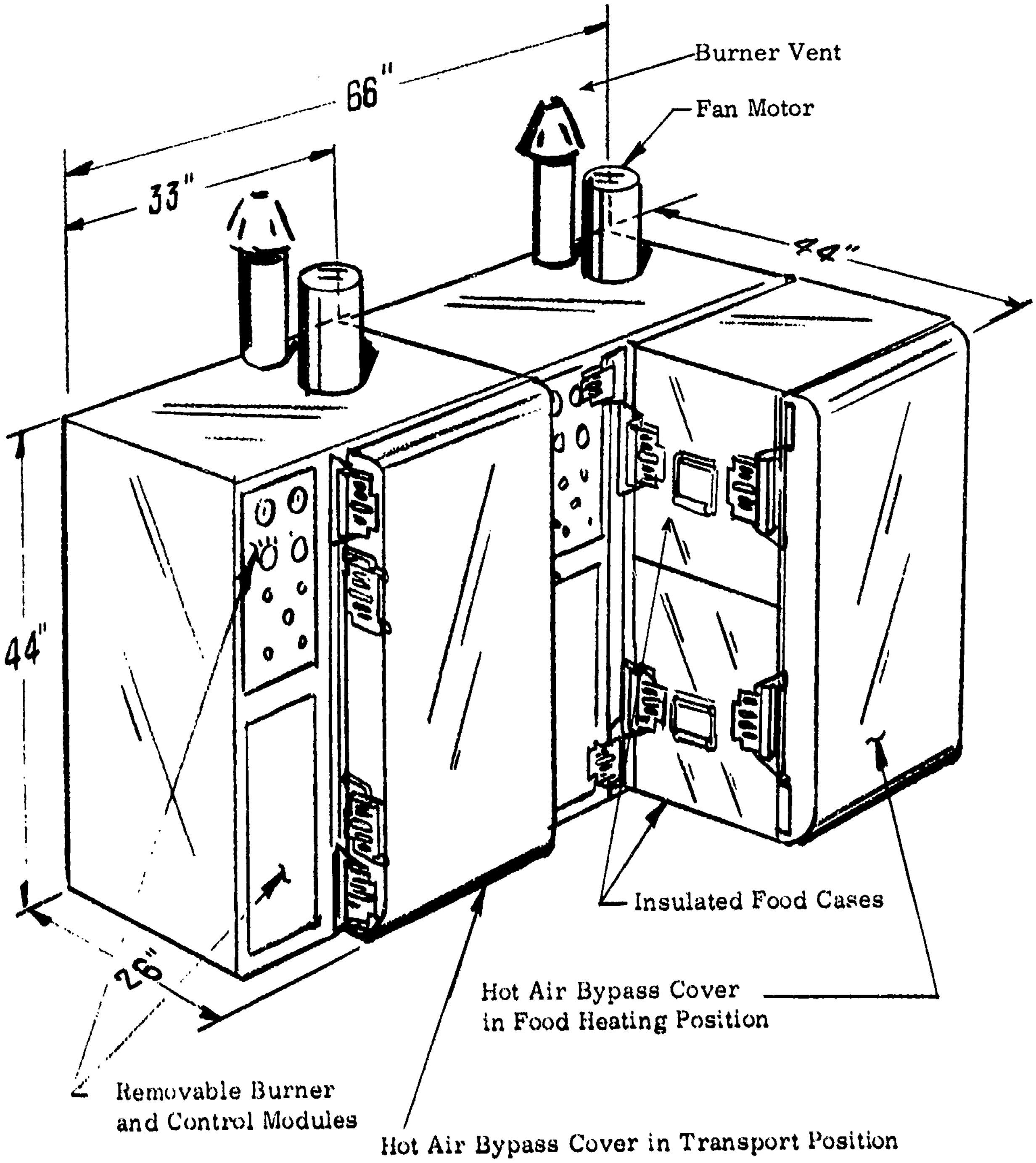
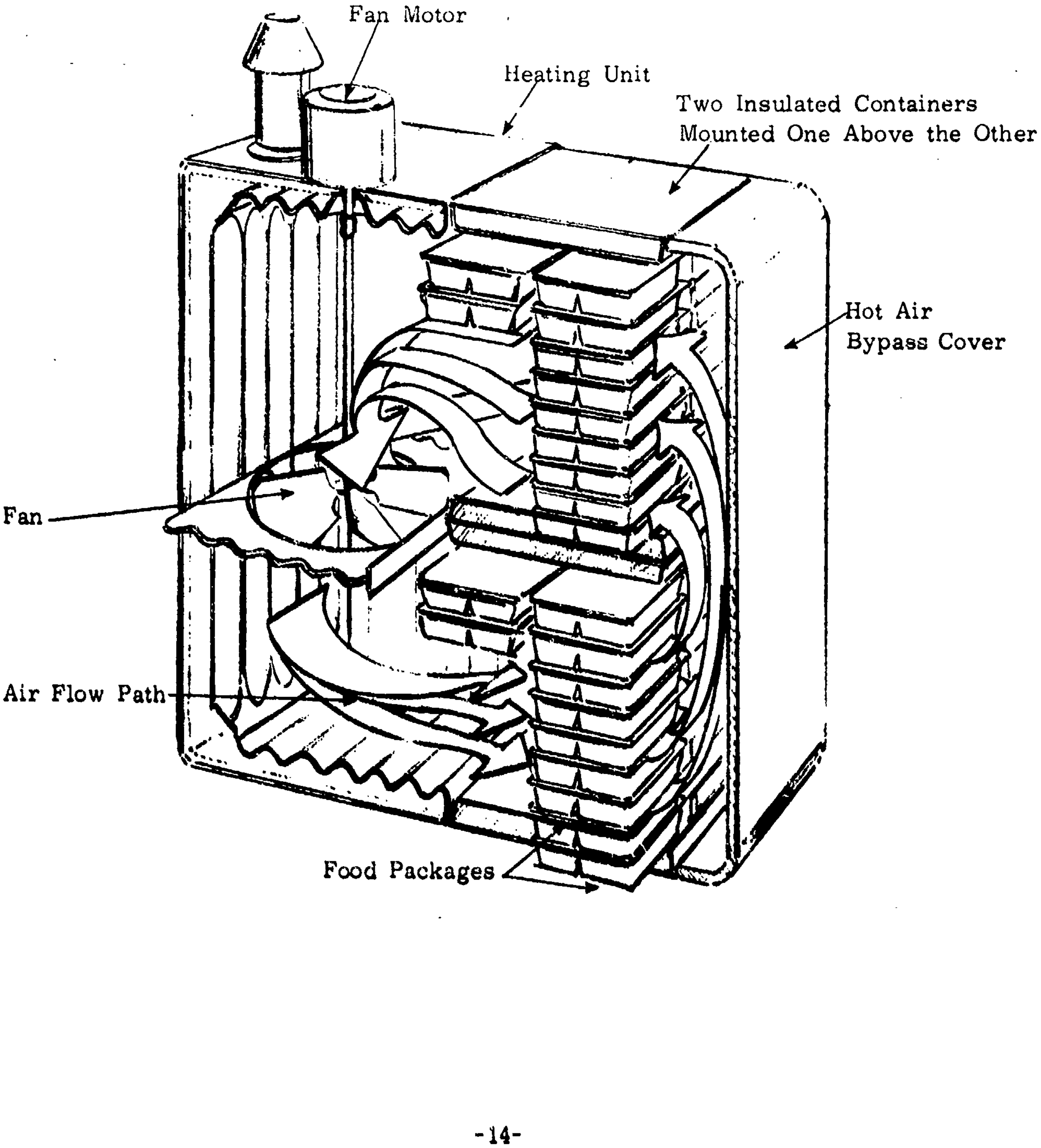


EXHIBIT IV-3
U. S. Army Natick Laboratories
FORCED AIR FLOW PATH



Operation of the field feeding system using this equipment would be as follows:

- The insulated food cases would be loaded with frozen food at a ration breakdown point. This center would have to be located within two days travel of the field kitchen to avoid the need for supplemental refrigeration. The clamp-on case covers would be secured to the cases. The type of meal and date by which the food is to be used would be marked on the case.
- Sixty insulated cases containing a three day supply of food would be transported to the field kitchen in a standard 2.5 ton truck along with the fuel, water, and other expendables. (Other transport modes can be used.)
- At the field kitchen, the insulated food cases could be stored in any convenient locaton as long as they were kept out of the sun. It would also be necessary to use the cases in accordance with the date and meal markings.
- One hour before serving time, four insulated cases would be moved to the field kitchen. After removing the covers from two insulated cases, the cases would be clamped onto a heating unit and the hot air bypass cover installed. The unit would then be started. Fifteen minutes later, the other two insulated cases would be loaded onto the second heating unit and it would be started.
- At serving time, the cases of heated food would be removed from the heating unit to the serving area. The hot packs would be removed from the case by the men being served.
- After eating, the disposable food containers could be disposed of locally or placed back into the cases by the men who have eaten and the covers secured.

- When the supply transport returns with the next supply of food, the cases, either empty or containing refuse, would be loaded onto the truck and taken to a central location for disposal of the refuse, if any, and cleaning. They would then be returned to the ration breakdown point.

This system was selected as the best of twenty different reconstitution system design concepts which were evaluated for field kitchen use. The Army field kitchen has requirements which are quite different from any other kitchen. Thirteen of the twenty concepts were rejected because they did not meet one or more of the field kitchen criteria. Most of these rejected concepts utilized equipment which is being used successfully in commercial or institutional reconstitution operations. The fact that the equipment has been rejected for use in the field kitchen does not imply that they are not suitable for their present use. On the contrary, the equipment rejected for use in the field kitchen might be optimum in a commercial or institutional kitchen.

The recommended reconstitution system concept will require additional development cost over other systems which simply adapt more conventional cooking equipment for use in the field kitchen. However, it is felt that the potential advantages of the recommended system outweigh this disadvantage.

The recommended system was identified as the best reconstitution system by using the decision matrix technique. This systematized comparison of the possible system concepts is based upon weighted criteria developed jointly with NLABS personnel. These criteria define both the mandatory and desirable characteristics which a reconstitution system should have for use as a field kitchen. The relative importance of these criteria was established by weighting the maximum rating which could be applied to each criteria. These criteria are discussed in detail in Appendix C.

Evaluation data relative to each of these criteria were then developed for each concept by the contractor. Except for the recommended concept, the concepts and their evaluation data are presented in Appendix D. The evaluation data for the recommended concept follows this discussion. Using the evaluation data, each concept was rated by the contractor relative to each criterion. The resulting numerical ratings appear in the concept evaluation matrix shown in Exhibit IV-4, on the following page. For example, reliability was considered to be very important and was assigned a maximum possible rating of 16, while packaging flexibility was considered as being less important and was assigned a maximum allowable rating of 3.

EXHIBIT IV-4
U.S. Army Natick Laboratories
CONCEPT EVALUATION MATRIX

CRITERIA	Rating Range	Recommended Concept High Velocity-Low Temp. Insulated Food Cases	Concept 1 - Convection Oven, Electric Preplated Food	Concept 2 - Convection Oven, Electric Bulk Packed Food	Concept 3 - Convection Oven, Diesel Fuel Fired, Preplated Food	Concept 4 - Convection Oven, Diesel Fuel Fired, Bulk Packed Food	Concept 5 - Heating Serving Unit, Preplated Food	Concept 6 - Low Temp. Natural Convection, Preplated Food
EFFECTIVENESS								
1. Percent Of Menu	8	8	8	8	8	8	8	8
2. Food Quality	10	10	3	7	3	7	4	8
3. Throughput	8	8	8	4	8	4	7	6
4. Emer. Cooking	8	7	8	8	8	8	6	5
5. Ease Of Operation	8	8	4	4	4	4	4	6
6. Pkg'g. Flexibility	3	3	1	2	1	2	1	2
7. Safety	8	7	8	7	6	5	8	8
8. Mobility	8	8	5	2	7	4	5	4
9. Reliability	16	15	16	14	14	13	12	13
10. Maintainability	8	8	8	7	8	7	5	6
11. Survivability	3	3	2	2	3	3	2	2
12. Environ. Suit.	4	4	2	2	4	4	2	2
13. Develop. Risk	8	4	8	8	7	7	6	6
TOTAL	100	93	81	75	81	76	70	76
RESOURCE REQUIREMENTS								
1. Manpower	20	20	17	10	17	10	14	12
2. Supply	25	20	25	20	25	20	24	24
3. Develop. Cost	10	4	10	8	8	6	8	10
4. Prod. Cost	25	20	18	15	18	15	16	6
5. Opert'g. Cost	20	15	10	6	14	8	10	5
TOTAL	100	79	80	59	82	59	72	57
TOTAL RATING	200	172	161	134	163	135	142	133

The highest rating was achieved by the recommended concept, indicating that it is the most effective and one of the least costly in terms of resource requirements of the reconstitution systems evaluated. Concept No. 1, Convection Oven, Electric, Preplated Food; and Concept No. 3, Convection Oven, Diesel Fuel Fired, Preplated Food, follow as second choices. The other concepts lag behind in the ratings. In addition, no systems were identified which would be equal to or better than the recommended system in the field kitchen environment, including those still in the laboratory.

The following is a summary of the data and the ratings used in the evaluation of the recommended reconstitution system concept.

EFFECTIVENESS - (Rated 93 Of 100)

(1) Percent Of Menu - (Rated 8 Of 8)

- 100 percent of the frozen precooked 28 Day Master Menu hot items can be reconstituted.

(2) Food Quality - (Rated 10 Of 10)

- All foods will be heated to the proper serving temperature, but not overheated. This is a major advantage of the low temperature - high velocity convection heating concept. As the food approaches the proper temperature, heat flow into the food is reduced because the temperature of the air is not significantly higher than the food temperature.

(3) Throughput - (Rated 8 Of 8)

- No preheat period is required.

- Extensive data is not available to directly determine the total time required to heat the food. Nevertheless, extrapolation of the available test data indicates a total elapsed time of 40 to 60 minutes for 1.5" thick preplated meal packages. The pertinent calculations in this section are based upon 60 minutes.

- There is no limit to the serving rate. All 216 meals could be ready simultaneously if desired.

(4) Emergency Raw Food Cooking - (Rated 7 Of 8)

- 100 percent of the 28 Day Master Menu raw ingredients can be cooked in emergencies.

- All cooked foods will have a baked or roasted quality.

- Items which require special preparation techniques and will not emerge in a traditional form are as follows:

    - Sauces
    - Breading
    - Liver
    - Beef Steaks
    - Pork Slices (chops)
    - Veal Steaks
    - Gravies
    - French Toast
    - Hot Cereal
    - Griddle Cakes

- Opening of the food heating chamber to stir, season or test the food while it is cooking is less convenient than with a normal convection oven. The hot air bypass cover would have to be removed for this purpose or a door could be added to the hot air bypass cover if necessary. A switch to stop the air circulating fan would be required.

(5) Ease Of Operation - (Rated 8 Of 8)

- No temperature adjustment is required. After clamping two insulated cases full of preplated meals to the hot air unit and clamping on the air bypass cover, the operator would simply push the start button. All food heating will be done at a single temperature, such as 225°F.

- The one consequence of operator error could be that the food would not be hot at serving time because the attendant didn't start heating early enough. If the food was heated longer than necessary, there is little likelihood of burning or overcooking the food within reasonable time limits. However, degradation would probably occur if heat was applied for an extended time.

- The reconstitution system operator would be free to perform other field kitchen tasks except for about five minutes at the start of reconstitution and during the time when the insulated case is moved to the serving area.

(6) Packaging Flexibility - (Rated 3 Of 3)

- Preplated meal packages may be processed in the system as shown in Exhibit IV-1. It would also be possible to reconstitute bulk packed food with the same heating unit. A different insulated case with the same open end dimensions would be used. The case would have approximate overall dimensions of 16.5" x 22" x 23" when closed for transport. It would hold 10 half size steam table pans of food. A total of eight insulated cases would be required to hold the food to feed 200 men. Adapter rings would be needed so that four of these cases could be clamped to one heating unit simultaneously. Aisle space would also be required to accommodate a total unit depth of 59" instead of 44" as shown in Exhibit IV-2.

- Any material which can withstand 230°F continuously and is compatible with the food may be used. This would possibly allow the use of low temperature plastic throwaway containers such as styrene, polyethylene, or polypropylene. Molded fiber containers would require coating to reduce their water vapor permeability.

- This system as conceived uses preplated meal packages of the configuration shown in Exhibit B-4. A different method of package support would have to be devised for single serving packages.

- Acceptable food quality should be achievable without package cover manipulation. All food packages are heated with their covers on in school lunch programs. If some food product is found to be significantly improved by uncovered heating, special procedures would have to be instituted. The food container might be uncovered at the time the insulated case is packed for transport if the case interior were humidified with damp sponges or the equivalent during transport and storage.

(7) Safety - (Rated 8 Of 8)

- This equipment can be designed and developed to meet all applicable recognized consensus codes and standards.
- There are no unusual hazards to the operator or repair personnel. The low heating temperature (225°F) reduces the likelihood of severe operator burn during loading and unloading of the food.
- No unusual hazards result from equipment or operator failure.
- No unusual potential for microbiological contamination has been identified.
- This concept requires only a 5.5 KW electric generator, whereas more than 30 KW capacity is required by concepts which use electric heating elements. Nevertheless, there is no significant reduction in electric shock hazard within this range of power reduction.

(8) Mobility - (Rated 8 Of 8)

- Sizes and weights of the reconstitution system and ancillary equipment have been estimated as follows:

	Volume Cu.Ft.	Weight Lbs.
- Two heating units (33"widex26"deepx44"high ea)	44	1100
- One 5.5 KW diesel electric generator*	10	480
- One power pack - electric motor driven fuel pump and compressor for heating units	5	200
- Insulated food containers(60) for three days food supply** (23"widex21"deepx22"high and 30 lbs empty weight ea)	369	1800
Total	428	3580

- The Bare Base diesel fuel burner would be incorporated into the heating unit. This burner was designed for mobile operation, and some field testing has indicated its capabilities.

- A simple rugged design appears to be possible.

- The only configuration change from mobile to operating condition is accomplished by clamping the insulated food case onto the heating unit. This labor is included as reconstitution system operating labor.

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* Diesel electric generator data shown is based upon commercially available self-contained units rated for continuous operation at the power level shown.

** Could be reduced to one or two days food supply under different resupply policies.

(9) Reliability - (Rated 16 Of 16)

- The Bare Base burner design is relatively new and its reliability has not necessarily been established by long experience.

- The following components have been identified as being potential causes of reconstitution system failure.

  - Hot air circulation fan motor
  - Hot air unit control system
  - Burner
  - Transformer
  - Power pack

  After development is completed, a low failure rate is anticipated. All of these components would be contained in easily replaced modules which could be carried as spares.

- The consequence of one hot air unit failing would be that the serving rate would be reduced to about 1.5 meals per minute, or half of the 200 men being served would have to wait about one hour for their food.

- The low temperature heating approach makes it virtually impossible to render the food inedible by burning or overcooking.

- If the diesel electric generator would fail, no hot food could be prepared. However, a spare generator could be carried at a cost of only 10 cubic feet and 480 pounds to the system. Further, many Army field vehicles have small auxiliary power units which may be used to operate the system in emergencies. This concept requires no mechanical refrigeration. The result of other ancillary equipment failure would be insignificant.

(10) Maintainability - (Rated 8 Of 8)

- Oven cleaning would be easy because the low air temperature would not bake on spills badly, and the insulated food case would be sent back to the food distribution center for cleaning and loading.

- The following will require periodic maintenance:

  - Hot air circulation fan motor
  - Burners
  - Fuel filter
  - Power pack

- Minimal skills and standard tools are required for field repairs.

- Diesel electric generator (5.5 KW) maintenance is required.

(11) Survivability - (Rated 2 Of 3)

- A design capable of withstanding combat conditions appears possible.

- 5.5 KW diesel electric generator noise will be a possible cause of enemy detection. Radio interference of the electrical system can be shielded.

- There is some increased hazard to kitchen personnel which might be caused by the presence of diesel fuel in the kitchen in the event of enemy fire. The amount is limited since the fuel tank can be located outside of the kitchen.

(12) Environmental Suitability - (Rated 4 Of 4)

- No problems would be caused by extreme environmental conditions. Startup of the 5.5 KW diesel electric generator in cold weather may require special procedures.

- The heating units will put some heat into the kitchen. This will be about half of that from normal ovens, because the temperature of the heating air would be 225°F.

(13) Development Risk - (Rated 6 Of 8)

- The Bare Base oven project has shown the feasibility of this diesel fuel burner. Laboratory tests have shown that frozen cooked preplated meals can be heated within a reasonable time, using high velocity low temperature air.

- Design and development of the equipment to utilize these new concepts is required. Nevertheless, the fundamentals of hot air food heating are well established and the design appears to be straightforward.

RESOURCE REQUIREMENTS - (Rated 80 Of 100)

(1) Manpower - (Rated 20 Of 20)

- Setup and disassembly of the reconstitution system and ancillary equipment each time the field kitchen is moved should require no more than 1 man-hour.

- The following labor requirements are estimated for operation of the reconstitution system each day:

- Reconstitution system operation	3.5 man-hours
- Cleanup and maintenance of the heating units	1.0 man-hours
- Operation and routine maintenance of 5.5 KW diesel electric generator and power pack	1.0 man-hours
Total	5.5 man-hours

(2) Supply - (Rated 20 Of 25)

- The following quantities of supplies are required for three days of operation.

	Volume Cu.Ft.	Weight Lbs.
- Food in insulated cases	369	4690
- Water for cleanup (three 5 gallon cans for three days)	2.1	155
- Diesel fuel (15 gallons in three 5 gallon cans)	2.1	141
	373	4986

- This concept requires that the empty insulated food cases be taken back to the food distribution center, but these cases are easily removed from the transport to free it for other service.

(3) Development Cost - (Rated 4 Of 10)

- The following development tasks are required.
  - Determine optimum combination of heating air temperature, air velocity, food package material, food package configuration, food package spacing, and food heating time.
  - Design, develop and build insulated food cases.
  - Design, develop and build one heating unit.
- Estimated development cost - $100,000 to $300,000, depending upon how comprehensive the package investigation is and whether the prototype is for laboratory or field use.

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* See Appendix G, Example Calculations.

(4) Production Cost - (Rated 21 Of 25)

.	Estimated cost of heating units (2 req'd.)	$8,000 to $12,000
.	Estimated cost of power pack	600 to 1,000
.	Estimated cost of insulated food cases (60 req'd.)	6,000
.	Estimated cost of pans for emergency cooking	500
.	Typical cost of commercial 5.5 KW diesel electric generator	2,500
		$17,600 to $22,000

- This concept would not require an insulated container as part of the transport truck and that cost could be saved. All other concepts evaluated require that the transport truck have a 75 cubic foot insulated container for food storage when the field kitchen is more than a short distance from the ration breakdown point.

(5) Operating Cost - (Rated 15 Of 15)

.	Labor expended	5.5 man-hours per day
.	Diesel fuel expended	5 gal.per day
.	Potable water expended	5 gal.per day

V. RECOMMENDED NEXT STEPS

V. RECOMMENDED NEXT STEPS

This program has resulted in a new concept for field feeding of the volunteer Army. Compared with all other approaches, the low temperature, high velocity air convection concept has clear advantages, such as:

- The assurance of consistently high food quality because it is nearly impossible to overcook the food.
- The small size and high mobility properties.
- The wide range of food packaging materials which can be used.
- The ability to handle all foods included in the 28 Day Master Menu and to cook raw foods in an emergency.

The concept as presented in this report was developed through engineering calculations substantiated by preliminary laboratory tests on selected frozen food components. We recommend a more extensive test and evaluation program as the immediate next step leading toward a reconstitution system development. Specifically, we recommend the program be continued and suggest the following activities as the principal steps.

- Develop a detailed test program designed to result in:
    - A comprehensive evaluation of the low temperature high velocity air convection concept.
    - Verification of the capability of the insulated case to store frozen foods for five days in a 100°F environment and maintain food temperature below 40°F.
    - The determination of any package design limitations.
- Select a variety of food components representative of the 28 Day Master Menu, cook and freeze them in a number of different package materials.

- Design and build a versatile laboratory heating unit.
- Design and build two versatile laboratory insulated cases.
- Conduct the heating tests.
- Evaluate the reconstituted food for such things as:
  - Appearance, texture and flavor
  - Speed of reconstitution
  - Heating uniformity
- Evaluate packaging materials.
- Repeat and expand tests as needed.
- Develop design parameters for the insulated case and the heating unit for service in the field.

Following the test and evaluation program, we recommend the design, construction, and testing of a field kitchen unit consisting of a heating unit and a limited number of insulated cases.

APPENDIX A

FIELD FOOD SERVICE WITH CONVENIENCE FOODS

APPENDIX A

FIELD FOOD SERVICE WITH CONVENIENCE FOODS

This study has concentrated on the development of a system concept for reconstituting cooked frozen food in the field. Cooked frozen food is one of several convenience food forms; some of the others are dehydrated, thermally processed, and irradiated foods. During this study, no comparison was made between cooked frozen foods and other convenience foods, or between using convenience foods and cooking in the field kitchen. Nevertheless, many distinct advantages to using convenience foods for field food service were identified. Further, consideration of the unique field feeding situation indicates that many of the normal arguments against using convenience foods in fixed environments like a garrison dining hall, may not be valid in the field environment.

1. THE LABOR REQUIRED IN THE FIELD IS REDUCED.

A convenience food is a menu item which is partially or completely cooked and then preserved until a later date when it is brought to serving condition. With this process, the preparation of the recipe including sauces, seasoning, etc., is usually conducted on a large-scale in a central location. The items are then finished for serving in a smaller quantity at the place the food is eaten.

One of the goals of this study is to minimize both the amount of labor and the skill required to man the kitchen in the field. The use of convenience foods simplifies the achievement of this goal. The only field labor required is for bringing the food to serving condition while the preparation labor is incurred at the processing center. This differs appreciably from that encountered in current field feeding in which food service personnel are frequently required to work 14-16 hours a day.

2. CENTRAL FOOD PREPARATION PROVIDES IMPROVED CONTROL OF QUALITY AND REDUCES THE CONTAMINATION HAZARDS.

At best, a field kitchen has limited equipment, cramped quarters, and operates with limited personnel. The environment varies widely with geographic location and with frequent relocations when on maneuvers or under combat conditions.

These conditions would not exist in a central preparation center located in a safe area and serving many individual field kitchens. The center could be well equipped and manned by a trained staff which would result in the following advantages:

- Consistent food quality could be achieved.

- Microbiological contamination hazard would be reduced by improved cleanliness.

- Economies of scale in the food preparation can be expected.

3. CONVENIENCE FOODS REDUCE THE FIELD SUPPLY PROBLEM.

The ingredients required by the 28 Day Master Menu include food in all forms, resulting in a variety of package sizes and shapes and storage requirements. The problem is amplified by the need for five to ten separate ingredients for most of the menu items. By using convenience foods packaged in standardized containers, the supply problem could be reduced. A day's rations for 200 men could be handled in a consistent number of containers. This would allow uniformity in the storage and shipping volume and tend to reduce the chance of errors.

Refrigeration would be required with frozen food. However, refrigeration is currently required for many of the 28 Day Master Menu items to prevent spoilage. Further, the need for refrigeration at the unit kitchen level could be circumvented by using insulated containers.

4. CONVENIENCE FOODS COULD PROVIDE THE SOLDIER WITH A CHOICE OF MENU.

Statistical data developed to establish menu preferences could be used to plan each meal. For example, if the data indicated a comparative distribution of 70 percent preference for pork chops, 20 percent for fried chicken and 10 percent for liver and onions, a meal could be prepared for 200 men in those proportions. Personal preferences for these three choices could then be exercised in the serving line. Of course, large population statistics applied to a given group of 200 men would not be entirely accurate. However, more diners would receive their preferred meal than if only one entree item were served.

Menu choices of this nature can be furnished with little, if any, increase in field labor if convenience foods are used. However, if fresh foods are prepared in the field, much more labor is required to provide menu choices.

5. ADDITIONAL STUDY AND DEVELOPMENT WILL BE REQUIRED BEFORE CONVENIENCE FOODS ARE USED EXTENSIVELY IN FIELD KITCHENS.

Several factors need additional study and development before the assessment of convenience foods in a field kitchen is complete. Some of these factors are:

- Total cost of fresh food field cooking compared with the total cost of convenience food.
- Troop acceptance of convenience food in the field.
- Recipe development for convenience foods.

In the commercial market, convenience foods cost more than fresh foods due to the added costs of packaging and processing. However, the cost differential will probably be reduced and may be eliminated when total costs are considered. Some of these additional cost factors are transportation, storage, and the labor required in the field to cook the raw food or warm the convenience food. These cost comparisons were not made during this study.

The level of acceptance combat troops would have to eating convenience foods in the field has not been measured. Since the field environment is entirely different from that found in a garrison mess hall, many of the findings from garrison feeding studies should probably be tested in the field environment. For example, interviews conducted during this study have indicated the public has a comparatively low preference for "TV" dinners. One frozen food processor stated that this is probably caused by the fact that some food packers have lowered the quality of the foods they pack as "TV" dinners to be more price competitive. Consequently, there apparently are people who associate a meal packaged in the "TV" dinner configuration with a previously experienced poor quality meal. In the field environment, concern about the wholesomeness of the food and the undesirability of the mess kit laundry operation may become important. The covered disposable "TV" dinner assures cleanliness and would eliminate the mess kit laundry. Thus, the "TV" dinner may be more acceptable in the field over other methods of serving. This is only one of many convenience foods acceptance measurements which need to be made in the field environment.

The convenience foods now available commercially tend to be based on recipes which require extensive preparation time. These are more attractive to the buyer because most of the time consuming preparation work is already done. These recipes do not necessarily match the taste preferences of the field soldier. He may want plain meat and potatoes and work is required to develop simple convenience food recipes of this type. Consequently, recipe development will probably have to be done.

Other factors for consideration are:

- Responsiveness of the ration breakout point to the preferences of the troops.
- Procurement specifications required to assure the receipt of convenience foods prepared in accord with specific recipes.

APPENDIX B

SUBSYSTEMS WHICH AFFECT RECONSTITUTION SYSTEM DESIGN

APPENDIX B

SUBSYSTEMS WHICH AFFECT RECONSTITUTION SYSTEM DESIGN

Subsystems identified as having significant influence upon the design of the reconstitution system were studied. The depth of study was limited to that required to assure a practical reconstitution system design. In some cases, a design requirement or limitation emerged from consideration of the subsystem. In others, no clear-cut choice could be made. Rather than make premature decisions between these alternative possibilities, a preliminary ranking to show degree of desirability was determined. The factors considered in the formulation of these preliminary judgments of rank are discussed in this Appendix.

Some quantitative comparisons of subsystem alternatives have been made through testing and analysis. The individual quantities used to make these comparisons should be treated as preliminary data. They are useful as indicators, but should not be considered absolute values.

1. MENU SUBSYSTEM

The types and quantities of food to be heated have a significant effect upon the reconstitution system design. It is required that typical varieties and quantities of food be based on Department of the Army Supply Bulletin SB10-261 "28 Day Master Menu" dated August 1969. This menu is designed to be cooked in a field kitchen. Some menu modification is anticipated when the food is precooked and reconstituted in the field.

Some types of food on the menu, such as green salads and [illegible]ed eggs, will not have an acceptable quality if frozen. A study is being conducted by the U.S. Department of Commerce to identify "nonfreezable" menu items and possible frozen food alternatives. If a menu can be developed which contains only frozen foods, field supply would be simplified. Nevertheless, the popularity of items like fried eggs and green salads suggests that they will probably persist on the menu as fresh food items.

The quantities of foods to be handled by the system are based upon the "28 Day Master Menu." Assuming that individual food items may be shifted from meal to meal to achieve uniform food packaging volume, a standard day's ration was developed for theoretical use throughout this study (see Exhibit B-1 on the following pages). Individual food items with their serving quantities were selected from the "28 Day Master Menu" to compose a day's ration with a reasonable menu and a total bulk packed volume of 70 cubic feet. This volume is the average of the bulk packaged volumes of five representative days of the "28 Day Master Menu." The bulk packed volumes were calculated using data from the appendix to U.S. Department of Commerce form DIB 952, Frozen Cooked Food Survey; food measurements; and normal commercial practice. The basis upon which the food volumes were determined is shown in Exhibit B-2 and the assumed bulk pack and case types are shown in Exhibit B-3.

STANDARD DAY'S RATION (200 MEN)

BULK PACKAGING

EXHIBIT B-1

FOOD ITEMS	SINGLE SERVINGS			BULK PACKS				CASES		TOTAL	
	WEIGHT OZ.	VOLUME BASIS(1)	PORTION SIZE	PACK TYPE (2)	VOLUME BASIS(1)	AMOUNT PACKED	NO. REQ'D	TYPE (2)	NO. REQD.	VOLUME CU. FT.	WEIGHT LBS.
BREAKFAST											
CHILLED JUICE	6.0	1	2.1"D. x 3.9"	—	—	—	–	I	3	2.7	101.5
OMELET OR PANCAKES	4.5	2, 3	0.6"x 2.7"x 5.4"	1	4	10	22	II	4	8.8	161.8
HASHED BROWN POTATOES	5.0	3	0.7 CUP	1	7, 8	36 oz.	30	II	4		
BACON	1.3	11	0.3"x 1.2"x 7" (2)	2	11	72 pcs.	6	II	4		
TOAST (2)	2.5	5, 6	0.6 x 4.2 x 5" (2)	3	7	20 pcs.	11	III	1	4.4	42.9
DINNER											
BEEF POT PIE	9.7	3	1 CUP	2	4	96 oz.	22	II	13	28.6	428.2
BUTTERED CORN	4.0	6	0.6 CUP	2	4	56 oz.	16				
GARDEN SALAD W/DRESS	3.5	3	1 CUP	2+4	7, 8	56 oz.	18				
CAKE	3.8	5	8.7 SQ. IN.	2	7	10 PCS.	22				
BUTTER (2)	0.5	6	0.3"x 1.2"x 1.2" (2)	2	10	43 oz.	3				
HOT BISCUITS (2)	3.4	6	2.7" DIA. x 1.7" (2)	2	7	12 PCS.	36				
SUPPER											
FRIED HAM STEAK	4.0	6	0.8" x 3.4" D.	2	7	18 PCS	12	II	10	22.0	367.2
SCALLOPED POTATOES	5.8	3	1 CUP	2	4	64 oz.	20				
BUTTERED MIXED VEG.	4.0	3	0.5 CUP	2	4	56 oz.	16				
COTTAGE CHEESE & PINEAPPLE SALAD	4.8	3, 6	3.2" to 4" D. x 1.5"	2	7	6 SALADS	36				
CHILLED PLUMS	3.2	6	0.4 CUP	2	7, 8	77 oz.	9				
BUTTER (2)	0.5	6	0.3"x 1.2"x 1.2" (2)	2	10	43 oz.	3				
BREAD (2)	2.0	5, 6	0.6"x 4.2"x 5" (2)	6	5	18 PCS	24	IV	2	3.6	33.0
								TOTALS		70	1134.6

(1) See Exhibit B-2 (6, 7 & 8)
(2) See Exhibit B-3

FIRST DAY'S RATION (200 MEN)

BULK PACKAGING

EXHIBIT B-2(1)

FOOD ITEMS	SINGLE SERVINGS			BULK PACKS				CASES		TOTAL	
	WEIGHT OZ.	VOLUME BASIS(1)	PORTION SIZE	PACK TYPE (2)	VOLUME BASIS(1)	AMOUNT PACKED	NO. REQ'D.	TYPE (2)	NO. REQ'D.	VOLUME CU. FT.	WEIGHT LBS.
BREAKFAST - 2001											
CHILLED ORANGE JUICE	5.6	1	2.1" D. x 3.9"	—	—	—	—	I	3	2.7	95.8
BACON OMELET	4.3	2,3	0.6" x 2.7" x 5.4"	1	4	10 OMELETS	22	II	4	8.8	146.9
COFFEE CAKE	4.5	5	8.7 SQ. IN.	2	7	10 PCS	22				
TOAST (2) WITH BUTTER	2.5	5,6	0.6" x 4.2" x 5" (2)	3	7	20 PCS	11	III	1	4.4	42.9
DINNER - 2101											
BAKED TUNA W/NOODLES	9.7	3	1.3 CUP	2	4	96 OZ.	22	II	8	17.6	361.8
BUTTERED GREEN BEANS	4.0	6	0.7 CUP	2	4	51 OZ.	17				
SALAD	5.0	3	0.5 CUP	2	7,8	120 OZ.	9				
CAKE	3.8	5	8.7 SQ. IN.	2	7	10 PCS.	22				
BUTTER (2)	0.5	6	0.3" x 1.2" x 1.2" (2)	2	10	43 OZ.	3				
BREAD (2)	2.0	5,6	0.6" x 4.2" x 5" (2)	6	5	18 PCS	24	IV	2	3.6	33.0
SUPPER - 2201											
GRILLED BEEF STEAK	8.0	6,12	0.7" x 3.8" x 5"	2	7	12 PCS	18	II	9	19.8	416.7
BAKED POTATOES	9.3	6	2.4" x 3" x 3.6"	2	7	6 PCS	36				
CARROTS	4.0	3	0.5 CUP	2	4	66 OZ.	13				
GREEN SALAD WITH	1.9	3	1 CUP	2	7,8	23 OZ.	18				
VINEGAR & OIL	1.3	3	2.4 CU. IN.	4	7	29 OZ.	10				
BUTTER (2)	0.5	6	0.3" x 1.2" x 1.2" (2)	2	10	43 OZ.	3				
APPLE PIE	8.0	3,5,6	1/6 OF 9" D. x 2.0"	5	4	6 PCS	36	VI	3	4.8	122.7
HOT ROLLS (2)	3.7	6	1.7" x 2.9" x 4.5" (2)	3	7	36 PCS	12	V	1	6.1	60.0
								TOTALS		68	1280

(1) See Exhibit B-2 (6,7+8)
(2) See Exhibit B-3

THIRD DAY'S RATION (200 MEN) BULK PACKAGING.

EXHIBIT B-2 (2)

FOOD ITEMS	SINGLE SERVINGS			BULK PACKS				CASES		TOTAL	
	WEIGHT OZ.	VOLUME BASIS (1)	PORTION SIZE	PACK TYPE (2)	VOLUME BASIS (1)	AMOUNT PACKED	NO. REQ'D	TYPE (2)	NO. REQ'D	VOLUME CU. FT.	WEIGHT LBS.
BREAKFAST - 2001											
CHILLED APPLE JUICE	6.1	1	2.1" D. x 3.9"	—	—	—	—	I	3	2.7	103
CREAMED GRD. BEEF	8.0	3	1 CUP	2	4	80 OZ.	22	II	8	17.6	275
HASH BROWN POTATOES	5.0	3	.7 CUP	1	7,8	36 OZ.	30				
BISCUITS (2)	3.4	6	2.7" D. x 1.7" (2)	2	7	12 PCS	36				
TOAST WITH BUTTER (2)	2.5	5,6	0.6" x 4.2" x 5" (2)	3	7	20 PCS	11	III	1	4.4	42.9
DINNER - 2103											
PEA SOUP	9.3	3	1 CUP	2	7	112 OZ.	18	II	11	24.2	411.9
SLICED BOLOGNA/CHEESE	5.7	6,9	3.8" x 5" x 0.6"	2	7,8	88 OZ.	14				
SCALLOPED POTATOES	4.3	3	1 CUP	2	4	64 OZ.	15				
CABBAGE SALAD	2.2	3	0.5 CUP	2	7,8	53 OZ.	9				
W/PICKLE DR.	1.3	3	2.4 CU. IN.	4	7	29 OZ.	10				
BROWNIES	2.1	5	3.7 SQ. IN.	2	7	10 PCS	22				
BUTTER (2)	.5	6	0.3" x 1.2" x 1.2" (2)	2	10	43 OZ	3				
BREAD (2)	2.0	5,6	0.6" x 4.2" x 5" (2)	6	5	18 PCS	24	IV	2	3.6	33
SUPPER - 2203											
ROAST BEEF W/GRAVY	5.5	12	0.3" x 3.3" x 5"	2	4	80 OZ.	15	II	8	17.6	319.6
MASHED POTATOES	5.0	3	0.7 CUP	2	7,8	68 OZ.	16				
HOT SPICED BEEF	5.1	3	0.5 CUP	2	4	66 OZ.	17				
GARDEN SALAD	2.2	3	1 CUP	2	7,8	27 OZ.	18				
W/FRENCH DR.	1.3	3	2.4 CU. IN.	4	7	29 OZ.	10				
BUTTER (2)	.5	6	0.3" x 1.2" x 1.2" (2)	2	10	43 OZ.	3				
BREAD (2)	2.0	5,6	0.6" x 4.2" x 5" (2)	6	5	18 PCS	24	IV	2	3.6	33
CHERRY PIE	8.0	3,5,6	1/6 OF 9" D. x 2.0"	5	4	6 PCS	36	VI	3	4.8	127.7
								TOTALS		78	1346

(1) See Exhibit B-2 (6,7 & 8)
(2) See Exhibit B-3

SEVENTH DAY'S RATION (200 MEN)
BULK PACKAGING

EXHIBIT B-2(3)

FOOD ITEMS	SINGLE SERVINGS			BULK PACKS				CASES		TOTAL	
	WEIGHT OZ.	VOLUME BASIS(1)	PORTION SIZE	PACK TYPE(2)	VOLUME BASIS(1)	AMOUNT PACKED	NO. REQ'D	TYPE (2)	NO. REQ'D	VOLUME CU. FT.	WEIGHT LBS.
BREAKFAST - 2007											
FRENCH TOAST (2)	4.7	5,6	0.6" x 4.2" x 5"	3	7	20 PCS.	11	III	1	4.4	73.1
MAPLE SYRUP	1.0	3	1.8 CU. IN.	7	4	1 GAL.	1	N.A.	—	0.2	8.9
STEWED PRUNES	4.0	3	0.5 CUP	2	8	48 OZ.	18	II	3	6.6	88.6
GRILLED BACON SLICES	1.3	11	0.3" x 1.2" x 7" (2)	2	11	72 PCS.	6				
TOAST WITH BUTTER	2.5	5,6	0.6" x 4.2" x 5" (2)	3	7	20 PCS.	11	III	1	4.4	42.9
DINNER - 2107											
VEALBURGER (2)	5.0	13	0.4" x 3.1" D.	2	7	24 PCS	18	II	10	22.0	369.6
HASH BROWN POTATOES	5.0	3	0.7 CUP	1	7,8	36 OZ.	30				
BUTTERED WAX BEANS	4.0	3	0.5 CUP	2	4	51 OZ.	17				
GARDEN VEG. SALAD	2.2	3	1 CUP	2	7,8	27 OZ.	18				
CHIFFONADE DRESSING	1.3	3	2.4 CU. IN.	4	7	29 OZ.	10				
APPLESAUCE TORTE	4.8	5	8.7 SQ. IN.	2	7	10 PCS.	22				
BURGER ROLLS (2)	3.7	6	2.3" x 3.5" D. (2)	8	7	6 PCS	72	VII	2	8.2	62.0
SUPPER - 2207											
FRIED HAM STEAK	4.0	6	0.8" x 3.4" D.	2	7	18 PCS	12	II	12	26.4	388.6
SCALLOPED POTATOES	5.8	3	1 CUP	2	4	64 OZ.	20				
BUTTERED MIXED VEG.	4.0	3	0.5 CUP	2	4	56 OZ.	16				
COTTAGE CHEESE & PINEAPPLE SALAD	4.8	3,6	3.2" to 4" D. x 1.5"	2	7	6 SALADS	36				
GINGERBREAD WITH	2.0	5	8.7 SQ. IN.	2	7	10 PCS	22				
WHIPPED TOPPING	1.5	3	0.3 CUP	2	6,7,8	65 OZ	5				
BUTTER (2)	.5	6	0.3" x 1.2" x 1.2" (2)	2	10	43 OZ	3				
BREAD (2)	2.0	5,6	0.6" x 4.2" x 5" (2)	6	5	18 PCS	24	IV	2	3.6	33.0
									TOTAL	76	1067

(1) See Exhibit B-2 (6,7 & 8)
(2) See Exhibit B-3

EXHIBIT B-2(4)

TWENTY FIRST DAY'S RATION
BULK PACKAGING

FOOD ITEMS	SINGLE SERVINGS			BULK PACKS				CASES		TOTAL	
	WEIGHT OZ.	VOLUME BASIS(1)	PORTION SIZE	PACK TYPE(2)	VOLUME BASIS(1)	AMOUNT PACKED	NO. REQ'D.	TYPE (2)	NO. REQ'D.	VOLUME CU. FT.	WEIGHT LBS.
BREAKFAST - 2021											
GRAPEFRUIT JUICE	5.0	1	2.1" D. X 3.9"	—	—	—	—	I	3	2.7	87.1
SCRAMBLED EGGS	3.7	3	0.5 CUP	2	4	80 OZ	10	II	2	4.4	88.4
GRILLED BACON SLICES (2)	1.3	11	0.3"X 1.2"X 7" (2)	2	11	72 PCS	6				
TOAST W/BUTTER (2)	2.5	5,6	0.6"X 4.2"X 5" (2)	3	7	20 PCS	11	III	1	4.4	42.9
DINNER - 2121											
BEEF POT PIE	9.7	3	1 CUP	2	4	96 OZ.	22				
BUTTERED CORN	4.0	6	0.6 CUP	2	4	56 OZ.	16				
GARDEN VEG. SALAD	2.2	3	1 CUP	2	7,8	27 OZ.	18				
LAMAZE DRESSING	1.3	3	2.4 CU. IN.	4	7	29 OZ.	10	II	13	28.6	428.2
DEVIL'S FOOD CAKE	3.8	5	8.7 SQ. IN.	2	7	10 PCS	22				
BUTTER (2)	0.5	6	0.3"X 1.2"X 1.2" (2)	2	10	43 OZ.	3				
BISCUITS (2)	3.4	6	2.7" D. X 1.7" (2)	2	7	12 PCS	36				
SUPPER - 2221											
ROAST PORK & GRAVY	6.5	4	14.4 CU. IN.	2	4	80 OZ.	18				
APPLESAUCE	1.3	6	3.9 CU. IN.	2	7,8	47 OZ.	6				
MASHED POTATOES	5.0	3	0.7 CUP	2	7.8	68 OZ.	16				
BUTTERED ASPARAGUS	4.0	6	0.8 CUP	2	7,8	62 OZ.	14	II	7	15.4	320.8
CARROT SALAD	3.0	3	0.5 CUP	2	7,8	72 OZ.	9				
BUTTER (2)	0.5	6	0.3"X 1.2"X 1.2" (2)	2	10	43 OZ.	3				
BREAD (2)	2.0	5,6	0.6"X 4.2"X 5" (2)	6	5	18 SLICES	24	IV	2	3.6	33.0
CHERRY PIE	8.0	3,5,6	1/6 OF 9" D.X 2"	5	4	6 PCS	36	VI	3	4.8	127.7
								TOTAL		64	1128

(1) See Exhibit B-2 (6, 7 & 8)
(2) See Exhibit B-3

TWENTY SECOND DAY'S RATION (200 MEN)

BULK PACKAGING

EXHIBIT B-2 (5)

FOOD ITEMS	SINGLE SERVINGS			BULK PACKS				CASES		TOTAL	
	WEIGHT OZ.	VOLUME BASIS(1)	PORTION SIZE	PACK TYPE(2)	VOLUME BASIS(1)	AMOUNT PACKED	NO. REQ'D.	TYPE (2)	NO. REQ'D.	VOLUME CU. FT.	WEIGHT LBS.
BREAKFAST – 2022											
PINEAPPLE JUICE	6.0	1	2.1" D. x 3.9"	—	—	—	—	I	3	2.7	101.5
CHEESE OMELET	4.5	2, 3	0.6" x 2.7" x 5.4"	1	4	10 OMELETS	22	II	5	11.0	271.4
WHEAT CEREAL	6.4	3	0.8 CUP	2	1, 8	77 OZ.	18				
BACON SLICES (2)	1.3	11	0.3" x 1.2" x 7"	2	11	72 PCS	6				
HASH BROWN POTATOES	5.0	3	0.7 CUP	1	7, 8	36 OZ.	30				
TOAST W/BUTTER (2)	2.5	5, 6	0.6" x 4.2" x 5" (2)	3	7	20 PCS	11	III	1	4.4	42.9
DINNER – 2122											
HOT BEEF SANDWICH											
BREAD (2)	2.0	5, 6	1.5" x 4.2" x 5"	6	5	18 SLICES	24	IV	2	3.6	33.0
BEEF & GRAVY	7.0	12		2	4	80 OZ.	19	II	8	17.6	369.2
MASHED POTATOES	5.0	3	0.7 CUP	2	7, 8	68 OZ.	16				
BROCCOLI	4.0	6	1 CUP	2	7, 8	48 OZ.	18				
FRUIT CUP	5.0	3	0.5 CUP	2	7, 8	90 OZ.	12				
COOKIES (2)	2.0	5	0.4" x 3.4" D. (2)	2	7	36 PCS	12				
BUTTER (2)	0.5	6	0.3" x 1.2" x 1.2" (2)	2	10	43 OZ.	3				
BREAD (2)	2.0	5, 6	0.6" x 4.2" x 5" (2)	6	5	18 SLICES	24	IV	2	3.6	33.0
SUPPER – 2222											
BARBECUED SPARERIBS	11.5	6	1" x 5.7" x 6"	2	7	60 OZ.	42	II	17	37.4	575.3
BUTTERED POTATOES	5.0	3	1 CUP	2	7, 8	60 OZ.	18				
MIXED VEGTABLES	4.0	3	0.5 CUP	2	4	56 OZ.	16				
LETTUCE & TOMATO SALAD	5.4	3, 6	3" TO 4" D. x 1"	2	7	6 SALADS	36				
SALAD DRESSING	1.3	3	2.4 CU. IN.	4	7	29 OZ.	10				
CHILLED PLUMS	3.2	6	0.4 CUP	2	7, 8	77 OZ.	9				
BUTTER (2)	0.5	6	0.3" x 1.2" x 1.2" (2)	2	10	43 OZ.	3				
BISCUITS (2)	3.4	6	2.7" DIA. x 1.7" (2)	2	7	12 PCS	36				
									TOTAL	80	1426

(1) See Exhibit B-2 (6, 7 + 8)
(2) See Exhibit B-3

EXHIBIT B-2 (6)
U.S. Army Natick Laboratories
BULK PACKAGING PARAMETERS

EXPLANATORY NOTES

The following notes indicate the basis for the size of single servings or the amount of food packaged in bulk food containers:

1. It was assumed that juice will be packaged in 6 ounce fiber cans with metal ends. A standard size measures 2.1" diameter x 3.9" and weighs 0.7 ounces.
2. Space allowed in half size steam table pans by commercial food processor.
3. Volume for this or a similar food item indicated as "EACH PORTION" on Army Recipe.
4. Weight, volume, or number of items packaged in the bulk container by a commercial food processor.
5. Area of serving calculated pan size and number of servings per pan shown on Army recipe.
6. Measurements of typical food items as follows:

	Overall Dimensions	Weight	Density Oz.Per Cu.In.
- Bread (loaf)	3.8x4.8x11"	10 oz.	0.08
- Butter	1.2x1.2x4.7"	4 oz.	0.59
- Buttered Green Beans	1 cup	6 oz.	0.42
- Corn (in plastic bag)	1x5.5x8"	20 oz.	0.45
- Pork Slice, Boneless			
Raw	4.1 dia.x.7"	5 oz.	0.54
Cooked	3.5 dia.x.7"	3 oz.	0.45
- Ground Beef Patty			
Raw	4.5 dia.x.5"	48 oz.	0.55
- Bak.Powd.Biscuit			
Raw	2.5 dia.x.5"	2 oz.	0.81
Baked	2.7 dia.x1.7"	2 oz.	0.21

EXPLANATORY NOTES (cont'd)

	Overall Dimensions	Weight	Density Oz.Per Cu.In.
- Spareribs (cooked)	1x5x6"	10 oz.	0.33
- Lunch.meats&cheese	Several Kinds		
- Applesauce	3.3 dia.x6"	35 oz.	0.63
- Hot Rolls	1.7x7x9"	9 oz.	0.08
- Pineapple Ring Can	3.2 dia.x0.4"	-	-
- Tomato	2.5" dia.	5.6 oz.	0.68
- Asparagus Spears	1.5x4x5"	10 oz.	0.33
- Broccoli Cuts	1.7x4x5"	10 oz.	0.29
- Cottage Cheese	3.7 dia.x3"	16 oz.	0.50
- Steak, (boneless, raw)	1x6x7.5"	26 oz.	0.58
- Baked Potato	2.4x3x3.6"	9 oz.	-
- Ham Steak (raw)	8.2 dia.x1.7"	48 oz.	0.53
- Apple Pie	9" dia.x2"	37 oz.	-
- Plums (heavy syrup)	3 dia.x4"	16 oz.	0.57

7. Calculated using single serving size and dimensions of bulk containers.

8. The following food product depths were assumed for half size steam table pans:

- Salads, mostly with raw vegetables	2.0"
- Salads with large percentage of liquid	1.5"
- Fruits with liquid	1.5"
- Hash browned potatoes	0.8"
- Parsley buttered potatoes	2.0"
- Asparagus and broccoli	2.0"
- Soup	1.5"
- Hot breakfast cereal	1.5"
- Applesauce	1.5"
- Mashed potatoes	1.5"
- Luncheon meat and cheese	2.3"
- Whipped topping	2.3"

EXPLANATORY NOTES (cont'd)

9. Sized for best fit into bulk pan.

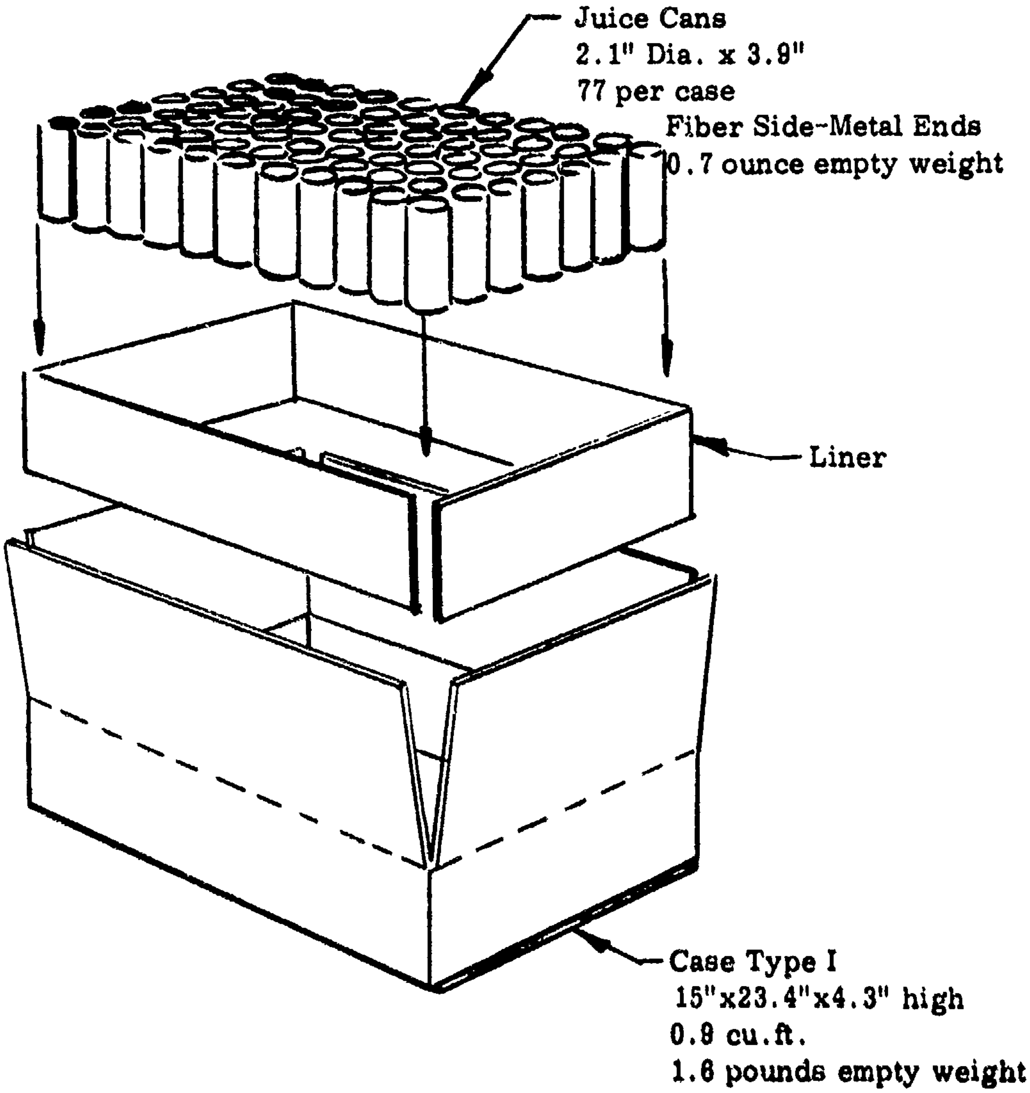
10. Assuming each pat of butter is placed upon an individual 1.5" x 1.5" fiber tray, 5 rows of 32 each may be placed in a half size steam table pan.

11. Assuming a cooked bacon piece size of 0.3" (with curl) x 1.2" x 7", 7 layers of about 10 pieces each may be placed in half size steam table pan. Total of 72 per pan was used.

12. It was assumed that beef steak would experience a 10 percent loss in weight and cross-grain dimension as with pork slices.

13. It was assumed that the dimensions of vealburgers would be reduced in proportion to weight loss. From Army recipe notes, 17 percent weight loss is indicated, and raw thickness is 0.5".

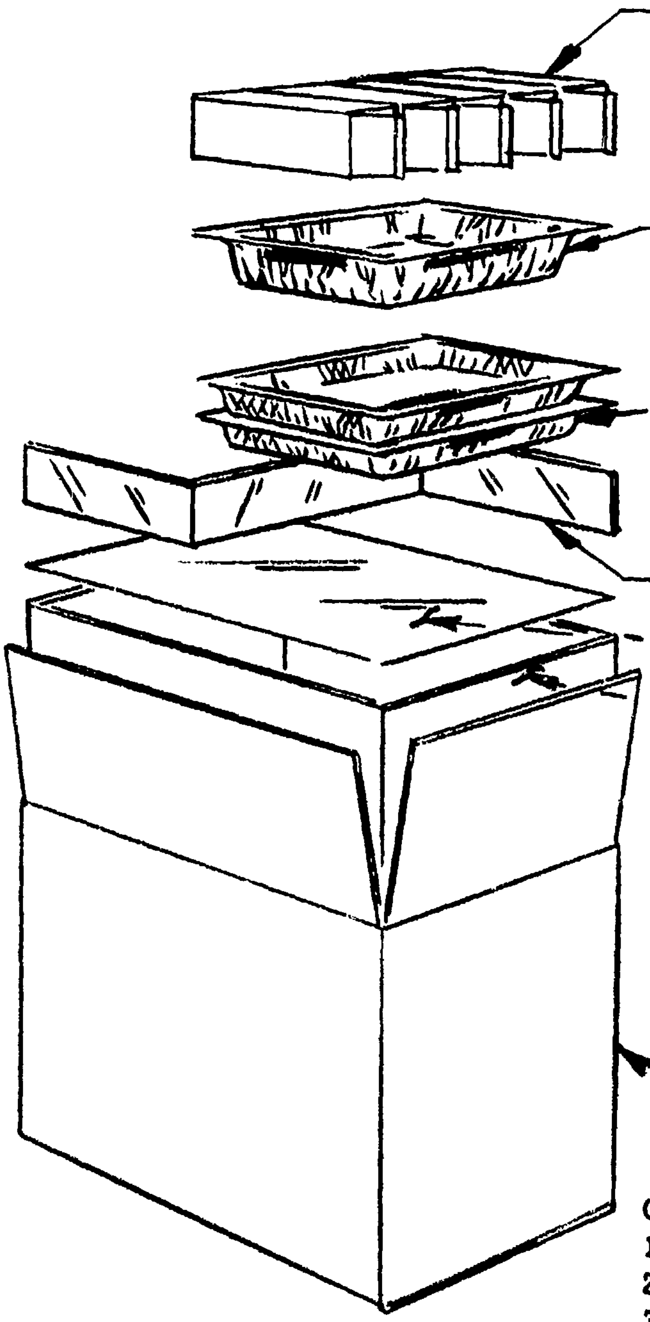
EXHIBIT B-3 (1)
U.S. Army Natick Laboratories
PACKAGING CONFIGURATIONS
BULK PACKED FOOD



Note: The following applies to all cases shown.

1. Cases are constructed of 0.1" thick corrugated fiberboard weighing 2 ounces per square foot.
2. Lateral clearance of 0.1" per compartment is provided.

EXHIBIT B-3 (2)
U.S. Army Natick Laboratories
PACKAGING CONFIGURATIONS
BULK PACKED FOOD



Bulk Pack Type 4
Salad Dressing Carton
2.5"x2.5"x10.3"
Coated Paper
0.08 pounds empty weight

Bulk Pack Type 2
2.5" x 10.3" x 12.6"
Aluminum Foil
0.25 pounds empty weight

Bulk Pack Type 1
1.2" x 10.3" x 12.6"
Aluminum Foil
0.13 pounds empty weight

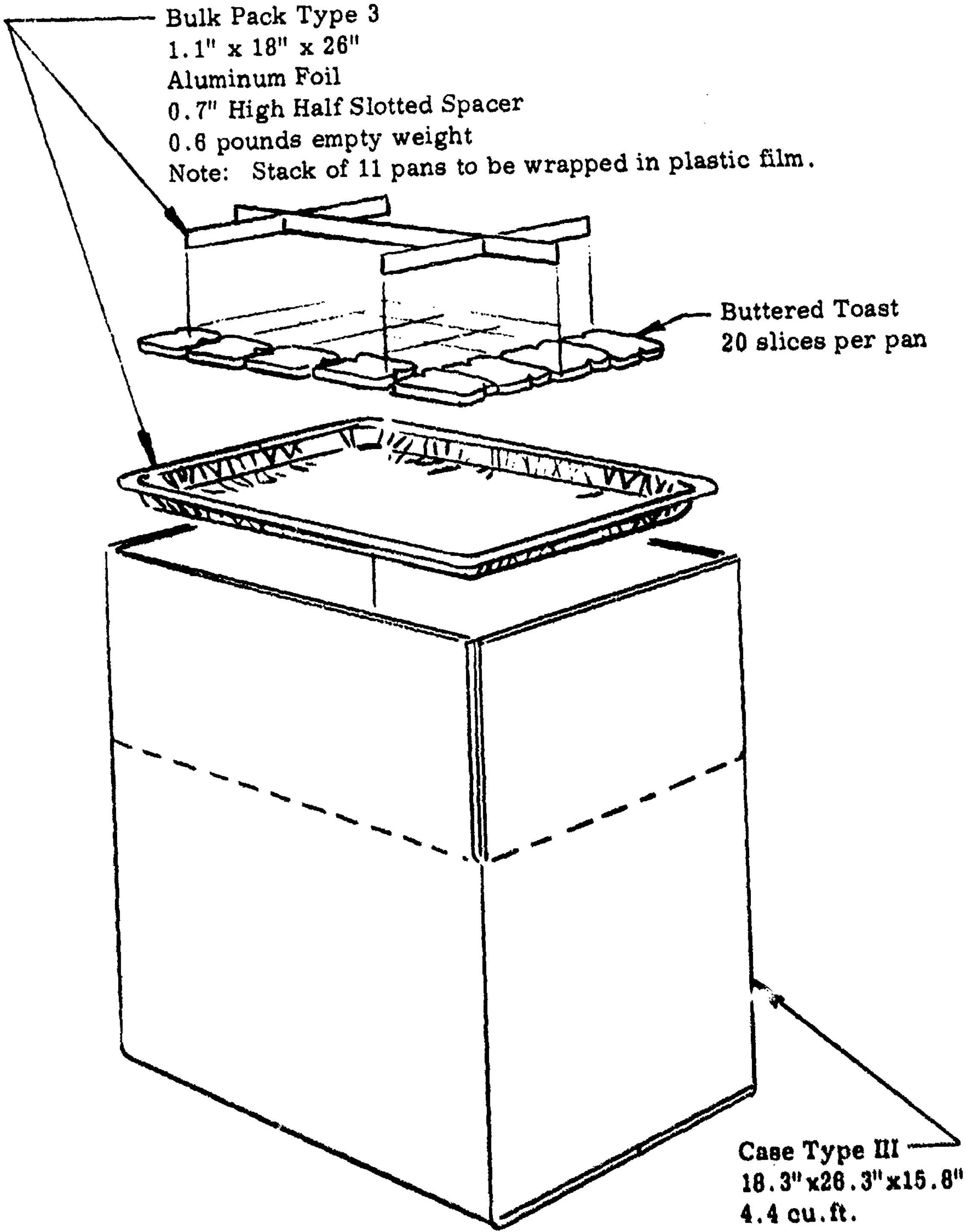
Cell Partition

Separator Pad

Liner

Case Type II
13.2" x 13.3" x 21.5" high
2.2 cu.ft.
3.7 pounds empty weight
(add 1.2 lbs if all Type 1
Bulk Packs)
10 cells per case

EXHIBIT B-3(3)
U.S. Army Natick Laboratories
PACKAGING CONFIGURATIONS
BULK PACKED FOOD



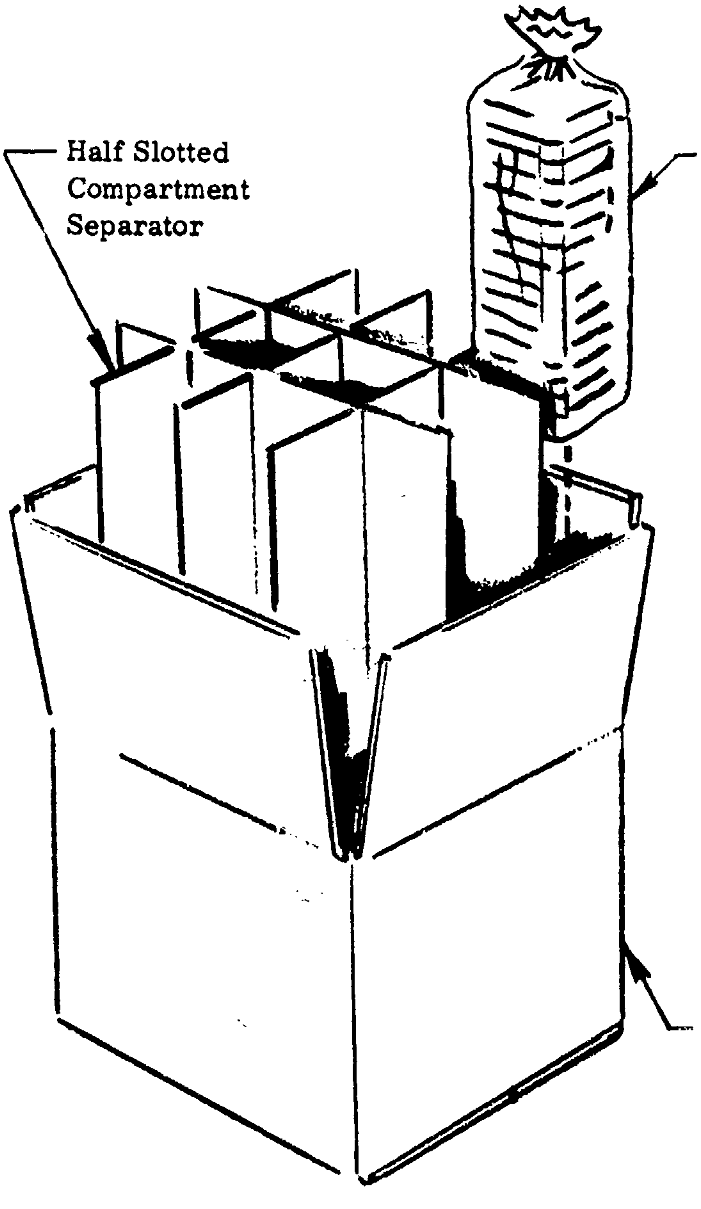
Bulk Pack Type 3
1.1" x 18" x 26"
Aluminum Foil
0.7" High Half Slotted Spacer
0.6 pounds empty weight
Note: Stack of 11 pans to be wrapped in plastic film.

Buttered Toast
20 slices per pan

Case Type III
18.3"x26.3"x15.8" high
4.4 cu.ft.
2.9 pounds empty wgt.

EXHIBIT B-3(4)
U.S. Army Natick Laboratories

PACKAGING CONFIGURATIONS
BULK PACKED FOOD

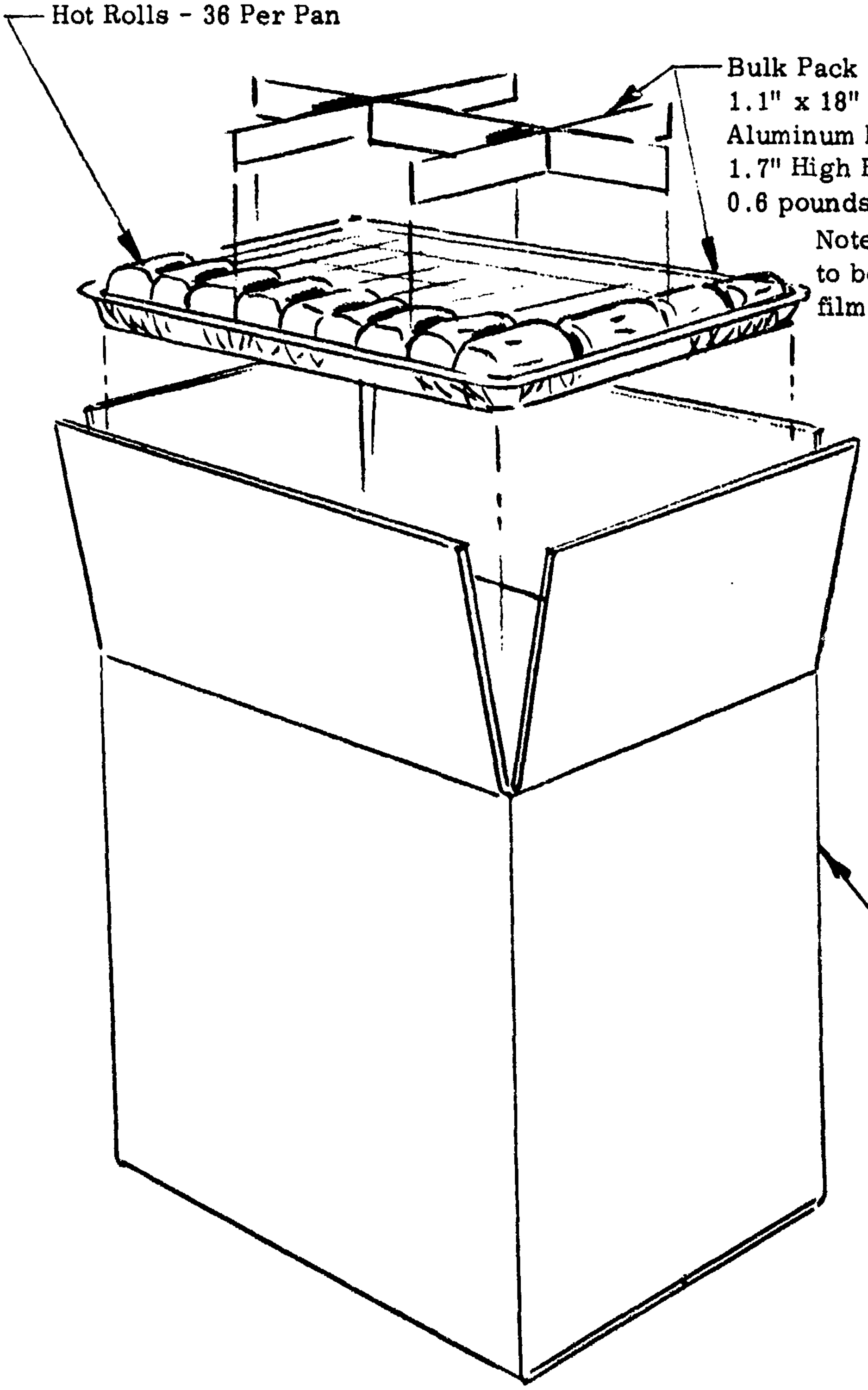


Half Slotted
Compartment
Separator

Bulk Pack Type 6
Plastic Bread Bag
12 per case

Case Type IV
15.7" x 17.7" x 11.4" high
1.8 cu.ft.
2.4 pounds empty weight

EXHIBIT B-3 (5)
U.S. Army Natick Laboratories
PACKAGING CONFIGURATIONS
BULK PACKED FOOD



Hot Rolls - 36 Per Pan

Bulk Pack Type 3
1.1" x 18" x 26"
Aluminum Foil
1.7" High Half Slotted Spacer
0.6 pounds empty weight

Note: Stack of 12 pans
to be wrapped in plastic
film before placing in case.

Case Type V
18.3"x26.3"x22" high
6.1 cu.ft.
3.9 pounds empty wgt.

EXHIBIT B-3(6)
U.S. Army Natick Laboratories
PACKAGING CONFIGURATIONS
BULK PACKED FOOD

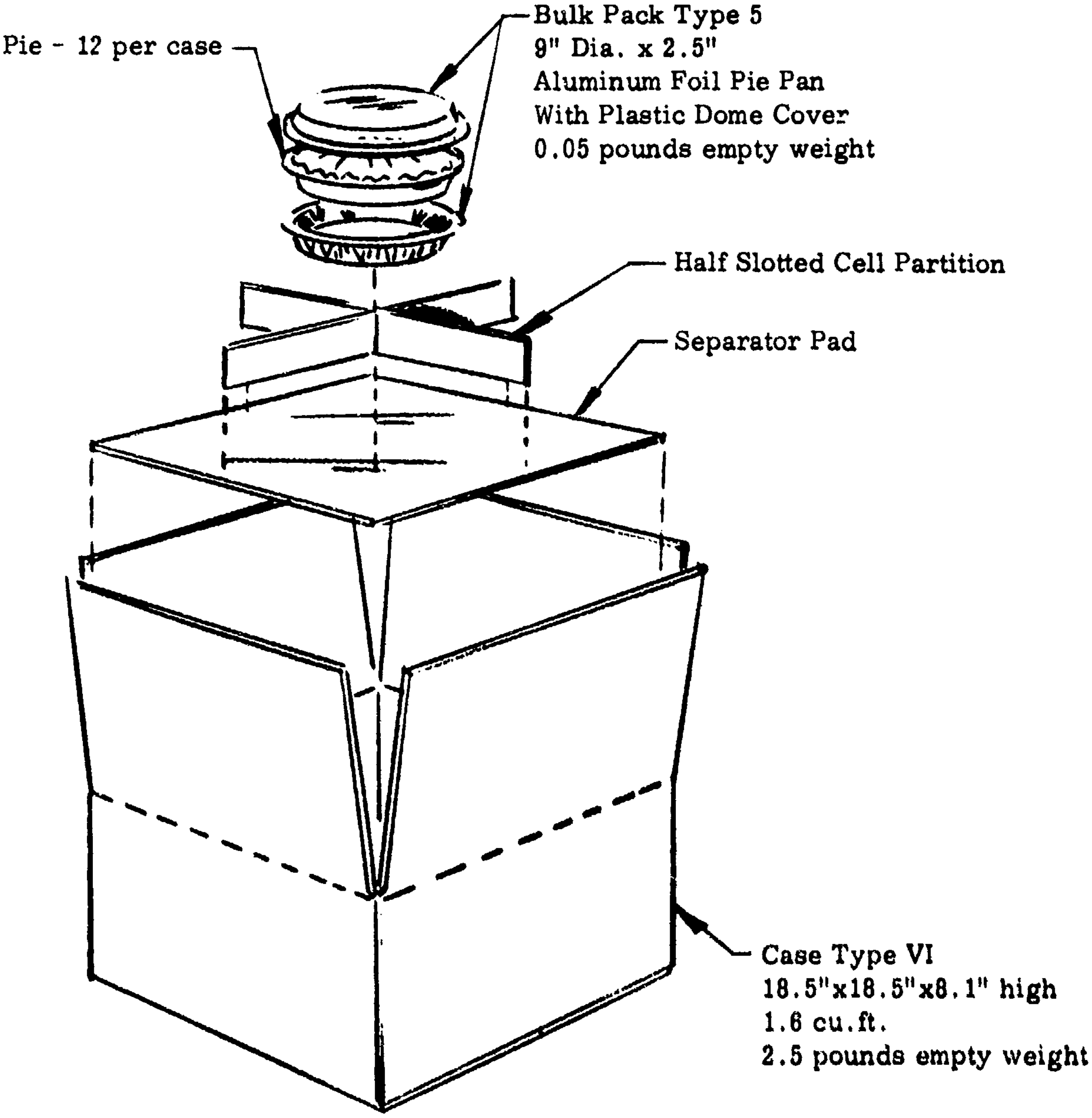
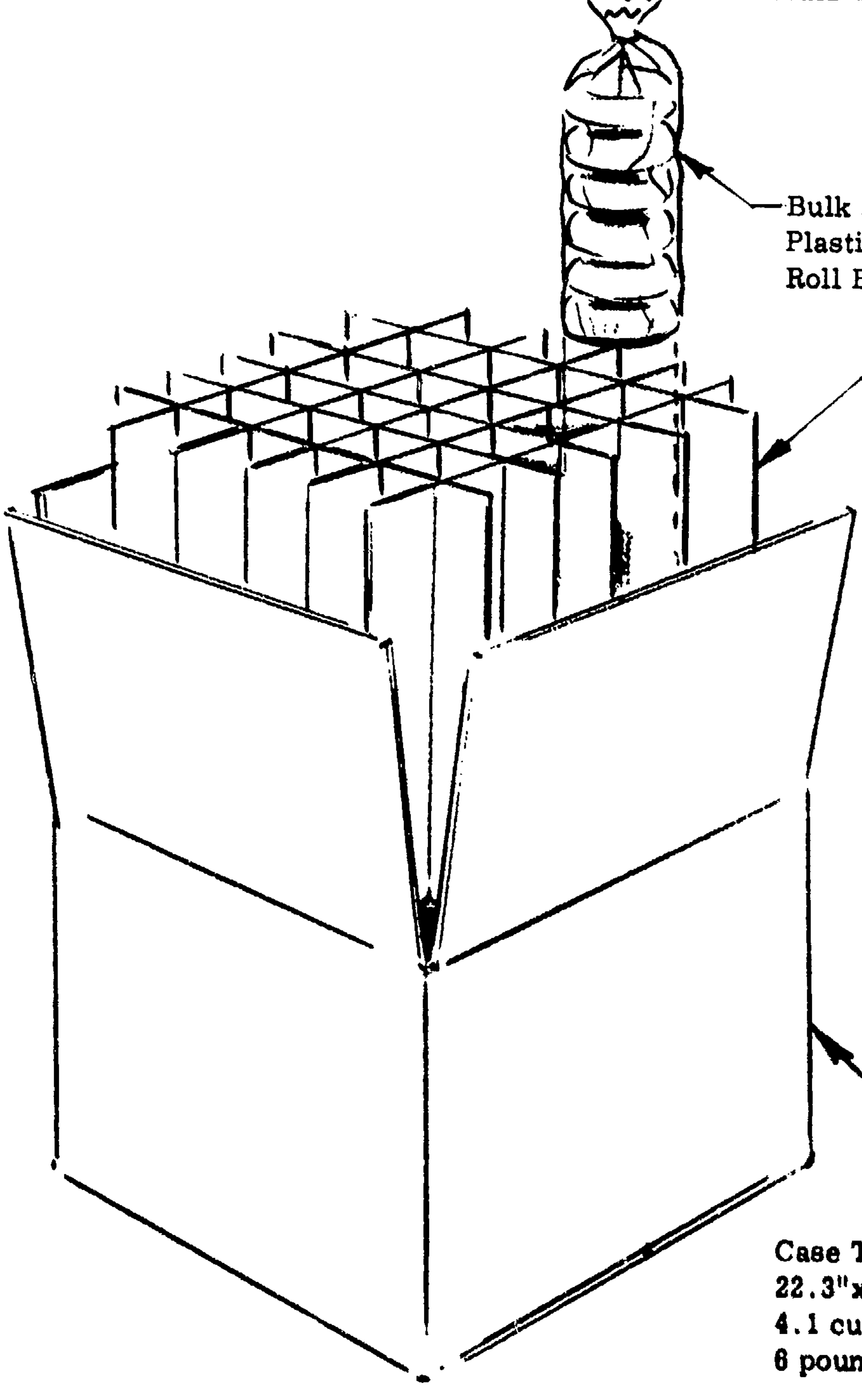


EXHIBIT B-3(7)
U.S. Army Natick Laboratories
PACKAGING CONFIGURATIONS
BULK PACKED FOOD



Bulk Pack Type 6
Plastic Hamburger
Roll Bag - 36 per case

Half Slotted
Cell Partitions

Case Type VII
22.3"x22.3"x14.2" high
4.1 cu.ft.
6 pounds empty weight

2. FOOD CONTAINER SIZE SUBSYSTEM

In addition to the bulk pack, the frozen food could be packaged as preplated meals or in single serving containers. Each of these packaging methods has advantages and disadvantages for field food service, and no selection of a preferred package can be made on the basis of the package alone. A reconstitution system design capable of heating any one or a combination of these three packages has the advantage of versatility over a system which can heat only one size. In those cases where only one size may be heated, the order of preference is as follows:

- Preplated meal - most desirable
- Bulk pack - less desirable
- Single serving - least desirable

The following advantages in relation to the field food service requirement led to this judgment.

- Preplated meal
  - Troops can serve themselves by picking up the preplated meal
  - Fast heating
  - Dish washing is eliminated when disposable containers are used
  - Food is covered until eating begins
  - Portion size is controlled
- Bulk pack
  - Highest food quality of the three packaging methods is possible with special heating (optimum heating conditions and selective cover removal)
  - Lowest packaging cost
  - Soldier being served has some control over serving size and may return for second helping of individual food items
  - Better storage life than the other methods - less susceptible to surface drying or accidental thawing
  - Food processors might package only their specialty items since there is only one food type in each pan

- Single serving (single portion of one food item per package)
    - Self-serving food
    - Fast food heating
    - Food is covered until eating begins
    - Higher food quality is possible with special heating (optimum time - temperature, but special manipulation of covering is not feasible)
    - Portion size is controlled but diners may choose to take second helpings or none of the items offered
    - Food processors might package only their specialty items

A major disadvantage which leads to the least desirable ranking of the single serving package is its high packaging cost. An indication of packaging costs was obtained by comparing the costs of aluminum foil containers for the standard day's ration (Exhibit B-1) packaged in the three sizes of containers The types of containers* assumed and the resulting costs per day are as follows:

- Preplated meal container costs
    - Breakfast plate
      Assumed this plate to be half the volume of the dinner and supper hot pack
      Based upon price of 1.2" x 5" x 6.5" aluminum foil plate with foil cover
      $.033 ea. x 216 = $ 7.13
    - Dinner-supper hot pack
      1.5" x 6.5" x 8.5" three compartment foil plate with epoxy - vinyl coating on inside and foil cover
      $.051 ea. x 2 x 216 = $22.03
    - Dinner-supper cold pack
      Based upon price of 2" x 5" x 6.5" compartmental throw-away plastic container with plastic film cover
      $.018 ea. x 2 x 216 = $ 7.78

Total $36.94 per day

---

* Breakfast toast and juice containers are assumed to be the same in all cases and thus were not included in calculations.

- Bulk pack container costs

  - Shallow half size steam table pan
    Based upon price of 1" x 10.4" x 12.8"
    aluminum foil pan with epoxy - vinyl
    coating on inside and foil laminated
    pasteboard plug lid
    $.140 ea. x 52 = $ 7.28

  - Standard half size steam table pan
    2.5" x 10.4" x 12.8"
    aluminum foil pan with epoxy - vinyl
    coating on inside and foil laminated
    pasteboard plug lid
    $.163 ea. x 128 = $20.86

  - Standard half size steam table pan
    2.5" x 10.4" x 12.8"
    throw-away plastic container with heat
    sealing plastic cover - assumed 35% of
    the cost of a standard half size aluminum
    foil pan as with preplated containers
    $.057 ea. x 91 = $ 5.19

    Total $33.33 per day

- Single serving container costs

  - Smooth formed 5 ounce capacity aluminum
    foil container to be covered with heat
    sealing coated foil*
    $.028 ea. x 216 x 5 = $30.24

  - Smooth formed 16 ounce capacity aluminum
    foil container to be covered with heat
    sealing coated foil*
    $.030 ea. x 216 x 3 = $19.44

---

* These were the lowest cost small aluminum foil containers which were found.

- Throw-away plastic 5 ounce container with plastic film cover Assumed 35 percent of same sized aluminum foil container cost as with preplated containers	$.010 ea. x 216 x 4 =	$ 8.64
- Throw-away plastic 16 ounce container with plastic film cover Assumed 35 percent of same sized aluminum container cost as with preplated containers	$.011 ea. x 216 x 2 =	$ 4.54
	Total	$62.86 per day

The shipping and storage volumes of the standard day's ration packaged in preplated meal and single serving size containers were determined for comparison with the bulk packed volume shown in Exhibit B-1. The volume of preplated meal packaging was calculated using the food container configurations shown in Exhibit B-4, and the case configuration shown in Exhibit B-5. The volume of single serving packaging was determined by increasing the volume for preplated meal packages by ten percent to allow for packaging space loss. The resulting shipping and storage volumes are as follows:

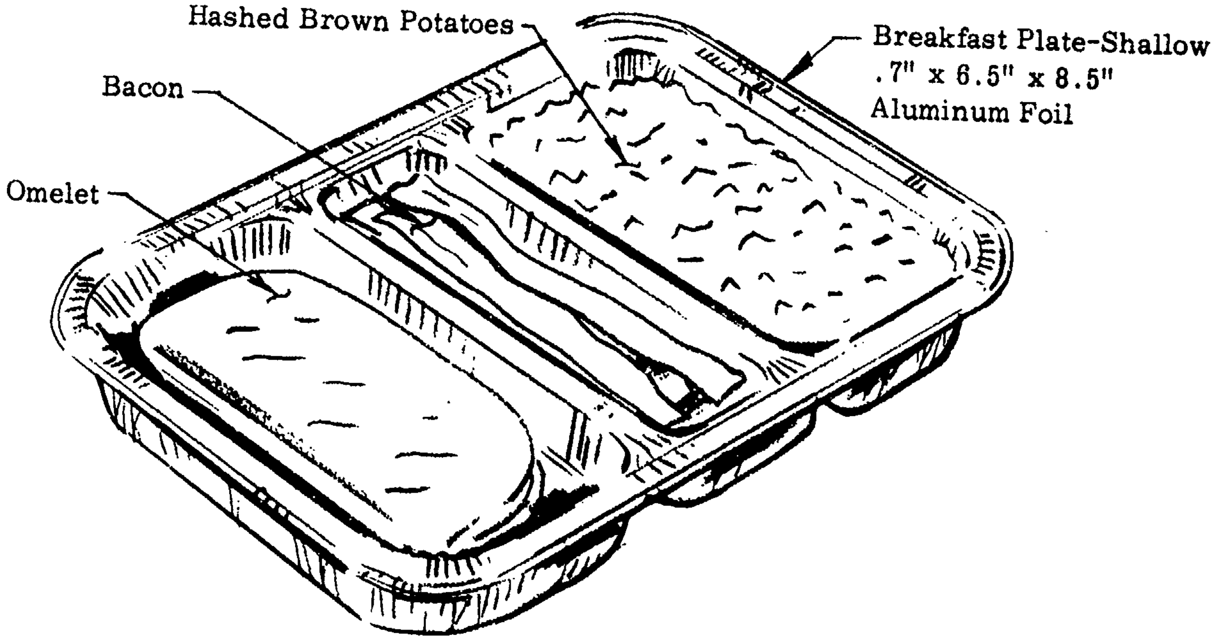
- Bulk packed - 70 cubic feet per day
- Preplated meal - 62.4 cubic feet per day
- Single serving - 67.9 cubic feet per day

Interviews indicated that bulk packaging is considered to be the most volumetrically efficient method. Nevertheless, this analysis indicates that for the Army's field menu, bulk packaging volume is significantly larger than the preplated meal packaging volume. There are three factors which contribute to this.

- In commercial practice many different depths of food are used to minimize the space lost at the top of the half size steam table pan. In this estimate, only two depths were used. The Department of Commerce frozen/cooked food survey indicates the desire to use only one depth.

- More space is allowed at the top of half size steam table pans to prevent product spillage in handling.

EXHIBIT B-4(1)
U.S. Army Natick Laboratories
PREPLATED MEAL
CONTAINER CONFIGURATIONS



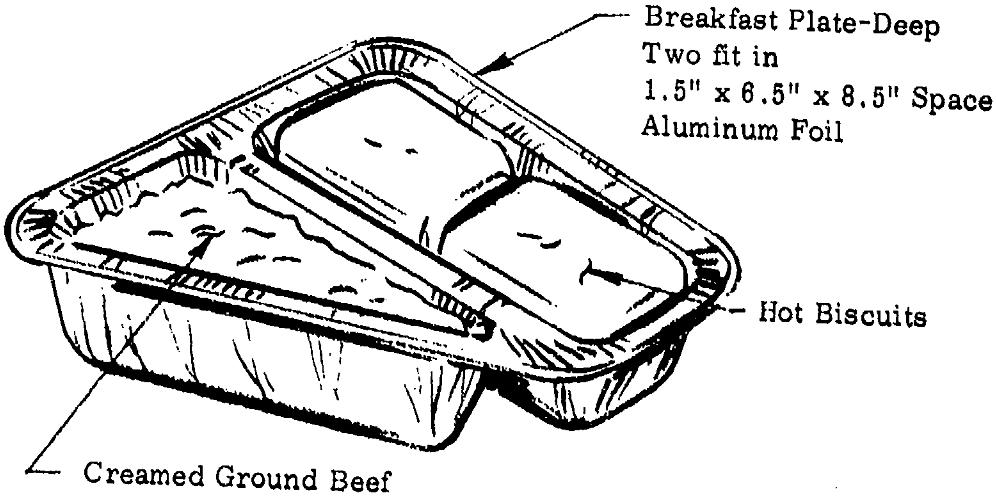
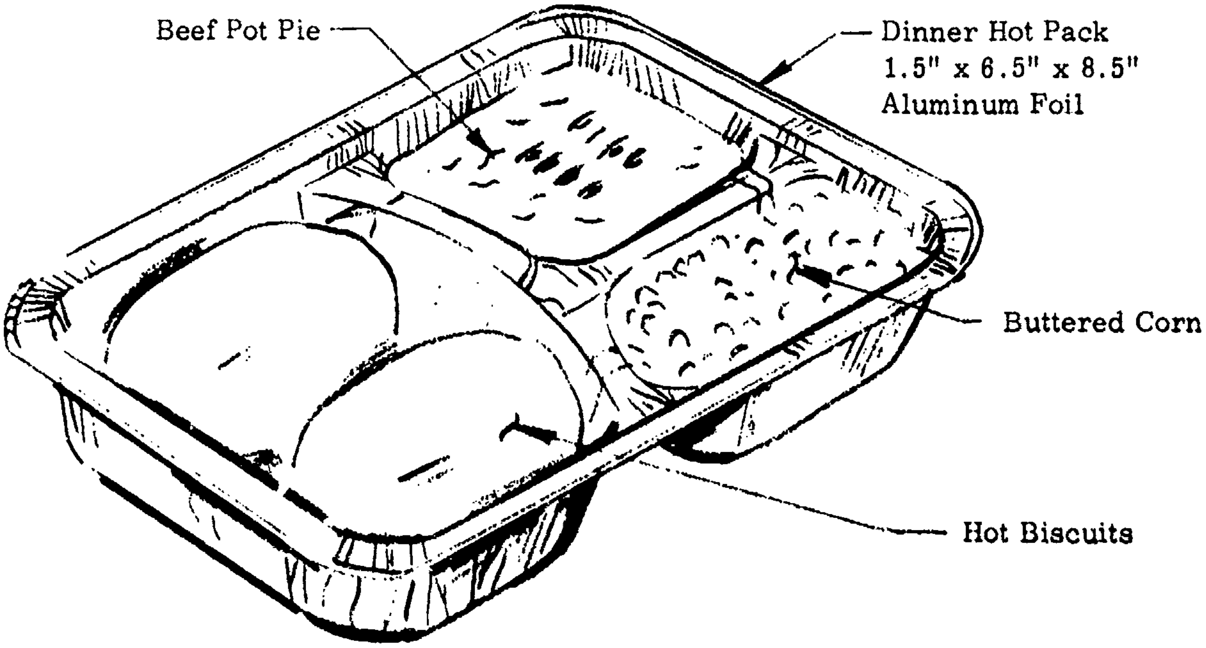


EXHIBIT B-4 (2)

U.S. Army Natick Laboratories
PREPLATED MEAL
CONTAINER CONFIGURATIONS



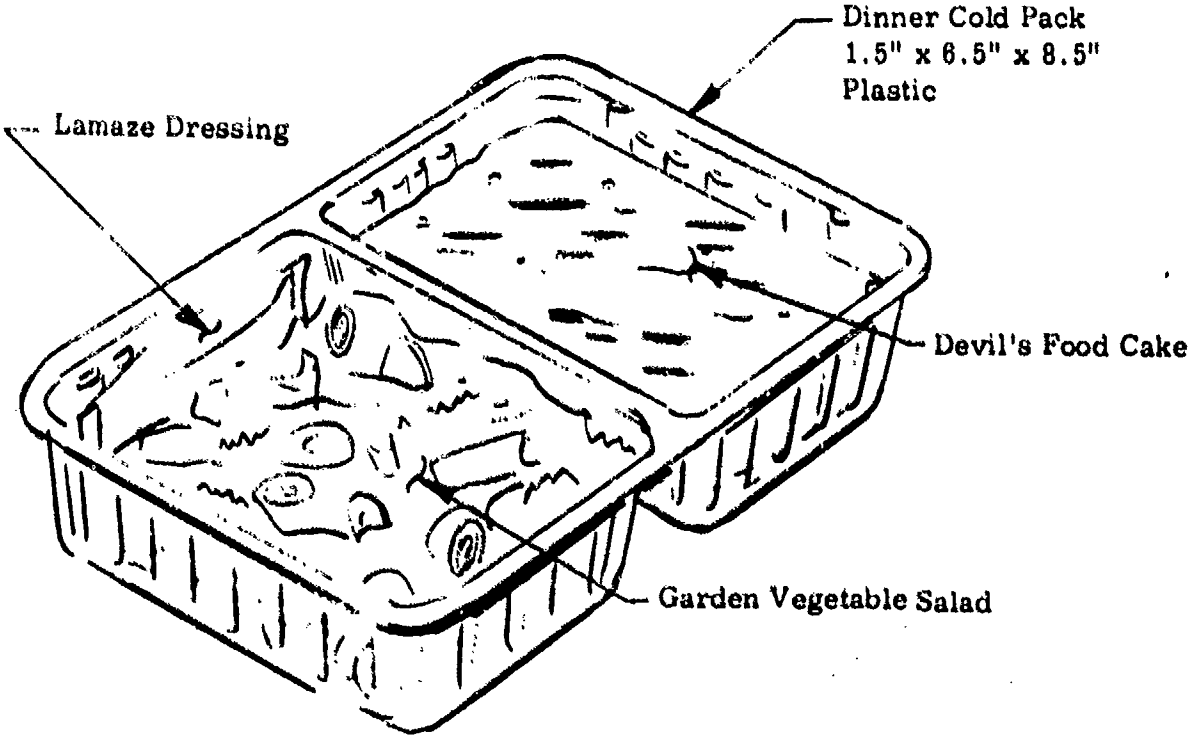
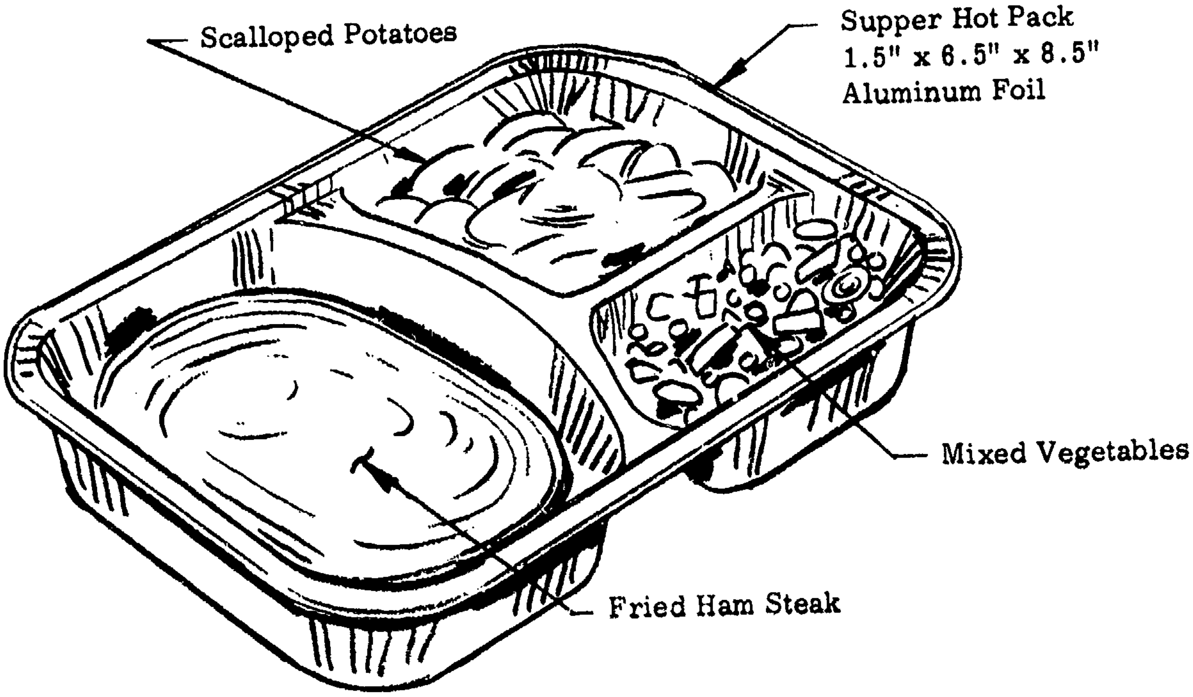


EXHIBIT B-4 (3)
U.S. Army Natick Laboratories
PREPLATED MEAL
CONTAINER CONFIGURATIONS



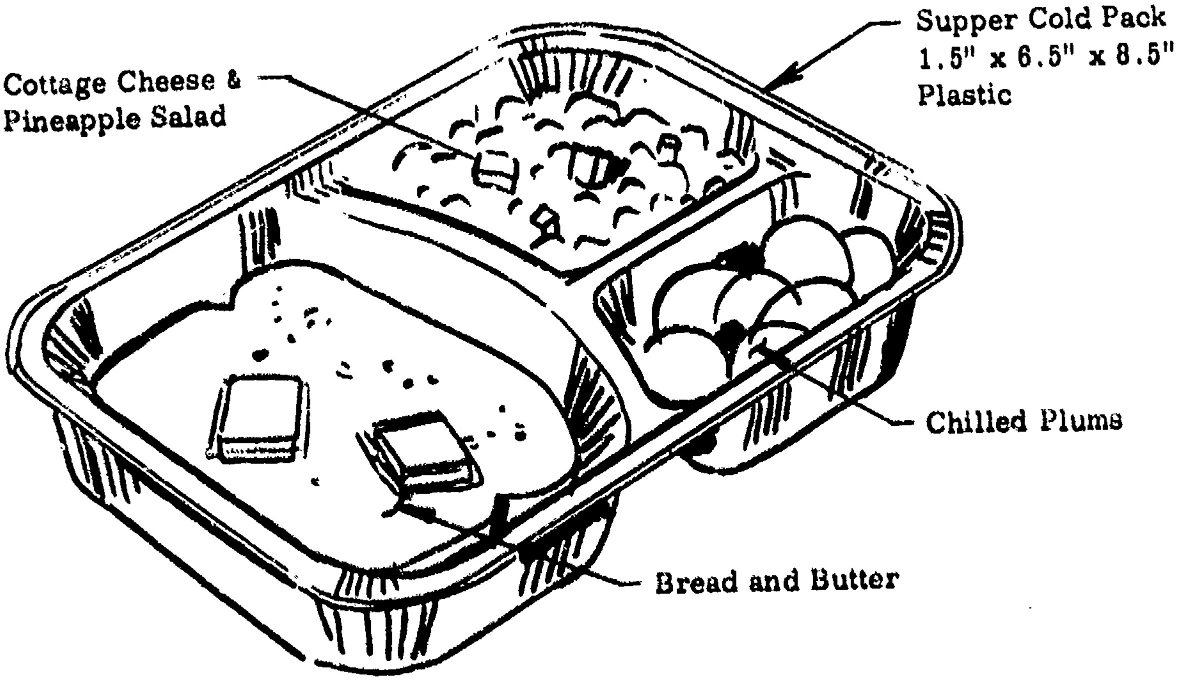
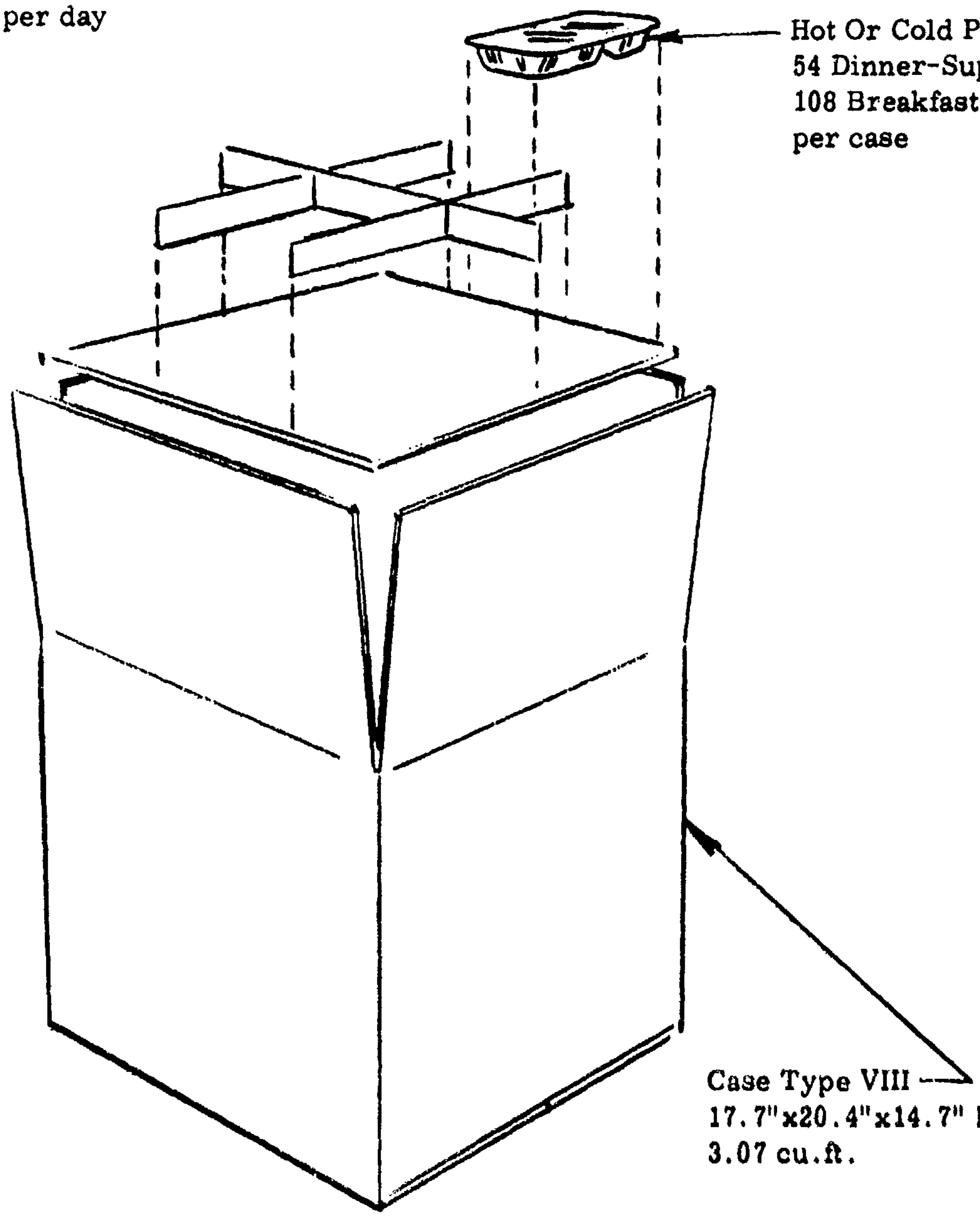


EXHIBIT B-5
U.S. Army Natick Laboratories
CASE CONFIGURATION
PREPLATED MEALS

Total preplated meal packaged volume per day =
= 10 hot pack cases + 8 cold pack cases + 3 juice cases + 1 toast case
= 10 x 3.07 + 8 x 3.07 + 2.7 + 4.4 = 62.4 cu.ft. per day

Total single serving packaged volume per day =
= 1.10 (10 x 3.07 + 8 x 3.07) + 2.7 + 4.4 =
= 67.9 cu.ft. per day



- Some space is lost by segregating the half size steam table pans by meal in cases. If pans for more than one meal were allowed to be packaged in the same cases, 4.4 cubic feet would be saved.

A detailed packaging system design is required to optimize all packaging parameters, including shipping and storage volume. However, these preliminary estimates indicate that preplated meal packaging does not introduce significant volumetric or cost penalties.

3. DISPOSABLE VERSUS REUSABLE FOOD CONTAINERS

Disposable food containers have advantages over reusable containers. To avoid objectionable odors and the insects the odors would attract, reusable containers would have to be sanitized or at least rinsed well with hot water immediately after use. Probably the only exceptions to this requirement would occur when there is short transport time to the preparation center after each meal or in a very cold weather environment. Consequently, reusable containers would impose washing capability upon the field kitchen. The advantages of using disposable food containers are, therefore, as follows.

- Less water and fuel would be required at the field kitchen. 650 gallons of hot potable water is required per day to wash mess gear for 200 men.*

- Less equipment such as immersion heaters and 32 gallon cans would be required at the field kitchen.

- Less kitchen labor would be required.

There is no significant difference between disposable and reusable metal food containers relative to the speed of heating. Since there is usually a substantial difference in the material thickness of the two types, a longer heating time would be expected for the thicker reusable container. A test was conducted to determine the magnitude of this difference. Similar equal portion of frozen Salisbury steak in gravy and mashed potatoes were placed in two aluminum containers and covered with aluminum foil. The disposable container was .004" thick while the reusable container was .035" thick. Subjecting these containers to a 212°F steam environment caused the food to be heated to 165°F as shown in the following table:

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* J.C. Perry, G.D. Bell, and CPT H.M. Toczylowski, An Evaluation Of Alternative Mobile Field Kitchen Concepts, U.S. Army Natick Laboratories Technical Report 73-44-GP, February 1972.

	Disposable Container .004" thick aluminum	Reusable Container .035" thick aluminum
Salisbury steak with gravy	11.5 min.	10.5 min.
Mashed potatoes	7.0 min.	9.5 min.

Within the limits of experimental accuracy, these data indicate no significant difference in heating time with almost a ten to one ratio of aluminum thickness.

4. FOOD CONTAINER MATERIAL SUBSYSTEM

Several different types of materials were identified which meet the food storage, handling and heating requirements. Final selection should be based upon optimization of cost factors and container aesthetics. The reconstitution system heating requirements have a significant effect upon cost factors. Lower heating temperatures allow the use of lower cost materials.

Food container materials for a cooked frozen food field feeding system must meet the following general requirements:

- The material must be compatible with the food and no odor, stain or taste may be imparted.
- The material must have low permeability for moisture and oxygen, as required, and to prevent ingress of microorganisms during frozen storage and heating.
- The material must be capable of withstanding handling loads while at temperatures from 0 to 165°F. Requirements imposed by the specific method of heating to be used are outlined below:
- Hot Air
    - Convection Oven - The material must withstand temperatures up to 400°F.
    - Low Temperature Natural Convection - The material must withstand temperatures up to 300°F.
    - High Velocity/Low Temperature Convection - The material must withstand temperatures up to the air temperature which can be 230°F in one system.

- Steam

  The material should have the capability to carry the loads caused by supporting half size steam table pans along two edges while at the temperatures shown below.

  - Atmospheric pressure - up to 212°F
  - Low pressure (5 to 7 psig) - up to 232°F
  - High pressure (15 psig) - up to 250°F

- Boiling Water

  The material must withstand temperatures up to 212°F, and the container must be watertight at this temperature.

- Infrared Radiation

  The material must withstand temperatures up to 850°F.*

- Microwave Radiation

  The material must withstand temperatures up to 230°F. This is estimated to be the temperature to which the food might be heated in localized spots. The container material should be transparent to microwaves to allow the energy to pass through the container and into the food without heating the container. Metal container materials are not permitted because they reflect the microwaves and can damage the magnetron, the microwave generator.** It is also necessary that the container material be nonhygroscopic because water is a good absorber of microwave energy.

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* G. E. Livingston, Second Generation Reconstitution Systems. The Cornell H.R.A. Quarterly, May 1972.

** Lewis Napleton, A Guide To Microwave Catering, Northwood Publications Limited; London, England - 1973.

Many possible container materials meet these requirements. The field survey indicates the following:

- Aluminum foil is most widely used for high temperature heating processes.
- High temperature plastics, such as polysulfone and nylon 6, are being used in some cases, although they cost about three times the cost of aluminum foil they provide better container appearance.
- A molded fiber material which costs about half as much as aluminum and can withstand convection oven heating has been recently introduced.
- Stainless steel is most widely used for reusable food containers.
- Flexible plastic film laminates are generally used for boiling water heating systems.
- Treated paper, plastic and ceramic food containers are used in microwave ovens.

Tests were conducted to determine the effect of container material upon food heating. Similar portions of Salisbury steak in gravy and mashed potatoes were placed in containers made of the materials shown in Exhibit B-6. The containers were covered with aluminum foil and heated in 205 ± 5°F air at a velocity of 40 feet per second as described in Appendix F.

The difference between plastic and aluminum foil heating times is negligible. The longer times experienced with the molded fiber container are attributed to the lower heat conductivity and greater moisture permeability of this material. The food was excessively dried out during heating in the molded fiber container. This evaporation of moisture has a cooling effect and retarded the heating process. To determine the degree of improvement that might be anticipated if the porosity of the molded fiber container were reduced, a container was coated with vinyl enamel paint to seal the inside surface. Testing this container in the same manner as the uncoated molded fiber container yielded a significant reduction in heating time as indicated. The coating reduced the moisture permeability, and only slight food drying occurred in this test.

EXHIBIT B-6
U.S. Army Natick Laboratories
CONTAINER MATERIAL
TEST RESULTS

Container Material	Salisbury Steak in Gravy		Mashed Potatoes	
	Heating Time Min.	Food Quality	Heating Time Min.	Food Quality
Aluminum Foil-.004" Thick	37	Good	31	Good
Plastic (polysulfone) .015" Thick	40	Good	35	Good
Molded Fiber-.025" Thick	>120*	Very Dehydrated	>44**	Very Dehydrated
Molded Fiber-.025" Thick Spray Painted On Inside Surface With Vinyl Enamel Paint	68	Slight Dehydration Noted		

Test Conditions - Air temperature - 205 ± 5°F
Air velocity - 40 feet per second
All containers covered with aluminum foil
All food samples same weight and size

"Heating Time" is the time required for the temperature measured at the center of the frozen product to reach 165°F.

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* The temperature was 145°F at 120 minutes when the test was stopped.

** The temperature was 115°F at 44 minutes when the test was stopped.

The effect of the lower thermal conductivity and high moisture permeability of the molded fiber container is reduced at high heating air temperatures. The tests described above were repeated at 285 ± 5°F using the molded fiber and plastic containers. The Salisbury steak heating time was 42 minutes in the molded fiber container compared to 14 minutes in the plastic container. The manufacturer of the molded fiber container claims that in a commercial convection oven at 350°F, it takes only 5 minutes longer to heat food in the molded fiber container than it does in an aluminum foil container. This difference is of little consequence, however. The moisture permeability of the molded fiber container would probably have to be reduced to achieve the desired 9 month frozen storage objective. The manufacturer states that if meals are to be stored in a frozen state for an extended period, a moisture barrier case or case liner should be used to retard dehydration.

Container material cost could be reduced if 200°F heating were used. This low temperature would allow consideration of several lower cost plastics such as styrene, polyethylene, and polypropylene. These materials may be easily thermoformed into aesthetically pleasing smooth walled containers which could be covered and sealed with a plastic film. This type of covering would probably increase storage life and be less costly than a crimped on aluminum foil cover.

Assuming the plastic is formed from .015" thick styrene capable of 230°F service, a 1.5" x 6.5" x 8.5" container would weigh 0.53 ounces. At the current market price of $.23 per pound, the material cost for this container is calculated to be $0.008. An aluminum foil container of this size weighs 0.64 ounces and the current market price of aluminum foil is $.70 per pound. Thus, the material cost for an equivalent aluminum foil container is $.028.

The 71 percent material cost advantage indicated would be increased by the fact that a coating such as vinyl epoxy should be applied to the inside surface of the aluminum foil container to prevent chemical reaction with acidic products like tomato sauces. Further, it should be noted that the .015" thick plastic is more likely than the .004" thick aluminum foil to be acceptable to the soldier being served. The plastic container would have a more pleasing appearance and be less susceptible to being punctured by operations such as meat cutting. This is particularly important in the field feeding situation since a supporting table or tray will probably not be available.

5. FOOD THICKNESS SUBSYSTEM

A thin food layer is desirable for fast freezing and heating of the food with minimum food surface deterioration. Thicker food is desirable for the following reasons:

- By tradition, the quality of some food items is associated with thickness. A thick steak, for example, is preferred over a thin steak.
- A thick layer of food will be less susceptible to dehydration, oxidation, or accidental thawing because less surface is exposed for a given volume of food.
- Less container material will be required for thicker food portions.

Because of the inherently thick food items such as hot rolls and baked potatoes, on the 28 Day Master Menu, food thickness of 1.5" can be expected. This thickness is used in school lunch programs. The fact that the thickness of food in "TV" dinners is about 0.8" indicates that food storage deterioration and container material requirements may be acceptable at this thickness.

If the menu could be modified or the form of thick food items changed so that a 0.8" food thickness could be used, food heating time would be substantially reduced. A test was conducted to indicate the difference in heating time caused by food thickness. A 0.8" thick layer of Salisbury steak in gravy and mashed potatoes was placed in an aluminum foil container and covered with aluminum foil. A 1.5" thick layer of the same food items was placed in another aluminum foil container. These containers were subjected to 200°F air at an average velocity of 19 feet per second. The heating times required to reach 165°F were as follows:

	Time To Raise Temperature To 165°F	
Food Item	0.8" Thick Food	1.5" Thick Food
Salisbury steak in gravy	30 min.	75 min.
Mashed potatoes	33 min.	70 min.

These data indicate that food heating time is approximately proportional to food thickness.

6. LOGISTICAL SUBSYSTEM

There are two major aspects of the logistics of field reconstitution system supply which have a bearing on development of the design.

- Period of resupply
- Thermal condition of the food

(1) Period Of Resupply

Whether the supplies for one meal, one day, or several days are to be handled by the field kitchen should be decided on the basis of supply transport requirements and field kitchen storage requirements. The conditions are quite different between combat and peacetime operation, and different periods of resupply might be used in these two cases. It appears that a three day period of resupply would be practical because it allows kitchen operation over weekends during peacetime.

Deliveries to the kitchen could be regularly scheduled three times a week, such as Monday, Wednesday and Friday. Of course, combat conditions may impose a different or irregular schedule. The three day resupply period on the above basis was assumed for this study. Food, fuel, and water supplies required by reconstitution system concepts are determined for the three day period.

(2) Thermal Condition Of the Food

Both advantages and disadvantages result from thawing the food prior to reconstitution. The advantages are as follows:

- Heating time would be significantly reduced. This would reduce the quantity of fuel required and for some reconstitution concepts, the amount of heating equipment required. For example, if only thawed food were to be heated in microwave ovens, the number of microwave ovens would be reduced by 6, the electrical power reduced by 25 KW and fuel consumption by more than 2 gallons per day.

- Somewhat better food quality might be realized, because the likelihood of overheating the outside surface is reduced as the amount of heat required to reach serving temperature is reduced.

- The development risk of some concepts, such as using microwave ovens, would be reduced because the bulk of experience is in heating food from the thawed state.

Imposing the requirement that all food must be thawed prior to the start of reconstitution penalizes the total field feeding system in several ways as indicated by the following disadvantages:

- Thawing refrigerators would have to be added to the field kitchen. Assuming specially sized units to hold the preplated meal hot packs for two meals in wire baskets, 95 cubic feet and 1000 pounds is added to the field kitchen. For bulk packed food, capacity for three meals is required because the thawing time is 12 hours.

- The kitchen food inventory must be increased by the number of meals in the thawing refrigerator to assure adequate thawing time. The thawing refrigerator does not reduce frozen food storage requirements.

- Reconstitution labor is increased because the frozen food must be transferred to the thawing refrigerator from the frozen food storage space.

- Added diesel electric generator capacity of 1.4 KW with its associated fuel requirement is needed.

- The thawing refrigerator adds a different type of equipment with its own maintenance and operational requirements.

- Some method for periodic thawing and cleaning of the thawing refrigerator must be provided. A duplicate portable thawing refrigerator might be required.

The penalties imposed by thawing the food prior to reconstitution outweigh the potential advantages. Thus, reconstitution system concepts using thawed food were not pursued.

Another aspect of the thermal condition of the food which has been considered is the supply and field kitchen storage required. The general types of food to be handled by the system are:

- Frozen foods to be heated to 165°F for serving
- Frozen foods to be thawed and then served
- Frozen foods to be served frozen
- Fresh foods which may not be frozen but require refrigerated storage

It would simplify the field feeding system if all of these foods could be packaged so that one common environment could serve as supply and field kitchen storage. If this could be done without mechanical refrigeration, further advantages would be realized. The frozen food is largely ice, so the concept of insulated food storage containers using the frozen food as the heat sink was investigated. Two major questions were identified.

- Can the frozen food be allowed to thaw so long as its temperature is not allowed to exceed 40°F?
- Can fresh salad vegetables be stored in the same container with frozen foods?

It is obvious that frozen foods which are to be served frozen must not be allowed to thaw. These could be shipped and stored in a separate insulated container with a specially contained low freezing temperature chemical, or dry ice. In any case, these items constitute a small percentage of the menu. The majority of foods are frozen food heated to 165°F and frozen food which is thawed and served cold. The question is, will the quality of these foods be jeopardized by using their latent heat of fusion as a refrigerant? A test program which has recently been completed under the direction of C. K. Wadsworth, Chief, Process Development Division, Food Laboratory, U.S. Army Natick Laboratories, indicates that the answer to this question is a qualified yes. Eight representative entree and vegetable items were prepared using the recipes of the Armed Forces Recipe Service for the vegetables, and the recipes used in the Fort Lee Central Food Preparation Facility for the entree items. The food items were divided between a frozen control sample held at -30^{O}F and a sample placed frozen in an insulated box. The sample in the insulated box was permitted to slowly thaw during storage. After storage periods of from two to four weeks, both food samples were tested for microbiological contamination and taste. It was found that these foods which have a high water content were not adversely affected by this style of storage. It was noted that foods such as bread, have a low water content, and thus do not have much self-refrigerating capacity. Further, bread becomes stale rapidly at temperatures close to its freezing point. More work is required to determine the extent to which this technique may be applied to the cooked frozen food field feeding system. Nevertheless, a ration breakout point with mechanically refrigerated freezer storage facilities is envisioned to exist within one day's travel of the field kitchen. Thus, with a three day maximum resupply period, the storage time required is four days. This is significantly less stringent than the objective of the above test.

Two tests were conducted to determine whether or not fresh salad vegetables could be stored in the same container with frozen foods. A salad of lettuce, tomato, and cucumber was prepared and placed in 1.5" x 5" x 6.5" clear plastic containers .008" thick. After overwrapping with a thin flexible plastic film, these containers were placed in a 40^{O}F environment for one hour. Two 1.5" x 5" x 6.5", .004" thick aluminum foil containers were filled with three 4 ounce frozen beef patties each, and covered with aluminum foil. These containers were placed in a 0^{O}F environment for about one hour. The two frozen beef patty containers and one salad container were then placed in a specially constructed .1" thick corrugated cardboard box. The salad container was placed between the two beef patty containers with .1" thick corrugated cardboard separator pads above and below the salad container. The box was taped closed and placed in the 40^{O}F environment. The second salad container was retained in the 40^{O}F environment as a control sample. After 24 hours, the beef patties had completely thawed. No deterioration of the salad vegetables could be detected by visual and taste comparison with the control sample. This test indicates that salad vegetables may be stored in the same container with frozen food if packaged as indicated in Exhibit B-3(2). Further testing of the final packaging configuration with many more combinations of food product and test conditions will be required to determine the limits of this approach.

A second test was conducted repeating all of the conditions described above except two 0.2" diameter steel rods were used to separate the frozen beef patty containers from the salad container. After 24 hours, the cucumbers in the salad were slightly frozen and their texture had deteriorated. Other salad components were not adversely affected. This test indicates that some insulating protection of fresh salad vegetables is necessary if they are to be stored in the same container with frozen foods. A cold pack material like styrene foam might be used for preplated meal configurations.

7. FOOD CONTAINER DISPOSAL SUBSYSTEM

The method of food container disposal will depend, to a great extent, upon the container material which is chosen. Sanitation should be the primary concern. Molded fiber and some plastic containers may be incinerated. Aluminum foil and some plastic containers should be buried or recycled because aluminum will not burn and certain plastics produce noxious fumes. Depending upon the handling costs, recycling may reduce the overall container cost (about 10 percent of aluminum foil container cost is recoverable), but special precautions are required with unwashed containers to prevent odor, vermin and contamination problems.

8. ENERGY SOURCE SUBSYSTEM

Diesel fuel oil is the preferred energy source for Army field operation. This liquid fuel may be burned to produce heat or used in a diesel electric generator to produce electrical energy at 208 volts. Burning the fuel to produce heat is preferred for the field kitchen because it is more efficient than converting to electrical power used to heat electrically. Less weight and greater reliability also result.

Gaseous fuels such as LPG, simplify burner control. However this fuel is not currently available in the field and introducing it complicates the field supply system. Gaseous fuels are not considered practicable for Army field use.

The capability to use solid fuels would have the advantage of using locally available fuels in the case of supply interruption. Such a system might also be capable of using the heat produced from incineration of waste Unfortunately, temperature control of solid fuel burners to the extent required by the field kitchen has not been developed.

Alternatives to diesel engines for generating electrical power were not considered because of the requirement that maximum use shall be made of components with a previous history of high reliability, and the Army has such a history on diesel electric generators.

9. FOOD SERVING SUBSYSTEM

The method of serving will depend, to a great extent, upon the size of the food container which is selected (preplated meal, bulk pack, or single serving). With preplated meals and single serving packaging, one person could maintain the serving area since the operation would be largely self-service. Some limited garrison feeding experiments with self-service from bulk packs, indicated this mode of operation to be preferred by many soldiers.

The problems which could be caused by improper portion control and slow serving line speed in the field make it probable that servers will be required with bulk food. Four men serving should be adequate for serving from bulk packs.

Serving line speed is an important factor affecting reconstitution system design. It has been assumed in this study that the reconstitution system must be capable of maintaining a serving line speed of six men per minute. In commercial operation, cafeteria lines generally move at a rate of five to seven people per minute. Using preplated meals, rates of 25 children per minute are achievable in school lunch programs. The field kitchen situation is not likely to be as well organized, and the serving rate will be slowed by the fact that hot beverages will be served. In tests of the Mobile Field Kitchen Trailer now being developed, rates of 4.5 men per minute have been achieved. Based upon these data, the rate of six men per minute was chosen. Serving line improvements like elimination of the serving line with a scatter system may be necessary, but the reconstitution system will be designed to prepare the food fast enough so that it is ready for serving at the six men/minute rate.

Whether or not the food is eaten from the reconstitution container or a different container, and whether that container is disposable or reusable, has no effect on the reconstitution system design. As noted previously, the preplated meal container, if disposable, could be eaten from directly. This would eliminate mess gear washing. This is not likely to be the case with disposable single serving containers, since it is probable that a tray would be needed to carry the six separate containers composing a meal. This tray would also have to be disposable to eliminate mess gear washing.

10. ANCILLARY EQUIPMENT SUBSYSTEM

The ancillary equipment required for best reconstitution system performance is detailed in the description of each system concept shown in Appendix D.

11. MODE OF TRANSPORT SUBSYSTEM

Selection of the mode of field kitchen transport affects reconstitution system design with regard to the degree of ruggedness required and the maximum allowable size of any one module. Air drop and jeep transport are probably the limits relative to ruggedness and small module size. While these modes have advantages in certain situations, a trailer mounted kitchen has advantages in most field operating situations.

APPENDIX C

CONCEPT EVALUATION CRITERIA

APPENDIX C

CONCEPT EVALUATION CRITERIA

Evaluation criteria were developed to provide a basis for objectively selecting the best reconstitution system concept from among all of those developed. The criteria reflect the requirements for the system as stated in the contract.

Two groups of criteria were identified; one group pertaining to the reconstitution effectiveness, and the other group pertaining to the resource requirements of the system. Within each group, weighted numerical ratings were ssigned to each criteria in accordance with the relative importance of that criterion compared with the others in the group. The total of the ratings in each group is 100.

Each concept was evaluated and rated on its ability to fulfill the requirements of each of the criteria. For example, if a concept completely fulfilled the requirements of a criteria with a rating of 8, the concept was rated 8. If the concept marginally met the requirements, it was rated 2. If the concept did not meet the requirement at all, it was rated 0 and eliminated from further consideration.

Following is a discussion which defines the criteria, their rating ranges, the minimum acceptable performance level, and other factors used to evaluate each design concept relative to the criteria.

1. EFFECTIVENESS

(1) Percent Of Menu (Rating Range - 8)

The reconstitution system must be capable of reheating a minimum of 85 percent of the hot food items on the 28 Day Master Menu. Percent of menu capability is based upon a determination of those foods which would be unacceptable if reheated in the reconstitution system. Food items which would not have acceptable quality if frozen are considered to be supplied fresh, and a judgment of the reconstitution system's capability to cook these items is included. The total number of times per man, N, these items are to be served in the 28 Day Master Menu is based upon the data presented in the Appendix to U.S. Department of Commerce form DIB 952, Frozen Cooked Food Survey. It was also determined from these data that a total of 286 hot food servings per man are required. The calculation of percent of menu capability is based upon the following formula:

$$\text{Percent of menu} = \frac{(286 - N) \times 100}{286}$$

(2) Food Quality - (Rating Range - 10)

As a minimum, food quality after reconstitution should be comparable to that of food served in CONUS garrisons. Those items included in the calculation of percent of menu above are not to be considered here. Questions to be considered are:

- What are the typical characteristics of the food quality?
- What is the usual temperature uniformity obtained throughout the food?

(3) Throughput - (Rating Range - 8)

The reconstitution system must be capable of reconstituting enough food from 0°F to 165°F in such a way that a serving rate of six men per minute can be maintained for a group of 200 men. Completion of heating within one hour is a design goal. Questions to be considered are:

- What equipment preheat time is required?
- What is the total elapsed time required from start of preheat until the first meal may be served?
- What is the maximum serving rate which could be sustained?

(4) Emergency Raw Food Cooking - (Rating Range - 8)

The reconstitution system must be capable of cooking raw food in emergencies. Questions to be considered are:

- What percent of the 28 Day Master Menu items which are cooked from raw ingredients could be cooked in emergencies? A total of 373 food item servings per man were identified as requiring cooking, if not supplied in frozen convenience form, based upon the data presented in the Appendix to U.S. Department of Commerce form DIB 952, Frozen Cooked Food Survey.
- What will be the cooked food quality?
- What items will require unusual preparation techniques which are likely to cause the food to emerge in an unfamiliar form?

(5) Ease Of Operation - (Rating Range - 8)

Reconstitution system operating personnel must not need special training or instruction other than that contained in a typical instruction manual issued for the equipment. All operations from the removal of the frozen food from its storage container to the transfer of the heated food to the serving area are considered reconstitution system operations. Questions to be considered are:

- How many adjustments and measurements are required to achieve acceptable food quality?
- What would be the consequences of possible operator errors?
- To what extent could the reconstitution system operator be utilized for other field kitchen tasks such as preparing beverages, preparing cold packs, or helping serve the food.

(6) Packaging Flexibility - (Rating Range - 3)

As a minimum, the reconstitution system must be capable of operating with one frozen food package type. The physical dimensions may be nonstandard, but wherever possible, currently available standard container types should be given preference. Questions to be considered are:

- How many of the three basic types of food containers (preplated meal, bulk pack, and single serving) can the system handle?
- What packaging materials may be used?
- What are the package size and shape requirements?
- Are operator manipulations of the package covering required to achieve acceptable quality?

(7) Safety (Rating Range - 8)

The reconstitution system should not introduce safety hazards other than those normally associated with cooking equipment. Questions to be considered are:

- Does the equipment meet the requirements of recognized consensus codes and standards?
- What is the danger of causing injury to the operator or repairman?
- If some part of the equipment fails or the operator does something wrong, what would be the consequences? (Fire, explosion, radiation, burns, or splashing?)
- What is the potential for causing personnel health problems as a result of microbiological contamination?

(8) Mobility (Rating Range - 8)

The reconstitution system must be compact and lightweight to allow for storage and transportation to and in the field by existing military equipment. The size of the reconstitution system and its ancillary equipment must not be of such volume as to prohibit a mobile field kitchen design. The typical existing military transport equipment and possible mobile field kitchen configurations shown in NLABS Technical Report 73-44-GP* will be used as a guide. Questions to be considered are:

- What are the sizes and weights of the reconstitution system and its ancillary equipment?
- Has the equipment been used in mobile applications?
- Is the equipment sufficiently rugged to withstand cross-country transportation?
- What time and manpower is required to assemble or disassemble from transport to operating configuration?

(9) Reliability - (Rating Range - 16)

The reconstitution system should maximize the use of components and techniques with a previous history of high reliability. Questions to be considered are:

- How well proven are the system components?
- What components might be expected to fail?
- What are the consequences of an equipment failure? (No meal, longer process time, poor food quality?)
- What is the potential for making the food unconsumable?
- What is reliability of ancillary equipment required by this concept?

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* J.C. Perry, G.D. Bell, and CPT H.M. Toczylowski, An Evaluation Of Alternative Mobile Field Kitchen Concepts, U.S. Army Natick Laboratories Technical Report 73-44-GP, February 1972.

(10) Maintainability - (Rating Range - 8)

The reconstitution system must be maintainable in the field by military personnel with some specialized maintenance training. Questions to be considered are:

- How difficult is normal maintenance, i.e., cleaning, oiling, etc.?
- What spare parts or tools are required?
- What skills and training are required to repair?
- What are the maintenance requirements of ancillary equipment required by this concept?

(11) Survivability - (Rating Range - 3)

The reconstitution system must be capable of operation in a combat environment without causing abnormal personnel hazards not present in a noncombat environment. Questions to be considered are:

- Is equipment capable of withstanding combat conditions?
- Will enemy detection be avoided?
- Could equipment failures caused by possible enemy fire endanger the kitchen personnel?

(12) Environmental Suitability - (Rating Range - 4)

The reconstitution system must be capable of operating in the extreme environmental conditions to which a field kitchen may be subjected. Further, the system must not cause the environment in the kitchen to become uncomfortable. Questions to be considered are:

- What equipment operating problems would be caused by extreme cold, heat, rain or snow?
- What effect will the equipment operation have on the kitchen environment?

(13) Development Risk - (Rating Range - 8)

The probability of successful development of the reconstitution system must be such that a workable system seems reasonable. Questions to be considered are:

- How well is the concept proven?
- What new equipment developments are required?
- What modifications to standard equipment are required?
- What special ancillary equipment is required?

2. RESOURCE REQUIREMENTS

(1) Manpower - (Rating Range - 20)

The reconstitution system must be operable by one person. All operations from the removal of the frozen food from its storage container to the transfer of the heated food to the serving area are considered reconstitution system operations. Questions to be considered are:

- How many man-hours and people are required for setup and assembly of the reconstitution system and its ancillary equipment?
- How many man-hours are required for the reconstitution operation?
- How many man-hours and people are required for cleanup and normal maintenance?
- How many man-hours and people are required to maintain ancillary equipment needed by this heating system concept?

(2) Supply - (Rating Range - 25)

The supply requirements of the reconstitution system must not exceed that which could be supplied by a standard 2½ ton tactical vehicle with trailer using a three day resupply interval. Questions to be considered are:

- What quantities (weight and volume) of supplies are required for three days of operation?
  - Food, including packaging
  - Water
  - Fuel
  - Other expendables
- Is transport mechanical refrigeration required for a 12 hour travel time?

(3) Development Cost - (Rating Range - 10)

An estimate is to be made of cost to develop the field reconstitution system to the point of a working prototype.

(4) Production Cost - (Rating Range - 25)

An estimate is to be made of the cost of producing the reconstitution system with its ancillary equipment in quantities of 100 systems.

(5) Operating Cost - (Rating Range - 20)

The operating costs of reconstitution system concepts are to be compared in terms of the labor, fuel, and water expended per day.

APPENDIX D

DESCRIPTION AND EVALUATION OF RECONSTITUTION SYSTEM CONCEPTS

APPENDIX D

DESCRIPTION AND EVALUATION OF RECONSTITUTION SYSTEM CONCEPTS

This appendix describes each of the reconstitution system concepts with regard to its configuration and operation in the field kitchen. Facts, findings, and judgmental data pertinent to the evaluation are summarized for each concept following its description. Data for each criterion were compared with similar data for the other concepts to establish the ratings used in the decision matrix to select the best concept. These ratings are included here for reference purposes.

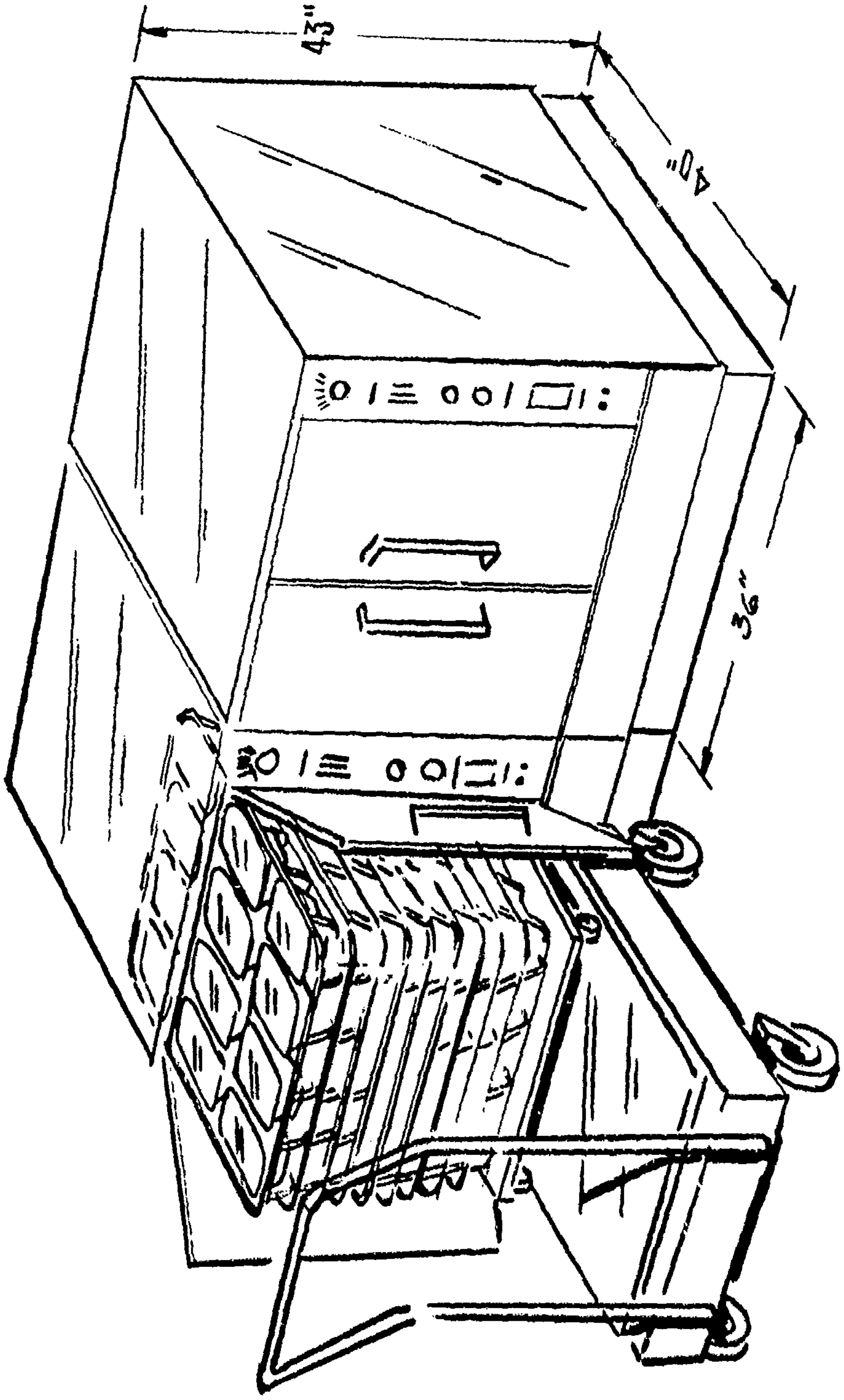
Many of the reconstitution system concepts incorporate cooking equipment which is similar to currently available equipment. In these cases, operating characteristics, dimensions, costs, and other values shown are based upon an evaluation of data from several manufacturers. In some cases, the size of equipment shown in the concept is not currently available. This resizing of the equipment was only done when the availability of sizes larger and smaller than the desired size and other technical evaluation indicated feasibility.

1. CONVECTION OVEN, ELECTRIC, PREPLATED FOOD

The convection oven is the most commonly used method of reconstituting frozen convenience foods in mass feeding operations. Air within the cooking chamber is heated and circulated around the food by a blower. The same convection oven is often used to cook food from the raw state, and bake breads and pastries. The major advantages are versatility and the capability to process large batches of frozen cooked food with little handling. The major disadvantage is that operator inattention can cause poor results.

An outline drawing of an electric convection oven system for reconstituting frozen cooked food in either preplated meal or single serving packaging is shown in Exhibit D-1. In these ovens the air is heated with electrical resistance heating elements. Wire baskets and dollies are included to facilitate the handling of preplated meals or single serving packages. The food would be served directly off of the baskets and dollies after heating is completed.

EXHIBIT D-1
U.S. Army Natick Laboratories
CONVECTION OVEN,
ELECTRIC PREPLATED MEALS



The basic operational steps for using this equipment would be as follows:

- The ovens would be turned on for preheating 20 minutes prior to loading.
- The containers of frozen food would be loaded into wire baskets on a dolly and pushed into the oven. A full oven load would be 108 meals.
- Completion of reconstitution would be determined by the operator. He could watch a thermometer inserted into a representative food container, or the elapsed heating time could be controlled. The time required depends upon the food and would typically be 20 to 35 minutes.
- When heating is completed, the stack of meals in wire baskets would be removed from the oven and moved to the serving area on a dolly. The dollies would be covered with an insulating blanket as required to keep the food warm.

The schedule for performing these operations is shown in Exhibit D-2.

In an emergency, raw foods would be cooked in baking pans which would be carried with the kitchen specifically for this purpose. Special wire oven shelves would also be required for this mode of operation.

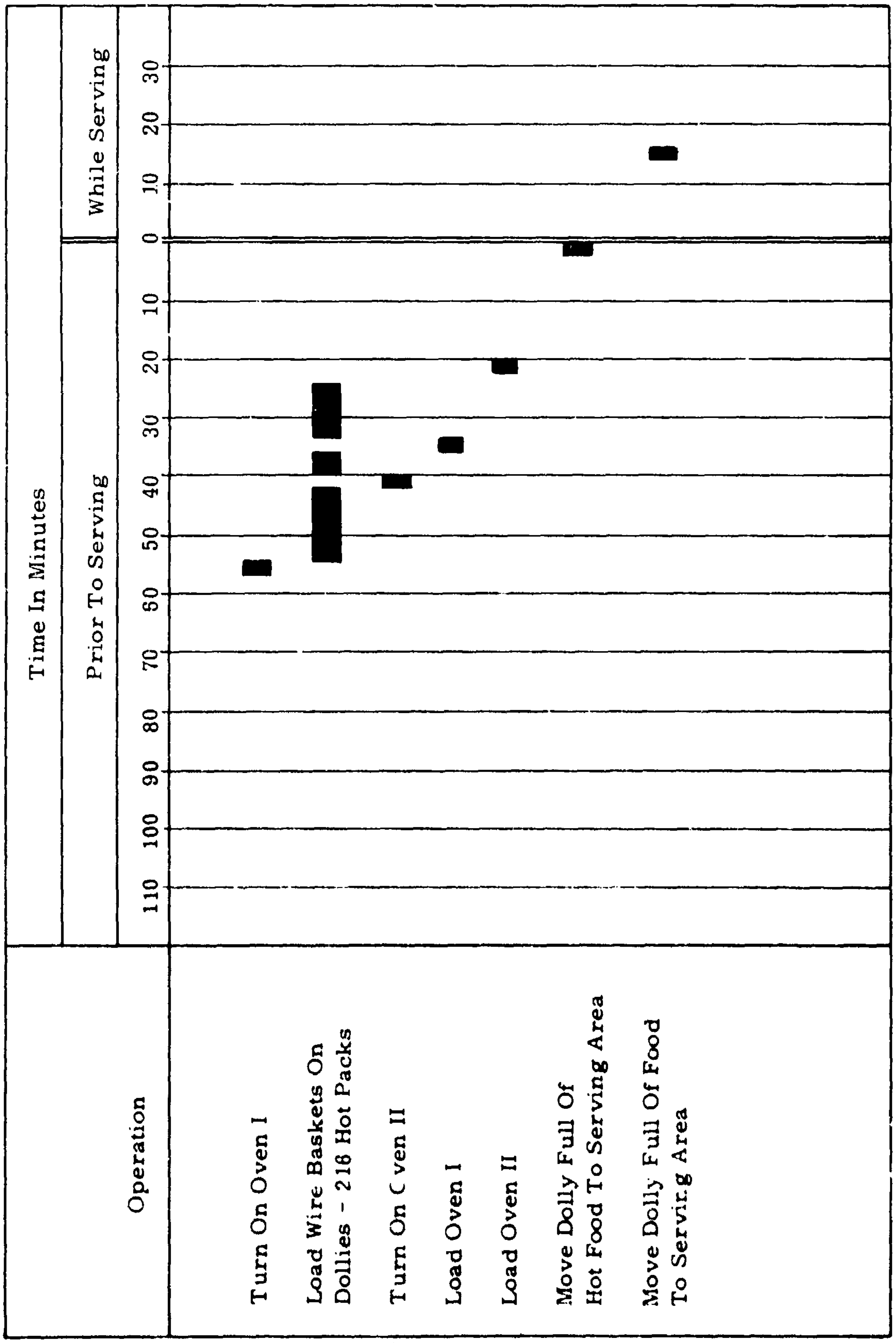
The following is a summary of data used to evaluate this concept.

EFFECTIVENESS - (Rated 77 Of 100)

(1) Percentage Of Menu (Rated 8 Of 8)

- 100 percent of the frozen precooked hot 28 Day Master Menu items can be reconstituted.
- Soups are not usually heated in this type of oven, but no problem is anticipated.

EXHIBIT D-2
U.S. Army Natick Laboratories
CONVECTION OVEN
PREPLATED MEALS



(2) Food Quality (Rated 3 Of 10)

- The maximum time the food would be held at serving temperature is 18 minutes.
- Some foods may be dried out or overcooked at the edges.
- No temperature uniformity data is available, however, it is generally recommended that the foods be allowed to stand after heating for a few minutes to achieve an even distribution of temperature.
- Breaded and other products requiring a crisp dry surface may be done by removing the container cover.
- "Brown and serve" type bakery products may be done well

(3) Throughput - (Rated 8 Of 8)

- 20 minute preheat is required.
- Total elapsed time from start of preheat to serving the first meal is 57 minutes.

There is no limit to the maximum possible serving rate. All 216 meals could be ready simultaneously, if desired.

(4) Emergency Raw Food Cooking - (Rated 8 Of 8)

- 100 percent of the 28 Day Master Menu raw ingredients can be cooked in emergencies.
- All cooked foods will have a baked or roasted quality.

- Items which require unusual preparation techniques and will not emerge in a traditional form are as follows:

  - Sauces
  - Breading
  - Liver
  - Beef Steaks
  - Pork Slices (chops)
  - Veal Steaks
  - Gravies
  - French Toast
  - Hot Cereal
  - Griddle Cakes

(5) Ease Of Operation - (Rated 4 Of 8)

- Some adjustment of temperature at the start of the heating process may be required. Acceptable food quality is very dependent upon the operator properly determining when heating is completed.

- The consequence of operator error could be that the food would be made inedible.

- For about 20 minutes before the start of serving and during the serving process, with the exception of short unloading periods, the operator would be relatively free.

(6) Packaging Flexibility - (Rated 1 Of 3)

- Preplated meals and single serving packages may be processed in this system. See Concept No. 2 for a convection oven system to process bulk packed food

- Any material which can withstand 400°F continuously and is food compatible may be used. Throwaway containers made of aluminum foil, molded paper fiber and high temperature plastics such as polysulfone and nylon 6 have been used.

- This system is designed to use preplated meal packages of the configuration shown in Exhibit B-4. Single serving packages would have to be similar to the individual compartments of the preplated meal packages.

- Acceptable quality is achievable without package cover manipulation All food packs are heated with their covers on in school lunch programs. If some food product is found to be significantly improved by uncovered heating, covers are available with plastic film windows which are self-opening at oven temperature.

(7) <u>Safety - (Rated 8 Of 8)</u>

- Commercial electric convection ovens typically meet the requirements of Underwriters Laboratories and the National Sanitation Foundation.

- There are no unusual hazards to the operator or repair personnel. The use of the loading dolly reduces the potential for burns.

- No unusual hazards result from equipment or operator failure.

- No unusual potential for microbiological contamination has been identified.

(8) <u>Mobility - (Rated 5 Of 8)</u>

Sizes and weights of reconstitution system and ancillary equipment are as follows:

-	Mechanically refrigerated food storage container for three day food supply (235 cu.ft. storage)**	330	3000
-	Two dollies w/removable handles (30"x28"x12"high ea)	11	100
-	18 wire baskets (2.6"x25.9"x26.8" ea; baskets are assumed to be stored in oven cavities during transport)	0	108
-	Two folding insulating blanket covers	2	5
-	12 pans with cover for emergency cooking (7"x17.5"x21" ea, nesting)	4	40
-	12 wire shelves for emergency cooking	3	60
	Total	468 cu.ft.	7113 lbs.

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* Diesel electric generator data shown is based upon commercially available self-contained units rated for continuous operation at power level shown.

** 90 percent packing efficiency assumed.

Convection Oven, Electric, Preplated Food (cont'd)

- Some electric convection ovens have been supplied with casters. Small models have been used to heat food in aircraft.

- The equipment appears to be sufficiently rugged.

- No configuration change is required from mobile to operating condition.

(9) Reliability - (Rated 12 Of 16)

- The equipment is well proven and has had a low failure rate during wide use in school lunch programs and in restaurants.

- Oven air circulation blower motor failure and calibration change of the temperature control have been identified as possible causes of oven failure. No data on frequency of occurrence was obtained, but a low rate is indicated.

- The consequence of one oven failing would be that the serving rate would be reduced to three meals per minute or the second half of the men being served would have to wait about half an hour for their food.

- If the diesel electric generator would fail, no hot food could be prepared. The consequence of other ancillary equipment failure would be insignificant.

(10) Maintainability - (Rated 8 Of 8)

Oven cleaning of baked-on spills is difficult. The self-cleaning oven approach is possible.

- The fan motor will require periodic oiling.

- Minimal skills and standard tools are required for repair.

- Diesel electric generator maintenance is required.

Convection Oven, Electric, Preplated Food (cont'd)

(11) Survivability - (Rated 2 Of 3)

- The equipment is apparently capable of withstanding combat conditions.
- 40 KW diesel electric generator noise will be a possible cause of enemy detection. Radio interference of the electrical system can be shielded.
- No increased personnel hazard is anticipated from equipment failures which might be caused by enemy fire.

(12) Environmental Suitability - (Rated 2 Of 4)

- No problems are caused by extreme environmental conditions. Startup of 40 KW diesel electric generator in cold weather may require special procedures.
- The ovens will put some heat into the kitchen, especially during loading and unloading of the food.

(13) Development Risk - (Rated 8 Of 8)

- This type of equipment is well proven. It is probably the most frequently used method of heating frozen convenience foods where large groups of people are to be fed.
- Modifications required include the following:
  - Increased ruggedness
  - Modularized controls and critical components

Convection Oven, Electric, Preplated Food (cont'd)

RESOURCE REQUIREMENTS - (Rated 87 Of 100)

(1) Manpower - (Rated 17 Of 20)

. Setup and disassembly of the reconstitution system and ancillary equipment each time the field kitchen is moved should require no more than 1 man-hour.

. The following labor requirements are estimated for operation of the reconstitution system each day:

-	Reconstitution system operation	4.5 man-hours
-	Cleanup and maintenance of two ovens and two dollies	1.5 man-hours
-	Operation and routine maintenance of 40 KW diesel electric generator	1.5 man-hours
	Total	7.5 man-hours per day

(2) Supply - (Rated 25 Of 25)

. The following quantities of supplies are required for three days of operation:

		Volume Cu.Ft.	Weight Lbs.
-	Food including packaging*	270	4200
-	Water for oven cleanup (nine 5 gallon cans for three days)	6.3	465

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* It is assumed here that the preplated meals are supplied in fiberboard cases as shown in Appendix B. An insulated container with 2" thick walls is used on the transport truck, and a mechanically refrigerated (38 to 40°F) food storage cabinet is used at the field kitchen.

Convection Oven, Electric, Preplated Food (cont'd)

		Volume Cu.Ft.	Weight Lbs.
-	Diesel Fuel* (27 gallons in six 5 gallon cans for three days)	4.2	259
	Total	280	4924

(3) Development Cost - (Rated 10 Of 10)

- Design and develop nonstandard size oven
- Increase ruggedness of oven and dollies
- Modularize controls and critical components to facilitate field service
- Estimated development cost - $30,000 to $100,000

(4) Production Cost - (Rated 25 Of 25)

. Approximate average cost of slightly smaller commercial ovens ($1600 ea)	$3,200
. Estimated cost increase for increased capacity	1,000
Estimated cost increase for increased ruggedness and modularized design	1,000
. Estimated cost of two ruggedized dollies	500
Estimated cost of 18 wire baskets	200
. Estimated cost of 75 cu.ft. capacity refrigerated storage container	3,500

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* See Appendix G, Example Calculations

Convection Oven, Electric, Preplated Food (cont'd)

. Estimated cost of two folding insulating blanket covers	$ 100
. Estimated cost of 12 pans for emergency food cooking	500
. Estimated cost of 12 wire shelves	100
. Estimated cost of 40 KW diesel electric generator	5,500
Total	$15,600

(5) Operating Cost (Rated 10 Of 20)

. Labor expended	7.5 man-hours per day
. Diesel fuel expended	9 gal.per day
. Potable water expended	15 gal.per day

2. CONVECTION OVEN, ELECTRIC, BULK PACKED FOOD

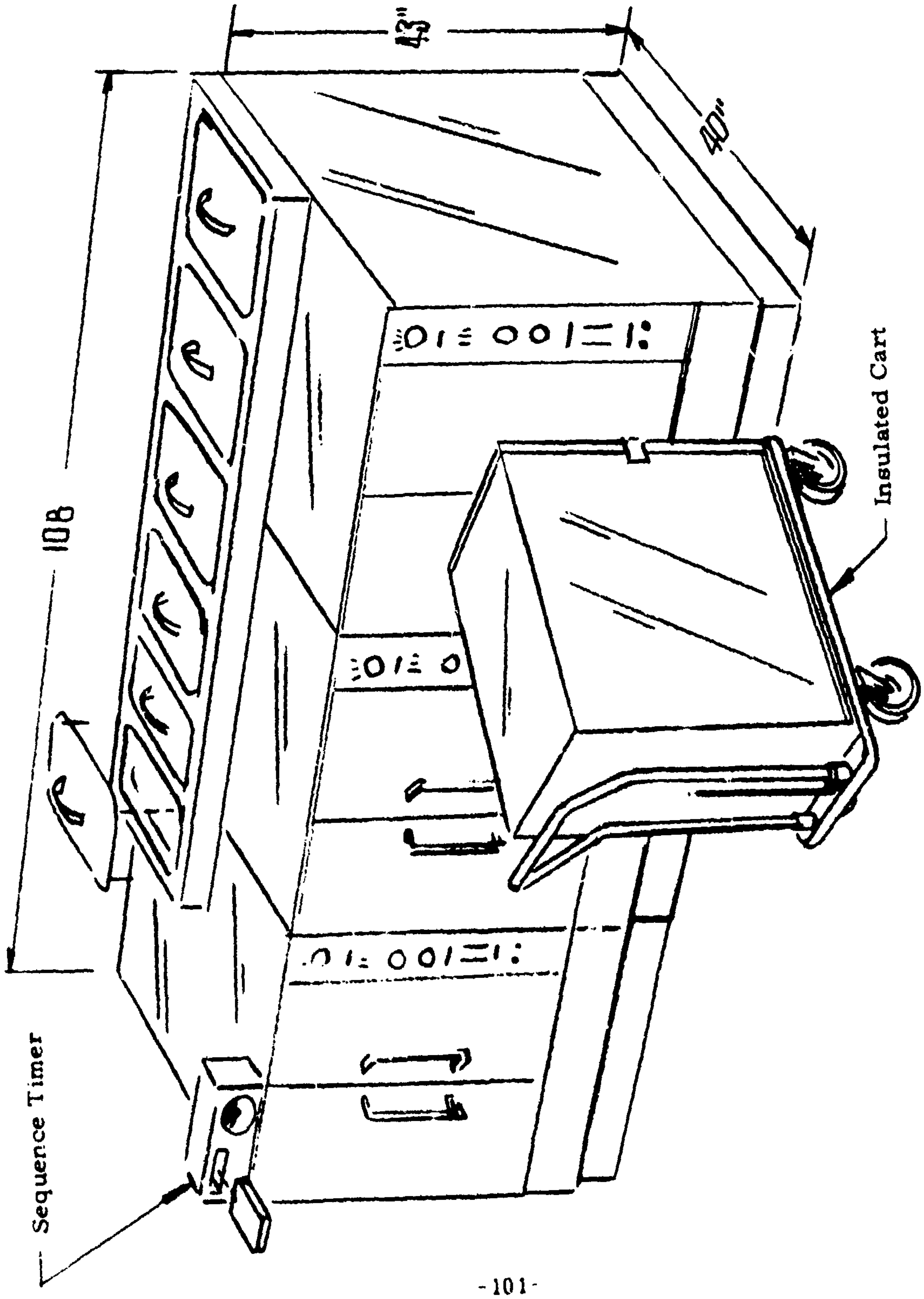
The convection oven used in this concept is the same type and size as that used in Concept No. 1. For heating frozen cooked food packaged in half size steam table pans, three ovens are needed instead of two because more space is needed around the thicker bulk packed food to provide more circulation of the hot air. A wheeled insulated cart is included for moving the food from the frozen storage space to the ovens and from the ovens to the serving area. The food would be kept hot in the insulated cart until it is needed for serving. A serving table with covered insulated wells is included to keep the opened pans warm during servings. If the kitchen layout permits, this feature could be incorporated into the top surfaces of the ovens. The back sides of the ovens would then have to be enclosed to protect the soldiers being served. A sequence timer is included to help assure that the proper operational sequence is followed. An outline drawing of the reconstitution system is shown in Exhibit D-3.

To take advantage of the improved food quality possible with bulk packed foods, the pans must be loaded into the oven at their proper times. For example, the loading sequence of the first oven would be as follows:

- 90 minutes before serving - load pans containing meat
- 75 minutes before serving - load pans containing starchy food products
- 60 minutes before serving - load pans containing vegetables
- 10 minutes before serving - load pans containing hot biscuits

When all the foods have reached 165°F the oven would be turned down to a holding temperature, to keep the food at the proper temperature until it is needed at the serving area. This procedure will improve quality because each type of food is heated for the right length of time. However, keeping track of the loading schedule adds complication. A sequence timer is included to help the operator. A tape cassette would be supplied for each meal. By inserting the cassette and setting the desired serving time, the operator would activate the timer. From then on, the sequence timer would give an audible command at the proper time for each operation. For example, "Load pans of meat into oven 1."

EXHIBIT D-3
U.S. Army Natick Laboratories
CONVECTION OVEN, ELECTRIC
BULK PACKED FOOD



Convection Oven, Electric, Bulk Packed Food (cont'd)

The basic operational steps using this equipment would be as follows:

- The ovens would be turned on for preheating 20 minutes prior to loading.
- Up to 72 half size steam table pans would be handled individually from the freezer to a cart, from the cart to the oven, and from the oven to the serving area. One oven load consists of 24 half size steam table pans.
- The operator determines completion of reconstitution as with preplated meals. Within one oven load, different food items would be loaded at different times for proper heating.
- When heating is completed the oven would be manually turned down to a holding temperature. The half size steam table pans would be individually removed to the serving area as needed.
- During serving, the open pans would be kept warm in insulated wells with covers in a serving table. The schedule for performance of these operations for the standard day's dinner is shown in Exhibit D-4.

Cooking of raw foods in an emergency would be done in specially provided baking pans. If 18 wire baskets and two dollies were added, this configuration could be used to reconstitute preplated meals and single serving packages also. The following is a summary of the data used to evaluate this concept.

EFFECTIVENESS - (Rated 71 Of 100)

(1) Percent Of Menu (Rated 8 Of 8)

- Same as for Concept No. 1.

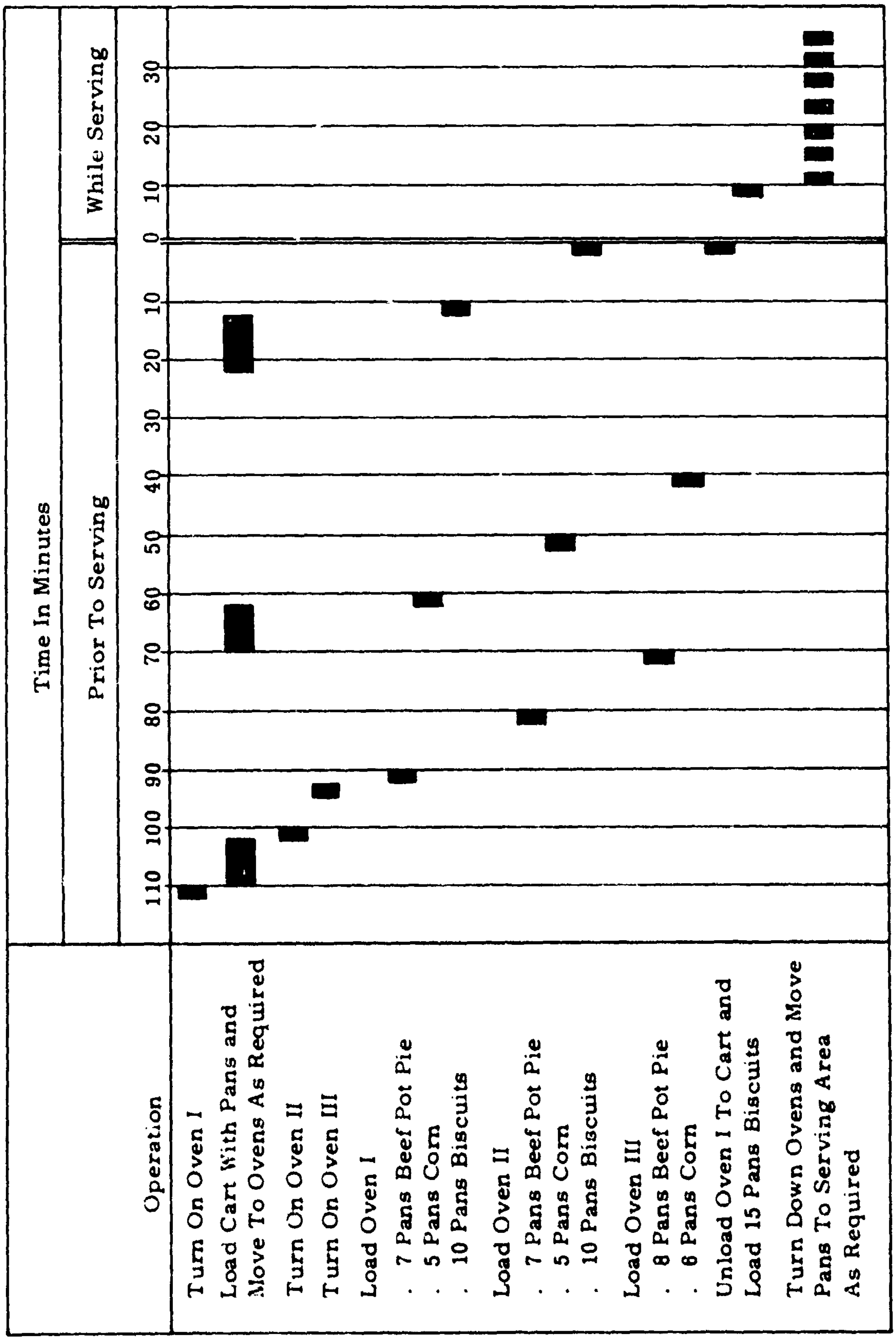
EXHIBIT D-4

U.S. Army Natick Laboratories

OPERATING SCHEDULE

CONVECTION OVEN

BULK PACKED FOOD



Convection Oven, Electric, Bulk Packed Food (cont'd)

(2) Food Quality (Rated 7 Of 10)

- The maximum time the food would be held at serving temperature is 13 minutes.
- The tendency to dry out or overcook some foods at the edges is greater than with preplated frozen food heated in a convection oven.
- The food in bulk pans can be stirred at serving time to take care of slight sauce separation, dried surfaces, and temperature nonuniformity.
- Each food product would be heated for its optimum time instead of heating meats, potatoes, and vegetables for the same time as is necessary with preplated meals.
- Removal of container covers for crisp dry food surfaces is easier than with preplated foods.
- "Brown and serve" type bakery products may be done well

(3) Throughput - (Rated 4 Of 8)

- 20 minutes preheat is required.
- 110 minutes is required from the start of preheat until the first meal may be served.
- A maximum serving rate of 6.3 meals per minute may be sustained for the standard day's dinner.

(4) Emergency Raw Food Cooking - (Rated 8 Of 8)

- Same as for Concept No. 1.

Convection Oven, Electric, Bulk Packed Food (cont'd)

(5) Ease Of Operation - (Rated 4 Of 8)

- Some adjustment of temperature at the start of the heating process may be required. Acceptable food quality is very dependent upon the operator properly determining when heating is completed. A sequence timer may improve the situation to some extent, but operator judgment would still be required.
- The consequence of operator error could be that the food would be made inedible.
- For about 40 minutes before the start of serving, with the exception of short loading and unloading periods, the operator would be relatively free.

(6) Packaging Flexibility - (Rated 2 Of 3)

- Bulk packed food may be processed in this system. If two dollies, 18 wire baskets, and two insulating blanket covers were added; preplated meals and single serving packages could be handled.
- Any material which can withstand 400°F continuously and is food compatible may be used. Throwaway containers made of aluminum foil are generally used.
- This system is designed to use bulk packed foods in containers of the configuration shown in Exhibit B-3.
- Foods which require a crisp or dry surface should be uncovered before heating. Some products, such as macaroni and cheese, can be improved by removing the cover during the last five minutes of heating for surface browning.

Convection Oven, Electric, Bulk Packed Food (cont'd)

(7) Safety (Rated 7 Of 8)

- Same as for Concept No. 1 except that the pans would be individually loaded into the oven. This increases the possibility for operator burns over that with a loading dolly.

(8) Mobility (Rated 2 Of 8)

- Size and weights of reconstitution systems and ancillary equipment are as follows:

	Volume Cu.Ft.	Weight Lbs.
- Three ovens (36"widex40"deepx43"high ea)	108	1650
- One 55 KW diesel elec.generator* (28"widex84"deepx49"high)	67	3300
- Mechanically refrigerated food storage container for three day food supply (233 cu.ft. storage**)	330	3000
- Insulated cart (28"widex32"deepx31" high)	16	150
- Sequence timer (24"widex12"deepx6" high)	1	20
- Serving table with insulated covered wells for opened hot food pans (66"widex14"deepx6"high)	3	30
- 12 pans with covers for emergency cooking (7"x17.5"x21" ea, nesting)	3	60
Total	528	8210

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* Diesel electric generator data shown is based upon commercially available self-contained units rated for continuous operation at power level shown.

** 90 percent packing efficiency assumed. Refrigerated storage data shown is based upon commercially available equipment.

Convection Oven, Electric, Bulk Packed Food (cont'd)

- Some electric convection ovens have been supplied with casters. Small models have been used to heat food in aircraft.
- The equipment appears to be sufficiently rugged.
- No configuration change is required from mobile to operating condition.

(9) Reliability - (Rated 10 Of 16)

- Same as for Concept No. 1 except the consequence of one oven failing would be a serving rate reduction to about 1.5 meals per minute, or the last third of the 200 men being served would have to wait about an hour and one-half for their food.

(10) Maintainability - (Rated 7 Of 8)

- Same as for Concept No. 1.

(11) Survivability - (Rated 2 Of 3)

- Same as for Concept No. 1 except 55 KW diesel electric generator noise would emanate from this system.

(12) Environmental Suitability - (Rated 2 Of 4)

- Same as for Concept No. 1 except 55 KW diesel electric generator cold weather startup may require special procedures.

(13) Development Risk - (Rated 8 Of 8)

- This type of equipment is well proven. It is probably the most frequently used method of heating frozen convenience foods where large groups of people are to be fed.

Convection Oven, Electric, Bulk Packed Food (cont'd)

. Development required includes the following:

- Increased ruggedness
- Modularized controls and critical components
- Serving table with insulated covered wells
- Sequence timer

RESOURCE REQUIREMENTS - (Rated 65 Of 100)

(1) Manpower - (Rated 10 Of 20)

. Setup and disassembly of the reconstitution system and ancillary equipment each time the field kitchen is moved should require no more than 1 man-hour.

. The following labor requirements are estimated for operation of the reconstitution system each day:

-	Reconstitution system operation	7.5 man-hours
-	Cleanup and maintenance of three ovens, serving table, and insulated cart	3 man-hours
-	Operation and routine maintenance of 55 KW diesel electric generator	2 man-hours
	Total	12.5 man-hours per day

(2) Supply - (Rated 20 Of 25)

. The following quantities of supplies are required for three days of operation:

		Volume Cu.Ft.	Weight Lbs.
-	Food including packaging*	270	4200
-	Water for equipment cleanup (eighteen 5 gallon cans for three days)	12.6	930

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* It is assumed here that the preplated meals are supplied in cardboard cases as shown in Appendix B. An insulated container with 2" thick walls is used on the transport track, and a mechanically refrigerated (38 to 40°F) food storage cabinet is used at the field kitchen.

Convection Oven, Electric, Bulk Packed Food (cont'd)

- Diesel fuel* (50 gallons in 5 gallon cans for three days)	7.0	470
Total	289	5600

(3) Development Cost - (Rated 8 Of 10)

- Design and develop nonstandard size oven
- Increase ruggedness of oven
- Modularize controls and critical components to facilitate field service
- Design and develop insulated serving table and cart
- Design and develop sequence timer
- Estimated development cost - $30,000 to $150,000

(4) Production Cost - (Rated 21 Of 25)

. Approximate average cost of slightly smaller commercial ovens ($1600 ea)	$4,800
. Estimated cost increase for increased capacity	1,500
. Estimated cost increase for increased ruggedness and modularized design	1,500
. Estimated cost of sequence timer	1,000
. Estimated cost of insulated cart	150
. Estimated cost of serving table with six insulated and covered wells	50
. Estimated cost of 75 cu.ft. capacity refrigerated storage container	3,500
. Estimated cost of 12 pans for emergency food cooking	500
. Approximate average cost of typical 55 KW commerical diesel generator	6,500
Total	$19,500

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[*] See Appendix G, Example Calculations.

Convection Oven, Electric, Bulk Packed Food (cont'd)

(5) Operating Cost (Rated 6 Of 20)

Labor expended	12.5 man-hours
Diesel fuel expended	16.7 gal.per day
Potable water expended	30 gal.per day

3. CONVECTION OVEN, DIESEL FUEL FIRED, PREPLATED FOOD

There is no commercially available diesel fuel fired convection oven, but one is being developed by NLABS for Bare Base. It has been assumed here that the Bare Base oven design could be modified to a slightly larger size having an oven cavity equal to that of the electric convection oven discussed previously. The exterior size of such an oven is a little larger than the electric model because more space is required for the diesel fuel burner and heat exchanger. The real advantage to this concept lies in the fact that only a small amount of electricity is required for controls and blowers. A substantial reduction in total equipment volume and weight is realized.

The method of operating this reconstitution system would be exactly as described for Concept No. 1. The following is a summary of the data used to evaluate this concept.

EFFECTIVENESS - (Rated 81 Of 100)

(1) Percent Of Menu - Rated 8 Of 8

- Same as for Concept No. 1.

(2) Food Quality - (Rated 3 Of 10)

- Same as for Concept No. 1.

(3) Throughput - (Rated 8 Of 8)

- Same as for Concept No. 1.

(4) Emergency Raw Food Cooking - (Rated 8 Of 8)

- Same as for Concept No. 1.

(5) Ease Of Operation - (Rated 4 Of 8)

- Same as for Concept No. 1.

(6) Packaging Flexibility - (Rated 1 Of 3)

- Same as for Concept No. 1.

Convection Oven, Diesel Fuel Fired, Preplated Food (cont'd)

(7) Safety - (Rated 8 Of 8)

- Consensus codes and standards were used to guide the design of this equipment.
- Many automatic safety checks have been built into the control system. Multiple control element failure would be necessary to cause fire or explosion.
- No unusual potential for microbiological contamination has been identified.

(8) Mobility - (Rated 7 Of 8)

- Sizes and weights of reconstitution system and ancillary equipment are as follows:

	Volume Cu.Ft.	Weight Lbs.
- Two ovens (42"widex40"deepx43"high ea)	84	1260
- One 5.5 KW diesel elec. generator*	10	480
- One power pack electric motor driven fuel pump and compressor for oven	5	200
- Two dollies w/removable handles (30"x28"x12" high ea)	11	100
- Mechanically refrigerated food storage container for three day food supply (233 cu.ft. storage)**	330	3000

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* Diesel electric generator data shown is based upon commercially available self-contained units rated for continuous operation at power level shown.

** 90 percent packing efficiency assumed.

Convection Oven, Diesel Fuel Fired, Preplated Food (cont'd)

	Volume Cu.Ft.	Weight Lbs.
- 18 wire baskets (2.6"x25.9"x26.8" ea; baskets are assumed to be stored in oven cavities during transport)	0	108
- Two folding insulating blanket covers	2	5
- 12 pans with covers for emergency cooking (7"x17.5"x21" ea, nesting)	4	40
- 12 wire shelves for emergency cooking	3	60
Total	449	5253

. The Bare Base oven has been designed for mobile field kitchen use. Some field testing has indicated its basic capability for mobile operation.

. The equipment appears to be sufficiently rugged.

. No configuration change would be required from mobile to operating condition.

(9) <u>Reliability - (Rated 12 Of 16)</u>

. The Bare Base design is relatively new.

. The following components have been identified as being potential causes of reconstitution system failure.

- Oven air circulation blower motor
- Oven control system
- Burner
- Transformer
- Power pack compressor and motor

After development is completed a low failure rate is anticipated. All of these components are contained in easily replaced modules which could be carried as spares.

- The consequence of one oven failing would be that the serving rate would be reduced to three meals per minute, or the second half of the men being served would have to wait about half an hour for their food.
- If the diesel electric generator would fail, no hot food could be prepared. However, a spare generator could be carried at a cost of only 10 cubic feet and 480 pounds to the system. Further, many Army field vehicles have small auxiliary power units which may be used to operate the system in emergencies. The consequence of other ancillary equipment failure would be insignificant.

(10) Maintainability - (Rated 8 Of 8)

- Cleaning of baked-on oven spills would be difficult. The self-cleaning oven feature would have to be developed.
- The following will require periodic maintenance.
  - Oven blower motor
  - Oven burner
  - Fuel filter
  - Power pack
- Minimal skills and stardard tools are required for field repair.
- Diesel electric generator maintenance is required.

Convection Oven, Diesel Fuel Fired, Preplated Food (cont'd)

(11) Survivability - (Rated 3 Of 3)

- The equipment is apparently capable of withstanding combat conditions.
- 5.5 KW diesel electric generator noise will be a possible cause of enemy detection. Radio interference of the electrical system can be shielded.
- There is some increased hazard to kitchen personnel which might be caused by the presence of some fuel in the kitchen in the event of enemy fire. The amount is limited since the fuel tank would be located outside of the kitchen.

(12) Environmental Suitability - (Rated 4 Of 4)

- No problems are caused by extreme environmental conditions. Startup of the 5.5 KW diesel electric generator in cold weather may require special procedures.
- The ovens will put some heat into the kitchen, especially during loading and unloading of the food.

(13) Development Risk - (Rated 7 Of 8)

- The completed Bare Base diesel fuel fired convection oven demonstrates the feasibility of this concept.
- The oven must be modified to the size required for operation with wire baskets.

RESOURCE REQUIREMENTS - (Rated 89 Of 100)

Convection Oven, Diesel Fuel Fired, Preplated Food (cont'd)

(1) Manpower - (Rated 17 Of 20)

- Same as for Concept No. 1.

(2) Supply - (Rated 25 Of 25)

- The following quantities of supplies are required for three days of operation:

	Volume Cu.Ft.	Weight Lbs.
- Food including packaging*	270	4200
- Water for cleanup (Nine 5 gallon cans for three days)	6.3	465
- Diesel fuel** (14 gallons in three 5 gallon cans for three days)	2.1	134
Total	278	4799

(3) Development Cost (Rated 8 Of 10)

- Design and develop new size oven
- Complete development of fuel burner and controls
- Increase ruggedness of oven dollies
- Estimated development cost - $30,000 to $150,000

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* It is assumed here that the preplated meals are supplied in cardboard cases as shown in Appendix B. An insulated container with 2" thick walls is used on the transport truck.

** See Appendix G, Example Calculations.

Convection Oven, Diesel Fuel Fired, Preplated Food (cont'd)

(4) Production Cost - (Rated 25 Of 25)

Estimated cost of fuel fired oven* ($4000 ea)	$ 8,000
Estimated cost of power pack	600
Estimated cost of 2 ruggedized dollies	500
Estimated cost of 18 wire baskets	200
Estimated cost of 75 cu.ft. capacity refrigerated storage container	3,500
Estimated cost of 2 folding insulating blanket covers	100
Estimated cost of 12 pans for emergency food cooking	500
Estimated cost of 12 wire shelves	100
Estimated cost of 5.5 KW diesel elec.generator	2,300
Total	$15,800

(5) Operating Cost (Rated 14 Of 20)

Labor expended	7.5 man-hours per day
Diesel fuel expended	4.7 gal.per day
Potable water expended	15 gal.per day

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* These costs were estimated using cost figures from the first order of 25 Bare Base ovens. It was assumed that design and production improvements would reduce that cost by one-third.

4. CONVECTION OVEN, DIESEL FUEL FIRED, BULK PACKED FOOD

The convection oven used in this concept is the same type and size as that used in Concept No. 3. The difference between this concept and Concept No. 3 is that frozen cooked food in bulk pack containers requires three ovens instead of two.

The convection ovens used in this concept are also the diesel fuel burning equivalent to the electric convection ovens used in Concept No. 2. The exterior size of this oven is a little larger than the electric model because more space is required for the diesel fuel burner and heat exchanger. However, an overall savings in equipment weight and volume is realized as a result of the fact that this oven uses only a small amount of electricity.

The method of operating this reconstitution system would be exactly as described for Concept No. 2. The following is a summary of the data used to evaluate this concept.

EFFECTIVENESS - (Rated 75 Of 100)

(1) Percent Of Menu - (Rated 8 Of 8)

- Same as for Concept No. 1.

(2) Food Quality - (Rated 7 Of 10)

- Same as for Concept No. 2.

(3) Throughput - (Rated 4 Of 8)

- Same as for Concept No. 2.

(4) Emergency Raw Food Cooking - (Rated 8 Of 8)

- Same as for Concept No. 1.

(5) Ease Of Operation - (Rated 4 Of 8)

- Same as for Concept No. 2.

(6) Packaging Flexibility - (Rated 2 Of 3)

- Same as for Concept No. 2.

Convection Oven, Diesel Fuel Fired, Bulk Packed Food (cont'd)

(7) Safety - (Rated 7 Of 8)

. Same as for Concept No. 3 except that the pans would be individually loaded into the oven. This increases the possibility for operator burns over that with a loading dolly.

(8) Mobility - (Rated 4 Of 8)

. Sizes and weights of reconstitution system and ancillary equipment are as follows:

		Volume Cu.Ft.	Weight Lbs.
-	Three ovens (42"widex40"deepx43"high ea)	125	1890
-	Power pack containing electric motor driven fuel pump and compressor	5	200
-	One 5.5 KW diesel electric generator*	10	480
-	Mechanically refrigerated food storage container for three day food supply (233 cu.ft. storage)**	330	3000
-	Insulated cart (28"widex32"deepx31"high)	16	150
-	Sequence timer (24"widex12"deepx6"high)	1	20

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* Diesel electric generator data shown is based upon commercially self-contained units rated for continuous operation at power level shown.

** 90 percent packing efficiency assumed. Refrigerated storage data shown is based upon commercially available equipment.

Convection Oven, Diesel Fuel Fired, Bulk Packed Food (cont'd)

Serving table with insulated covered wells for opened hot food pans (66"widex14"deepx6"high)	3	30
12 pans with covers for emergency cooking (7"widex17.5"deepx21"high ea, nesting)	3	60
Total	493	5830

. Additional mobility data same as for Concept No. 3.

(9) Reliability - (Rated 10 Of 16)

. Same as for Concept No. 3 except the consequence of one oven failing would be a serving rate reduction to about 1.5 meals per minute, or the last third of the 200 men being served would have to wait about an hour and one-half for their food.

(10) Maintainability - (Rated 7 Of 8)

. Same as for Concept No. 3.

(11) Survivability - (Rated 3 Of 3)

. Same as for Concept No. 3.

(12) Environmental Suitability - (Rated 4 Of 4)

. Same as for Concept No. 3.

(13) Development Risk - (Rated 7 Of 8)

. Same as for Concept No. 3.

RESOURCE REQUIREMENTS - (Rated 64 Of 100)

Convection Oven, Diesel Fuel Fired, Bulk Packed Food (cont'd)

(1) Manpower - (Rated 10 Of 20)

. Same as for Concept No 2

(2) Supply - (Rated 20 Of 25)

. The following quantities of supplies are required for three days of operation.

		Volume Cu.Ft.	Weight Lbs.
-	Food including packaging*	270	4200
-	Water for cleanup (eighteen 5 gallon cans for three days)	12.6	930
-	Diesel fuel** (15 gallons in three 5 gallon cans for three days)	2.1	141
		285	5271

(3) Development Cost - (Rated 6 Of 10)

. Design and develop new size oven

. Complete development of fuel burner and controls

. Develop sequence timer

. Estimated development cost - $50,000 to $200,000

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* It is assumed that the bulk packed food is supplied in cardboard cases as shown in Appendix B, and an insulated container with 2" thick walls is used on the transport truck.

** See Appendix G, Example Calculations

Convection Oven, Diesel Fuel Fired, Bulk Packed Food (cont'd)

(4) Production Cost - (Rated 20 Of 25)

Estimated cost of fuel fired oven* ($4000 ea)	$12,000
Estimated cost of power pack(*)	600
Estimated cost of 5.5 KW diesel elec.generator	2,300
Estimated cost of sequence timer	1,000
Estimated cost of insulated cart	150
Estimated cost of serving table with 6 insulated and covered wells	50
Estimated cost of 235 cu.ft. capacity refrigerated storage container	3,500
Estimated cost of 12 pans for emergency food cooking	500
Total	$20,100

(5) Operating Cost (Rated 8 Of 20)

Labor expended	12.5 man-hours per day
Diesel fuel expended	5 gal.per day
Potable water expended	30 gal.per day

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* These costs were estimated using cost figures from the first order of 25 Bare Base ovens. It was assumed that design and production improvements would reduce that cost by one-third.

5. HEATING - SERVING UNIT, FORCED CONVECTION, PREPLATED MEALS

Combined heating and serving units using forced air convection are currently being used in some school lunch programs. A two-speed blower circulates electrically heated air at 350°F around preplated meals in wire baskets. The baskets are on a self-leveling elevator so that the stack rises as baskets are emptied and taken off the top. All experience to date has been with heating meals from the thawed state, but no problem other than longer heating time is anticipated with frozen food. Major advantages claimed include uniform temperature, automatic control, and ease of serving. The major disadvantage is the large floor area required.

An outline drawing of a reconstitution system concept using this type of heating-serving unit is shown in Exhibit D-5. A dolly would be included to facilitate moving the wire baskets full of preplated meals or single serving packages from the frozen food storage area to the heating units. The food would be served directly out of the units after serving temperature has been reached. The air circulation blower is turned down to low speed when the heating compartment cover is removed.

The basic operational steps for using this equipment would be as follows:

- The unit would be turned on for preheating 15 minutes prior to loading.
- The preplated meal or single serving containers of frozen food would be loaded into wire baskets on a dolly and pushed to the heating unit.
- The baskets of food would be individually loaded into the heating unit. A full unit load would be 108 meals.
- Completion of reconstitution would be determined by the operator. He could watch a thermometer inserted into a representative food container, or elapsed heating time could be controlled. The time required would depend upon the type of food The time for heating from the frozen state is calculated to be 45 minutes.*

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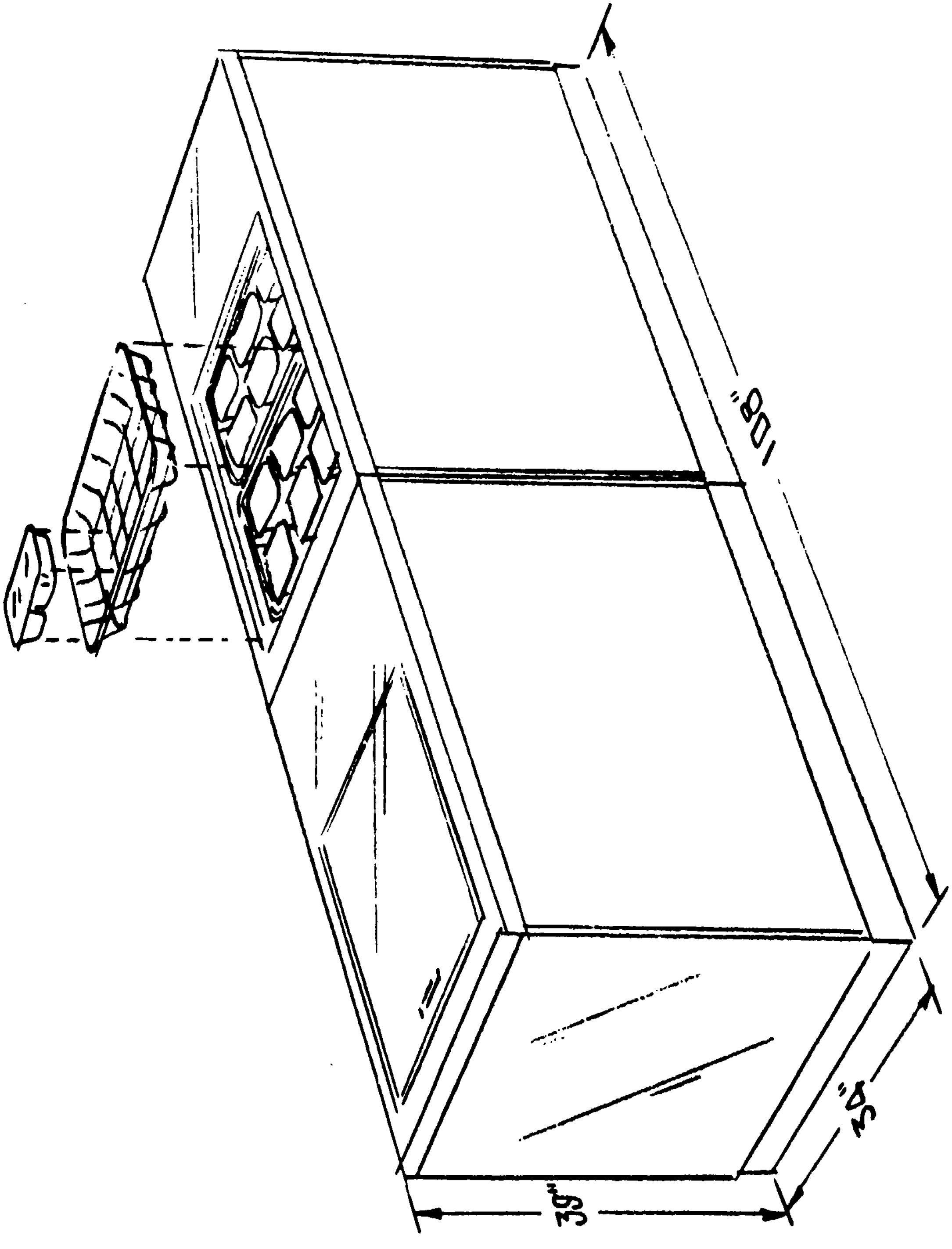
* Calculation of heating time from frozen is based upon 30 minute heating time when meals are thawed, and the knowledge that heating takes about 1.5 times longer from frozen than from thawed in normal convection ovens.

EXHIBIT D-5
U.S. Army Natick Laboratories
HEATING-SERVING UNIT
FORCED CONVECTION,
PREPLATED MEALS



- When heating is completed, the unit would be turned down to holding temperature, the blower would be turned to low speed, the cover removed, and serving would begin.

The schedule for performing these operations is shown in Exhibit D-6.

The heating-serving unit is not currently capable of cooking raw food in emergencies. Special folding wire pan racks and baking pans would have to be carried by the field kitchen. The elevator self-leveling drive system would also have to be modified to allow manual raising and lowering so that pans might be placed onto the wire pan racks at any level.

No practical way of reconstituting frozen food in half size steam table pans could be envisioned.

The following is a summary of data used to evaluate this concept.

EFFECTIVENESS - (Rated 66 Of 100)

(1) Percentage Of Menu - (Rated 8 Of 8)

- Same as for Concept No. 1.

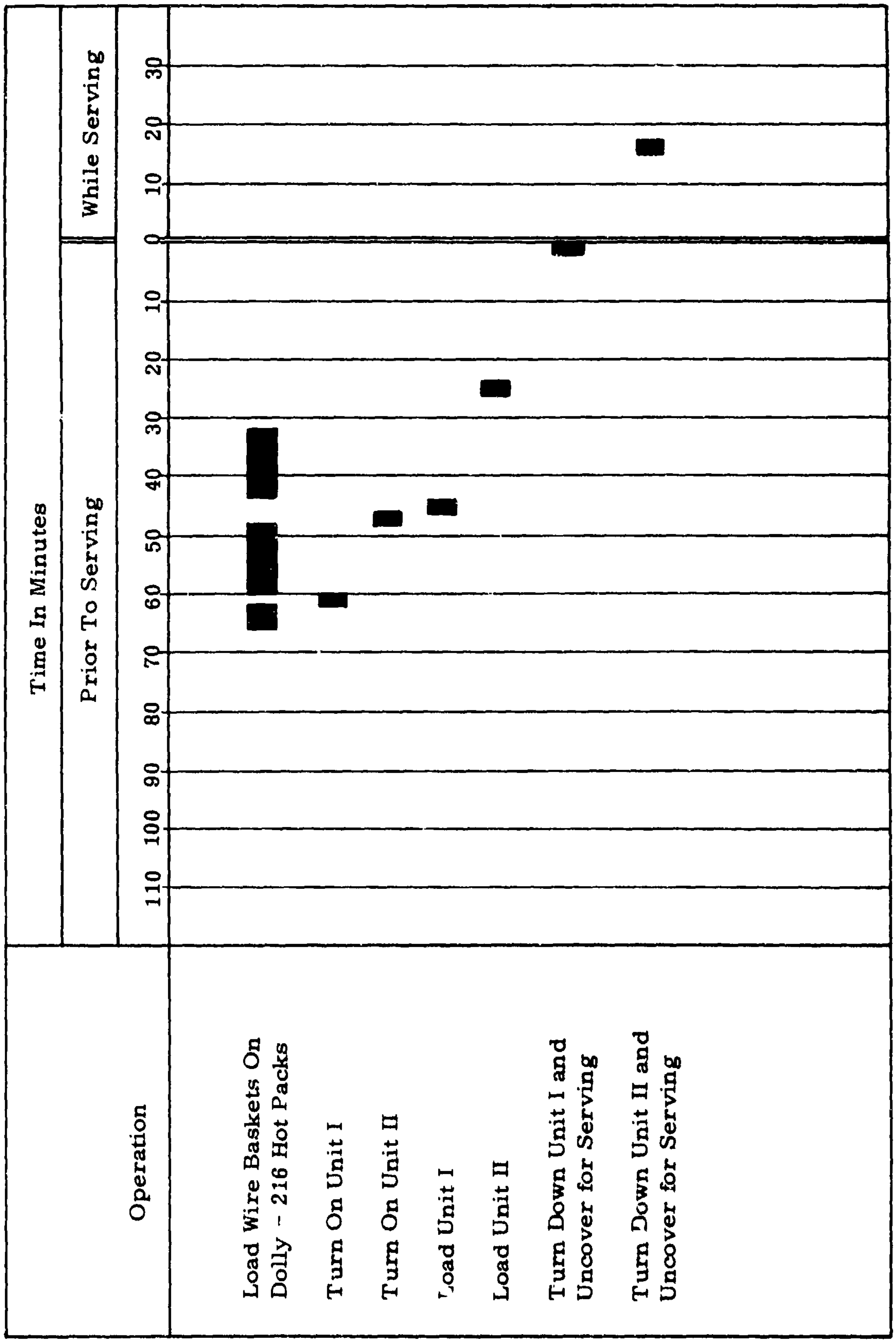
(2) Food Quality - (Rated 4 Of 10)

- Same as for Concept No. 1 except the food serving temperature would probably be better controlled.

(3) Throughput - (Rated 7 Of 8)

- 15 minute preheat is required.
- Total elapsed time from start of preheat to serving of the first meal would be 60 minutes.
- There is no limit to the maximum possible serving rate. All 216 meals could be ready simultaneously if desired.

EXHIBIT D-6
U.S. Army Natick Laboratories
OPERATING SCHEDULE
HEATING-SERVING UNIT, PREPLATED MEALS



Heating - Serving Unit, Forced Convection, Preplated Meals (cont'd)

(4) Emergency Raw Food Cooking - (Rated 6 Of 8)

- Same as for Concept No. 1 except the cooking operation would be less convenient than in a convection oven.

(5) Ease Of Operation - (Rated 4 Of 8)

- Same as for Concept No. 1 except loading is more difficult, and no unloading is required.

(6) Packaging Flexibility - (Rated 1 Of 3)

- Same as for Concept No. 1.

(7) Safety - (Rated 8 Of 8)

- Same as for Concept No. 1. The self-leveling shelf mechanism reduces the potential for operator burns as the loading dolly does in Concept No. 1.

(8) Mobility - (Rated 5 Of 8)

- Sizes and weights of reconstitution system and ancillary equipment are as follows:

	Volume Cu.Ft.	Weight Lbs.
- Two heating-serving units (54"widex34"deepx39"high ea)	83	1100
- One 30 KW diesel elec.generator* (28"widex80"deepx48"high)	62	2300

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* Diesel electric generator data shown is based upon commercially available self-contained units rated for continuous operation at the power level shown.

Heating - Serving Unit, Forced Convection, Preplated Meals (cont'd)

-	Mechanically refrigerated food storage container for three day supply (233 cu.ft.storage)*	300	3000
-	One dolly w/removable handles (30"widex28"deepx8"high)	4	30
-	36 wire baskets (2.6"widex13.4"deepx25.9"high ea; baskets are assumed to be stored in heating-serving unit during transport)	0	120
-	12 pans with covers for emergency cooking (7"widex17.5"deepx21"high ea, nesting)	4	40
-	2 folding wire racks for emergency cooking	2	40
	Total	485	6630

- This equipment is often mounted on casters, but it has not been used in a mobile application.
- The equipment appears to be sufficiently rugged for cross-country travel, but the self-leveling basket elevator will probably have to be locked for transport.
- Change from transport to operating configuration should require no more than 0.5 man-hours.

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* 90 percent packing efficiency assumed.

Heating - Serving Unit, Forced Convection, Preplated Meals (cont'd)

(9) Reliability - (Rated 8 Of 16)

- The heating-serving unit has been used in some school lunch programs, but the unit proposed here would be bigger than the standard unit.
- Components which have been identified as possible causes of unit failure are as follows:
  - Blower motor
  - Temperature control system
  - Electrical heating elements
- The consequence of one unit's failing would be that the serving rate would be reduced to three meals per minute, or the second half of the men being served would have to wait about three-quarters of an hour for their food.
- If the diesel electric generator would fail, no hot food could be prepared. The consequence of other ancillary equipment failure would be insignificant.

(10) Maintainability - (Rated 5 Of 8)

- Cleaning of baked-on spills would be difficult with the recessed food cavity and self-leveling elevator mechanism.
- The fan motor would require periodic maintenance.
- Minimal skills and standard tools are required for repair.
- Diesel electric generator maintenance is required.

(11) Survivability - (Rated 2 Of 3)

- Same as for Concept No. 1 except 30 KW diesel electric generator noise from this system may be slightly less detectable.

(12) Environmental Suitability - (Rated 2 Of 4)

- Same as for Concept No. 1 except 30 KW diesel electric generator may be slightly easier to start in cold weather.

(13) Development Risk - (Rated 6 Of 8)

- This concept has been proven, but not in a mobile situation and not with a unit of the size used in this system.

- Modifications which are required include the following:

  - Increased ruggedness

  - Modularized controls and critical components

  - Locking device to protect the self-leveling elevator mechanism during cross-country travel

  - Drive system for self-leveling elevator to allow cooking in emergencies

RESOURCE REQUIREMENTS - (Rated 78 Of 100)

(1) Manpower - (Rated 14 Of 20)

- Setup and disassembly of the reconstitution system and ancillary equipment each time the field kitchen is moved should require no more than 1.5 man-hours.

- The following labor requirements are estimated for operation of the reconstitution system each day:

- Reconstitution system operation	4.5 hours
- Cleanup and maintenance of two units	3 hours
- Operation and routine maintenance of 30 KW diesel electric generator	1.5 man-hours
Total	9 man-hours per day

(2) Supply - (Rated 24 Of 25)

- The following quantities of supplies are required for three days of operation:

	Volume Cu.Ft.	Weight Lbs.
- Food including packaging*	270	4200
- Water for cleanup (Nine 5 gallon cans for three days)	6.3	465
- Diesel fuel** (25 gallons in five 5 gallon cans for three days)	3.5	235
Total	280	4900

(3) Development Cost - (Rated 8 Of 10)

- Design and develop nonstandard size unit.
- Increase ruggedness and modularize controls and critical components.

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* It is assumed here that the preplated meals are supplied in cardboard cases as shown in Appendix B. An insulated container with 2" thick walls is used on the transport truck.

** See Appendix G, Example Calculations.

Heating - Serving Unit, Forced Convection, Preplated Meals (cont'd)

- Design and develop self-leveling elevator lock for transport.
- Design and develop drive mechanism for self-leveling elevator to allow emergency cooking.
- Design and develop folding wire rack for emergency cooking.
- Estimated development cost - $30,000 to $150,000

(4) Production Cost - (Rated 22 Of 25)

. Approximate cost of 2 smaller commercial units ($2500 ea)	$ 5,000
. Estimated cost for increased size (2)	2,000
. Estimated cost for increased ruggedness modularized design, and elevator modifications	1,500
. Estimated cost of dolly	200
. Estimated cost of 36 wire baskets	300
. Estimated cost of 235 cu.ft. capacity refrigerated storage container	3,500
. Estimated cost of folding wire racks (2)	50
. Estimated cost of 12 pans for emergency food cooking	500
. Typical cost of 30 KW diesel electric generator	5,100
Total	$18,150

Heating - Serving Unit, Forced Convection, Preplated Meals (cont'd)

(5) Operating Cost - (Rated 10 Of 20)

· Labor expended	9 man-hours per day
· Diesel fuel expended	8.3 gal.per day
· Potable water expended	15 gal.per day

6. LOW TEMPERATURE NATURAL CONVECTION HEATING UNIT, PREPLATED FOOD

A specialized unit designed specifically for rethermalizing preplated meals and single serving packages is being introduced for hospital food service systems. The unit has been under test at three independent food service facilities for several months.

Low temperature (275°F to 285°F) natural air convection inside individual compartments which are automatically controlled, gently heat the food. Temperature sensors and heating elements in each "shelf" automatically control the temperature of each food heating compartment. The control system determines when heating is completed by sensing when the heaters are on for only short periods to maintain temperature. When this occurs, an indicator light goes on and the heat is automatically turned down (190°F to 205°F). High food quality, low cost throwaway plastic food containers, and simple operation are the major advantages claimed. The major disadvantage is that reconstitution takes a long time.

An outline drawing of a reconstitution system using the low temperature natural convection heating units is shown in Exhibit D-7. Wire baskets and a dolly would be included for moving the food from the frozen food storage area to the heating unit. It is intended that the tops of the heating units be used as the hot food serving table. The baskets of heating food containers would be placed on the top of the heating unit one at a time as needed.

The basic operational steps for using this equipment would be as follows:

- The containers of frozen food would be loaded into wire baskets on a dolly and taken to the heating unit. A full heating unit load would be 56 meals.
- The wire baskets would be loaded into the heating unit 80 to 100 minutes prior to the desired serving time, depending on the type of food. No adjustments or settings would be required.
- After the indicator lights have come on, the baskets of hot food would be taken out and placed on the top of the unit when needed for serving. If necessary, the meals may be held in the unit for extended periods without any further adjustment.

The schedule for performing these operations is shown in Exhibit D-8.

EXHIBIT D-7
U.S. Army Natick Laboratories
LOW TEMPERATURE NATURAL
CONVECTION HEATING UNIT
PREPLATED MEALS

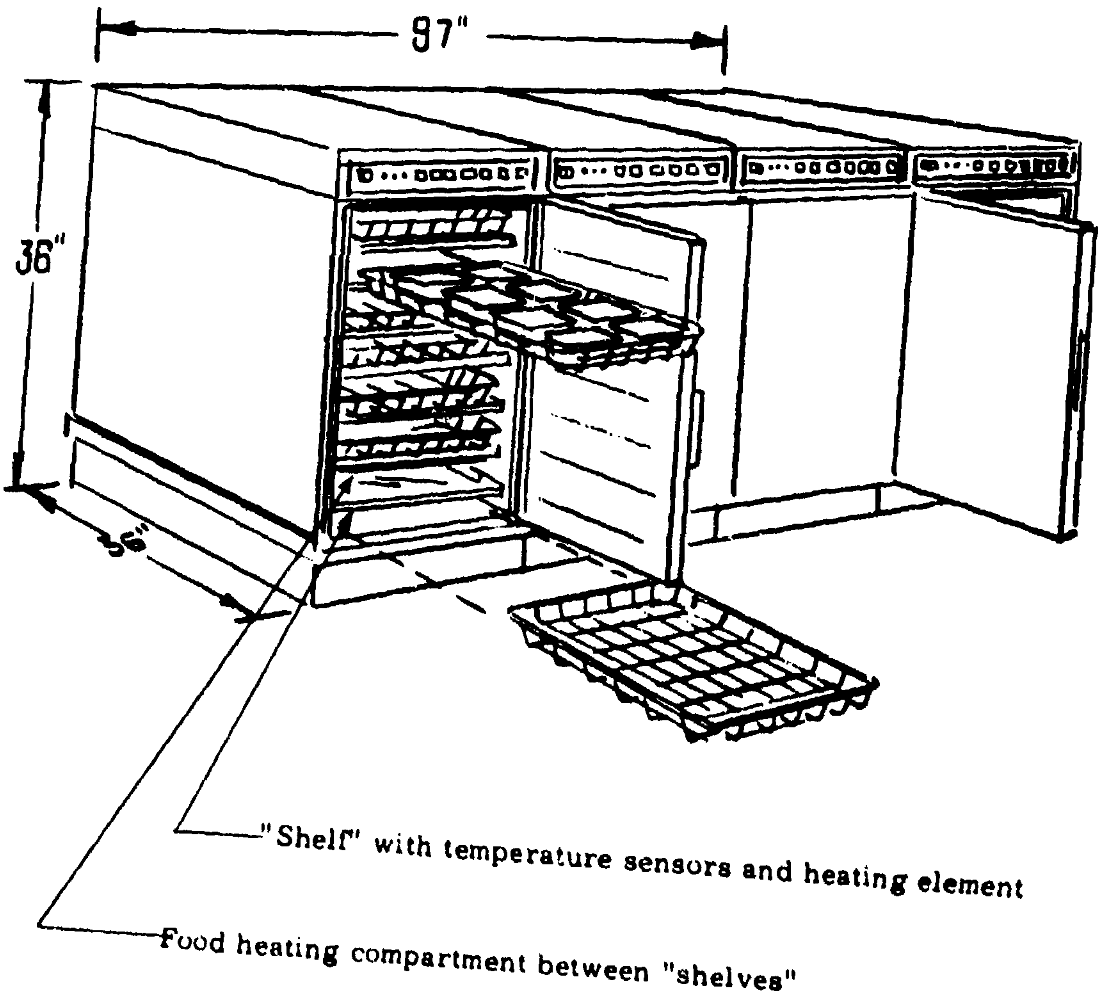
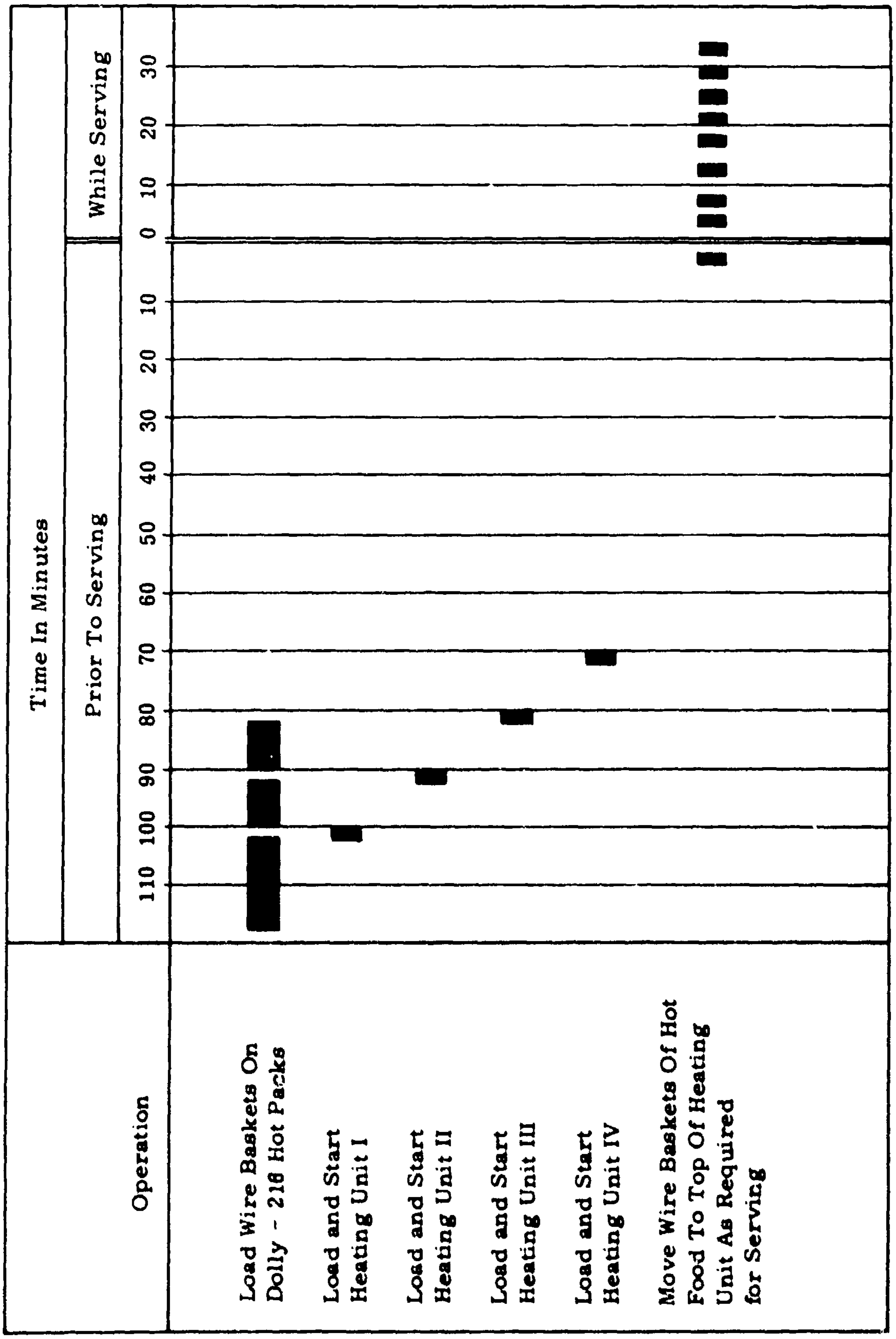


EXHIBIT D-8

U.S. Army Natick Laboratories
OPERATING SCHEDULE
LOW TEMPERATURE NATURAL CONVECTION, PREPLATED MEALS



Low Temperature Natural Convection Heating Unit, Preplated Food (cont'd)

For the emergency raw food cooking requirement, a special covered switch would be added. This would activate a high temperature (400°F) cooking cycle. Raw food would be placed in baking pans carried especially for this purpose by the field kitchen and cooked as in a conventional oven. This is not currently a part of units being developed, and no experience is available.

It is not practical because of the extended heating time required to reconstitute bulk packed food in these low temperature, natural convection heating units. Tests made by the manufacturer indicate heating times of more than two hours for thawed food in half size steam table pans.

The following is a summary of data used to evaluate this concept.

(1) Percent Of Menu - (Rated 8 Of 8)

- 100 percent of the frozen precooked hot 28 Day Master Menu items can be reconstituted.
- There are no problems anticipated with preplated combinations. More than 150 have been successfully tested.
- Soups have not been tested. A shallow bowl would be needed.

(2) Food Quality - (Rated 8 Of 10)

- Gentle controlled heating is claimed to give superior food quality.
- This equipment was originally designed and developed to process thawed precooked food items because the manufacturer felt this would give the best quality food. All experience with processing food from the frozen state has been in field tests.
- The temperature uniformity is claimed to be excellent because of slow, gentle heating and individual compartment temperature control.

Low Temperature Natural Convection Heating Unit, Preplated Food (cont'd)

(3) Throughput - (Rated 6 Of 8)

. No preheat is required.

. Total elapsed time from loading to serving of the first meal is 100 minutes.

. There is no limit to the maximum possible serving rate. All 206 meals could be ready simultaneously.

(4) Emergency Raw Food Cooking - (Rated 5 Of 8)

. Same as for Concept No. 1 except cooking would be slower.

(5) Ease Of Operation - (Rated 6 Of 8)

. No adjustments or operator judgment is required to determine when the heating process is complete.

. The only possible operator error would be loading the heating unit late or forgetting to push the start button. The consequence of these errors would be that the meals would not be ready at serving time.

. The operator would be relatively free for about an hour before serving time.

(6) Packaging Flexibility - (Rated 2 Of 3

. Preplated meals and single serving packages may be heated in this unit. Bulk packed food is too thick and takes too long to heat in this system. It would be possible to use a new size of this bulk pack, such as 1.2" x 18" x 26" sheet pans, but this is not a commercially used method of packaging.

- Any material which can withstand 300°F for brief periods and 285°F continuously and is food compatible may be used. A throwaway plastic which costs 3.5¢ each for a 1" x 5" x 7.5" container is being used. Aluminum foil and high temperature plastics could also be used.

- This system is designed to use preplated meal packages of the configuration shown in Exhibit B-4. Single serving packages would be similar to the individual compartments of the preplated meal packages.

- In some cases, package covers should be punctured or partially removed to achieve acceptable food quality. Self-opening package covers would not work at the low temperatures used by this system.

(7) Safety - (Rated 8 Of 8)

- The heating units are designed to meet the requirements of Underwriters Laboratories and the National Sanitation Foundation.

- There are no unusual hazards to the operator or repair personnel. The lower than normal operating temperature reduces the potential for burns.

- No unusual hazards result from equipment or operator failure.

- No unusual potential for microbiological contamination has been identified. The food does spend a longer than average time in the 40°F to 140°F zone of high microbiological growth rate. However, since the food is heated to 165°F, it is the opinion of NLAB Food Lab personnel that this period of exposure in this temperature zone could be tolerated with no unusual problems.

Low Temperature Natural Convection Heating Unit, Preplated Food (cont'd)

(8) Mobility - (Rated 4 Of 8)

. Sizes and weights of reconstitution system and ancillary equipment are as follows:

	Volume Cu.Ft.	Weight Lbs.
- Four heating units (24.2"widex36"deepx 36"high ea)	73	900
- One 30 KW diesel elec.generator* (28"widex80"deepx48"high)	63	2300
- 28 wire baskets (2"widex18"deepx26"high ea; baskets are assumed to be stored in heating units during transport)	0	150
- One dolly w/removable handle (8"widex20"deepx28"high)	3	50
- Mechanically refrigerated storage container for three day food supply (235 cu.ft. storage)**	330	3000
- Pans with covers for emergency cooking (20) 2"widex18"deepx26"high, nesting (4) 5"widex18"deepx26"high, nesting	8	50
Total	477	6450

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* Diesel electric generator data shown is based upon commercially available self-contained units rated for continuous operation at the power level shown.

** 90 percent packing efficiency assumed.

- These units are normally supplied on casters, but they have not been used in mobile applications.
- The equipment appears to be sufficiently rugged.
- No configuration change is required from mobile to operating condition.

(9) Reliability - (Rated 9 Of 16)

- The unit has been recently introduced so the concept has not been proven by experience.
- The following components have been identified as potential cases of reconstitution system failure:
  - Electronic control system
  - Shelf compartment divider with heating elements and temperature sensors. These are easily replaced modules.
- The consequence of one unit failing would be that the serving rate would be reduced to 1.9 meals per minute.
- The low temperatures and automatic controls used in this system reduce the potential for making the food inedible.
- If the diesel electric generator failed, no hot food could be prepared. The consequence of other ancillary equipment failure would be insignificant.

(10) Maintainability - (Rated 6 Of 8)

- Normal cleaning would be easy because low temperature doesn't bake on spills badly.

Low Temperature Natural Convection Heating Unit, Preplated Food (cont'd)

- Plug-in spare parts modules would make field repair easier.
  - Control module
  - "Shelves" with thermostats and heating elements
- Minimal skills and standard tools are required for repair.
- Diesel electric generator maintenance is required.

(11) Survivability - (Rated 2 Of 3)

- Same as for Concept No. 5.

(12) Environmental Suitability - (Rated 2 Of 4)

- Same as for Concept No. 5.

(13) Development Risk - (Rated 6 Of 8)

- This concept has been recently introduced and is not yet proven.
- Modifications and development which is required include the following:
  - Increased ruggedness
  - Emergency food cooking capability
  - Wire baskets
  - Enclose back of units so that the serving line may pass on that side

RESOURCE REQUIREMENTS - (Rated 64 Of 100)

Low Temperature Natural Convection Heating Unit, Preplated Food (cont'd)

(1) Manpower - (Rated 12 Of 20)

- Setup and disassembly of the reconstruction system and ancillary equipment each time the field kitchen is moved should require about 1 man-hour.

- The following labor requirements are estimated for operation of the reconstitution system each day:

-	Reconstitution system operation	6.5 hours
-	Cleanup and maintenance of four units	3 hours
-	Operation and routine maintenance of 30 KW diesel electric generator	1.5 man-hours
	Total	11 man-hours per day

(2) Supply - (Rated 24 Of 25)

- The following quantities of supplies are required for three days of operation:

		Volume Cu.Ft.	Weight Lbs.
-	Food including packaging*	270	4200
-	Water for cleanup (nine 5 gallon cans for three days)	6.3	465
-	Diesel fuel** (30 gallons in six 5 gallon cans for three days)	4.2	282
	Total	280	4947

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* It is assumed here that the preplated meals are supplied in cardboard cases as shown in Appendix B. An insulated container with 2" thick walls is used on the transport truck.

** See Appendix G, Example Calculations.

Low Temperature Natural Convection Heating Unit, Preplated Food (cont'd)

(3) Development Cost - (Rated 10 Of 10)

- Increase ruggedness of heating unit
- Develop emergency cooking capability
- Develop dolly and baskets
- Modify back of units for serving from that side
- Estimated development cost - $30,000 to $100,000

(4) Production Cost - (Rated 13 Of 25)

Approximate cost of commercial unit ($4000 ea)	$16,000
Estimated cost for increased ruggedness	2,000
Estimated cost of dolly	200
Estimated cost of 28 wire baskets	300
Estimated cost of 235 cu.ft. capacity refrigerated storage container	3,500
Estimated cost of pans for emergency food cooking	500
Typical cost of 30 KW diesel electric generator	5,100
Total	$27.600

(5) Operating Cost - (Rated 5 Of 20)

Labor expended	11 man-hours per day
Diesel fuel expended	10 gal.per day
Potable water expended	15 gal.per day

7. OTHER RECONSTITUTION SYSTEM CONCEPTS

In addition to those concepts previously described, thirteen other reconstitution system concepts based on existing methods of reconstitution were developed. Upon evaluation these concepts were eliminated from further consideration when it was found that a minimum acceptance level for a criterion was not met. These concepts and the reasons they were rejected are discussed in this section.

(1) Low Pressure Steamer

The low pressure (5 to 7 psig) steamer is used in many commercial and institutional kitchens to reconstitute frozen cooked bulk packed foods. Its major advantage is superior food quality of vegetables and other moist products. The major disadvantages are that foods with crisp, dry surfaces cannot be prepared and the heating process is slow. This concept was rejected for the following reasons:

- Percent Of Menu

  Only 79 percent of the 28 Day Master Menu hot items would be of acceptable quality. Those items judged to be unacceptable with steam reconstitution are as follows:

Food Item	Number Of Times Served
- French Fried Potatoes	2
- Hashed Brown Potatoes	8
- Chicken, Oven Fried	2
- Fish, Pan Fried	1
- Toast	29
- Bread, Garlic, French, Toasted	1
- Eggs, Fried	5
- Biscuits, Hot	7
- Corn Bread	3
- Rolls, Hot	3
Total	61

- Mobility

  A steamer reconstitution system is not sufficiently compact to allow storage and transportation to and in the field by existing military equipment. Nine oven cavities, holding 8 half size steamer pans each, would be required to maintain a serving rate of six meals per minute. This yields a bank of steamers with overall dimensions of 164" wide x 33" deep x 74" high. A large diesel electric generator would also be required for electric steam generation.

(2) High Pressure Steamer

The high pressure (15 psig) steamer is used in many commercial and institutional kitchens for reconstituting frozen cooked bulk packed foods. Its advantages and disadvantages are about the same as those of the low pressure steamer, but the high pressure steamer is a little faster than the low pressure steamer. This concept was rejected for the following reasons:

- Percent Of Menu

  Same as for low pressure steamer.

- Mobility

  Seventeen oven cavities holding four half size steam table pans each would be required to maintain a serving rate of six meals per minute. This yields a bank of steamers with overall dimensions of 180" wide x 27" deep x 75" high. A large diesel electric generator would also be required to generate steam with electricity.

(3) Atmospheric Pressure, Convection Steamer

This steamer is used in commercial and institutional kitchens. It generates steam at 15 psig in a boiler and releases this steam into the food heating chamber. This chamber is kept at atmospheric pressure by continually drawing steam out to a condenser. The condensed steam is discarded to avoid possible boiler fouling problems. The major advantage of this steamer is that the dryer steam atmosphere and continuous steam circulation heat the food at about the same speed as the high pressure steamer without pressure. It has the same disadvantages as the other steamers, plus the fact that it requires a large quantity of water. This concept was rejected for the following reasons:

- Percent Of Menu

  Same as for low pressure steamer.

- Mobility

  Twelve compartments holding six half size steam table pans each would be required to maintain a serving rate of six meals per minute. This yields a bank of steamers with overall dimensions of 108" wide x 34" deep x 57" high. A large diesel electric generator would also be required for steam generation.

- Supply

  More than 2500 gallons of water would be used by these steamers in a three day period.

(4) Infrared Ovens

Commercial and institutional kitchens use infrared ovens to reconstitute frozen cooked bulk packed foods. The major advantages of this equipment are that it is fast, and products with crisp, dry surfaces can be achieved. The major disadvantages are that operator error can make the food inedible and only one layer of food pans can be heated in the oven. This concept was rejected for the following reason:

- Mobility

  Twenty-four infrared ovens, each measuring 34" wide x 14" high x 19" deep would be required to maintain a serving rate of six meals per minute. If these ovens were stacked three high, this would yield a bank of ovens 272" wide.

(5) Combination Of Pulsed Infrared Energy, Refrigeration, and Forced Hot Air Convection

This device is being used in commercial and institutional kitchens. Its major advantages are the same as the infrared oven. Its major disadvantages are that the complexity of a refrigeration system is added and a large device results. This concept was rejected for the following reason:

- Mobility

  Two units, each measuring 51" wide x 37" deep x 108" high would be required to maintain a serving rate of six meals per minute. The 108" height requirement is a major drawback to mobile field kitchen operation.

(6) Combination Of Low Pressure Steamer With Infrared Ovens

The major advantage of a system combining these two heating methods is that high food quality would be achieved. The major disadvantages are that the operator would have to be familiar with two different operating procedures and the equipment takes a lot of space. This concept was rejected for the following reason:

- Mobility

  Two steamer cavities, each holding 8 half size steam table pans and sixteen infrared ovens and each measuring 34" wide x 14" high x 19" deep would be required to maintain a serving rate of six meals per minute. If the infrared ovens were stacked three high, the combined bank of ovens with steamers would be 240" wide. A large diesel electric generator would also be required for steam generation.

(7) Microwave Oven

The microwave oven is not generally used to reconstitute frozen cooked foods. In most cases the food is thawed before reconstitution begins. Nevertheless, a concept was developed to reconstitute frozen preplated meals. The manufacturer's instructions require rest periods and movement of the food during thawing. It was assumed that the equipment could be developed to eliminate the need for operator participation. The major advantage of microwave heating is that it is fast. The major disadvantage is that it is sensitive to operator error or improper food configuration. The concept was rejected for the following reason:

- Mobility

  Twenty-one microwave ovens measuring 28.2" wide x 23.4" deep x 24.3" high each would be required to maintain a serving rate of six meals per minute. If these units were stacked three high, the bank of ovens would be 197" wide. A large diesel electric generator would also be required.

(8) Microwave Oven With Graduated Shielding

A microwave oven which allows the use of a shield which controls the amount of energy reaching each area of a food tray is being introduced to the hospital feeding market. With this system, a tray holding ice cream, cake, warm rolls, salad, and the food to be heated, would be placed in a microwave oven. Each food would be heated to the proper temperature as the result of the shield controlling the amount of energy which passes through to the food. The major advantage of this concept is that it reduces confusion at serving time since the entire tray may be made up before heating. This concept was rejected because it does not meet the mobility criterion. This system would be more than twice as large as that using microwave ovens above.

(9) Plate Contact Heating

This heating system concept has been developed for reconstitution of frozen precooked meals in hospital satellite pantries. Heat is generated directly on the bottom surface of a metal dish by electric current passing through a coated ceramic resistance heating element. The metal dish is an integral part of a plate assembly which also includes a plastic base with electrical contacts on the bottom. These plates are filled with frozen precooked meals, covered, and loaded onto rails in a heating cabinet. An automatic control system applies electrical voltage to the rails in a cyclical manner. Current flows through the plate contacts which rest on the rails and generates heat in the ceramic resistance elements in each plate. High food quality and automatic operation are the major advantages claimed. The major disadvantages are that expensive dishes must be cleaned and filled with precooked meals at the field kitchen, and the system has difficulty heating bulky or crisp food products. The concept was rejected for the following reason:

- Percent Of Menu

Only 78 percent of the 28 Day Master Menu hot items would be of acceptable quality. Those items judged to be unacceptable with plate contact reconstitution are as follows:

Food Item	Number Of Times Served
- French Fried Potatoes	2
- Hashed Brown Potatoes	8
- Chicken, Oven Fried	2
- Chicken, Barbecued	1
- Chicken, Country Style	2
- Fish, Pan Fried	1
- Toast	29
- Bread, Garlic, French, Toasted	1
- Eggs, Fried	5
- Biscuits, Hot	7
- Corn Bread	3
- Rolls, Hot	3
Total	64

(10) Disposable Plate Contact Heating

An aluminum foil resistance element is being developed to be imbedded in throwaway paper or plastic plates. These plates might be used in the manner as described for reusable contact heating plates. The major advantage would be that washing and filling of plates at the field kitchen would be eliminated. The major disadvantages are that this system would probably have difficulty with the same foods as that using reusable plates, and further, the product is not yet available. The concept was rejected for the following reasons:

- Percent Of Menu

  Same as for Plate Contact Heating.

- Development Risk

  This concept is in the very early stages of development. No cost or performance data is available.

(11) Deep Fat Frying

The deep fat fryer is used in commercial kitchens and fast-food outlets. Its major advantage is that it is fast, and the quality of certain foods such as french fries, is excellent. The major disadvantage is that many foods cannot be heated in this device. This concept was rejected because less than 25 percent of the 28 Day Master Menu hot items would be acceptable with deep fat frying reconstitution.

(12) Conveyorized Oven With Movable High Velocity Jets

This device was designed for baking pizzas. The high velocity jets allow baking at lower than normal temperatures. Its major advantage is fast baking without local burning of the crust. The major disadvantages are that the device is large, and a gaseous fuel is required. The concept was rejected because four ovens, each measuring 88" wide x 44" deep x 54" high would be required.

(13) Boil-In-Bag

Commercial kitchens are using frozen cooked food that is packaged in sealed flexible plastic bags. These foods are reconstituted simply by boiling in water. The major advantage of this system is that no specialized equipment is required. The major disadvantage is that many foods will not be of acceptable quality if processed in this way. The concept was rejected for the following reason:

- Percent Of Menu

  Only 73 percent of the 28 Day Master Menu hot items would be of acceptable quality. Those items judged to be unacceptable in the boil-in-bag system are as follows:

Food Item	Number Of Times Served
- French Fried Potatoes	2
- Hashed Brown Potatoes	8
- Roast Beef	4
- Hot Sliced Beef Sandwich	1
- Grilled Beef Steak	2
- Cheeseburgers	1
- Chicken, Oven Fried	2
- Fish, Pan Fried	1
- Hamburgers, Grilled	3
- Pork Roast	2
- Pork Slices (Chops), Breaded	1
- Pork Slices (Chops), Grilled	1
- Vealburgers	1
- Veal Steaks, Grilled	1
- Biscuits, Hot	7
- Bread, Garlic, (French), Toasted	1
- Toast	28
- Corn Bread	3
- Rolls, Hot	3
- Eggs, Fried	5
Total	78

APPENDIX E

FOOD RECONSTITUTION FUNDAMENTALS AND NEW CONCEPTS

APPENDIX E

FOOD RECONSTITUTION FUNDAMENTALS AND NEW CONCEPTS

Consideration of the fundamental principles which govern the process of heating frozen cooked foods led to some new concepts. These fundamentals and new concepts are discussed in this appendix. In some cases, preliminary evaluation of the new concept showed that this approach was not practical for the field kitchen. The findings and rationale which led to these rejections are also included here.

1. HEATING FROZEN COOKED FOOD REQUIRES SPECIAL CARE.

When food is cooked, its outside surface is subjected to high temperatures for a period of time which is long enough to cause browning, caramelization, fiber breakdown, etc. These complex chemical and physical changes are a desirable end result of the cooking process. However, when cooked frozen foods are reheated, these chemical/physical changes should not continue during reconstitution. Scorching, color deterioration, mushy texture, and drying out of the food, are examples of cases where the normal cooking process was continued. Thus, the object of reconstituting food which has already been cooked is to heat it, without cooking it. Temperatures of 180°F to 190°F are sufficient to cause noticeable chemical/physical changes to many food items. This is not the limiting temperature for all food items, but if all foods are to be subjected to the same conditions, this upper temperature limit must be observed. So, heating must be done without causing any part of the food to reach these temperatures for too long a time.

2. PARTIALLY THAWED FROZEN FOODS PRESENT A CONTROL PROBLEM.

The ice in frozen foods has to be melted during the heating process. Because of its high latent heat of fusion, it takes about as much heat to melt the ice as it does to raise the temperature from 40°F (thawed) to 165°F. Thus, it takes almost twice as long to heat a frozen food in a given heating environment. The control systems of most existing reconstitution equipment control the heating temperature and the length of heating time. It is obvious that different heating times should be used for frozen and thawed foods, but what is not obvious is the time setting which the operator should use for partially thawed foods.

In most commercial and institutional situations, the frozen food is reconstituted from the fully frozen or fully thawed state. This avoids the problem of what to do with partially thawed food. As previously discussed (see Appendix B), the concept of allowing the frozen food to slowly thaw in insulated storage containers has advantages and disadvantages in the field feeding system. This approach would make it likely that in at least some cases, the reconstitution system would be heating partially thawed foods with the attendant heating time problem. Two control system concepts were developed aimed at reliably determining when the foods have been properly heated. Diagrams of these concepts are shown in Exhibit E-1, Concept No. 1.

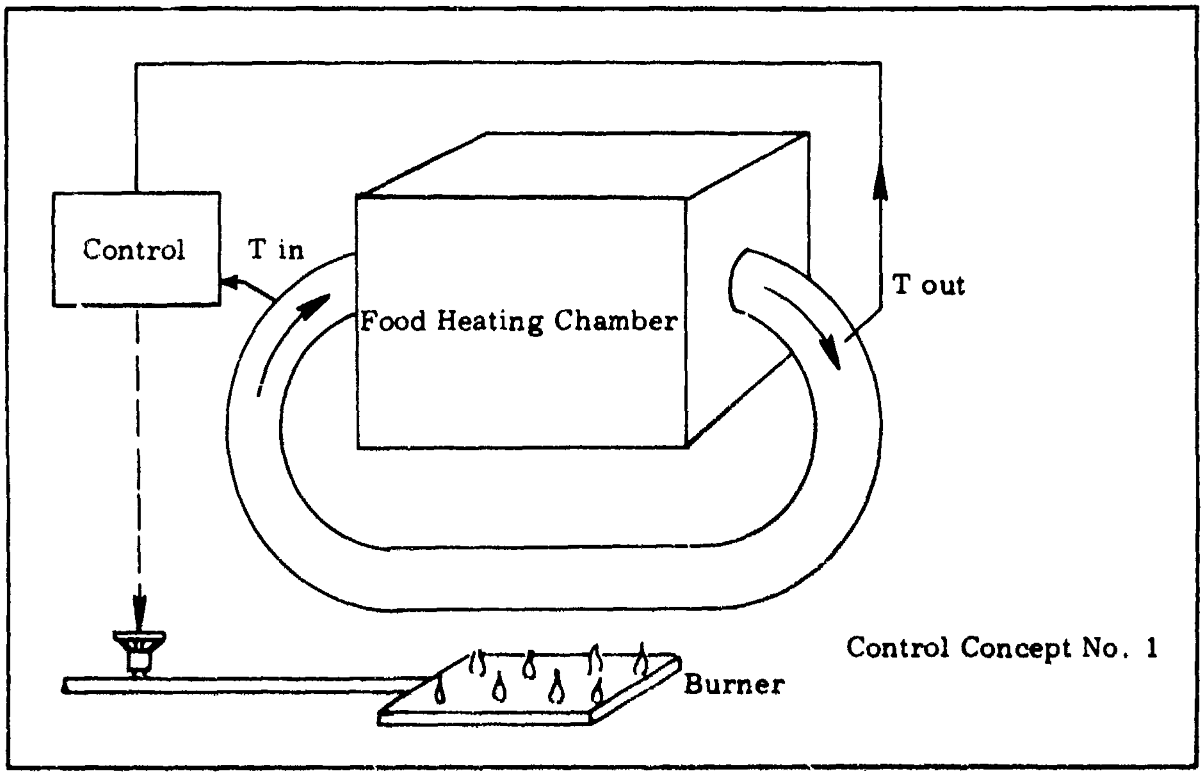
Concept No. 1 uses the fact that as the heating fluid heats the food it drops in temperature. Early in the heating process, the food is cold and the greatest heat flow occurs. As the food comes to temperature, the flow of heat is reduced. Thus, as the food approaches its desired temperature, the heating fluid temperature drop is reduced. It would be possible to determine the heating fluid temperature drop which indicates completion of heating of a given batch of food. However, further consideration revealed that this temperature drop at completion of heating would be different for different quantities and types of foods. Further, the kitchen temperature would affect the heating fluid temperature drop. For these reasons, this concept was rejected.

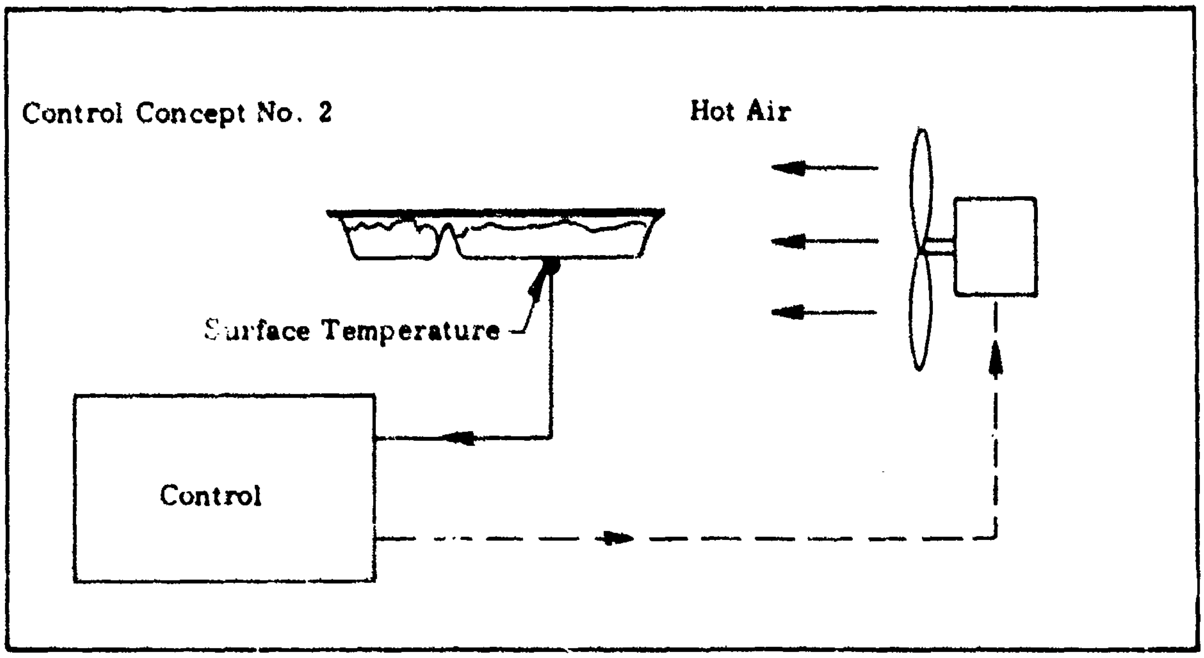
Control Concept No. 2 would sense the package surface temperature and turn the heating system on and off to keep this temperature at 180 to 190°F. Early in the heating process, heat conduction to the frozen interior of the food would be greater and the heating system would have to be on most of the time to keep the surface temperature up. As the heating process neared completion, the heat flow to the food interior would be reduced, and the heating system would be off most of the time. It would be possible to determine the percent of heating on to off time at which the food in the container has been heated to the desired 165°F. After further consideration, this concept was rejected because all of the food in the oven must be of one type, and temperature sensing element would be too vulnerable to damage.

3. FAST RECONSTITUTION OF FROZEN FOOD ON DEMAND WOULD BE DIFFICULT IN THE FIELD FEEDING SITUATION.

Reconstitution of frozen cooked food on demand would have considerable advantage in fixed-site feeding situations such as CONUS garrison mess halls. If reconstitution could be done in about a minute, the food could be kept frozen until the soldier to be served requested it. With such a system, a wide menu selection could be offered and no food would be wasted. The food would simply be held frozen longer. Greater frozen food inventory and storage facilities are probably required to realize these advantages, but this would probably not be too great a problem in the fixed-site situation.

EXHIBIT E-1
U.S. Army Natick Laboratories
CONTROL SYSTEM CONCEPTS





In the mobile field kitchen, storage space will be limited. Thus, menu selection will be limited and saving unused frozen food will probably not be feasible at the field kitchen. It might be possible to save unused food by transporting it back to the central preparation or distribution center, but to do this, refrigerated frozen storage would have to be assured throughout the time the food is in the field. The cost penalties associated with this requirement may outweigh any possible cost savings.

Several reconstitution system concepts were generated which were aimed at faster heating. These concepts are as follows:

- Use of metal skewers to conduct heat to the inside of food items.
- Processing the food into thin layers.
- Using refrigeration in combination with microwave heating to retard defrosting at the surface and local "runaway" heating.
- Penetrating the food as it is thawed with needle heat pipes.
- Passing electrical current through the food using the internal electrical resistance of the food to generate heat.
- Using a heat "reservoir" to reduce the recovery time required to bring the reconstitution system back to temperature after the loading of frozen food.
- Controlling the humidity of hot air in a convection oven to allow heating of the food packages without covers on them.

These concepts have disadvantages such as reducing the acceptability of the food, increasing the complexity and size of the system, and introducing considerable development risk. Since faster food heating would not be a great advantage to the field kitchen, these concepts were rejected.

4. LOW TEMPERATURE HEATING HAS ADVANTAGES

All conventional methods of heating foods (hot air convection, steaming, boiling in water, boiling in oil, contact heating, and infrared radiation) transfer heat to the outside surface of the food. From that point, the heat flows to the interior of the food by conduction. A difference in temperature is what causes heat to flow from one point to another. With greater temperature difference, more heat will flow and the cold area will be heated faster. Since the outside surface temperature of the food is limited to 180 to 190°F, the fastest possible heating* occurs when the food surface is maintained at these temperatures. However, high temperatures such as 350°F in convection ovens, and 850°F in infrared ovens, are used and the food surface is not damaged. This is because these temperatures are the heat source temperatures in the heating system and there is high thermal resistance between these source temperatures and the food surface. The high temperatures are used to keep the heating time short despite high thermal resistance. If, in these ovens, the heating process is stopped at the proper time, the surface temperature is kept below the 180 to 190°F limit. However, if the food were left in the oven long enough with the heat source on, the food would reach the temperature of the heat source.

One approach to keeping the heating time reasonably short while using a low heat source temperature is to cut down the thermal resistance. If thermal resistance could be eliminated, a heat source temperature of 190°F could be used. If this could be done, the following advantages would be realized:

- The food would be heated in the fastest possible time.
- It would be impossible to damage the food by overheating.
- Foods with vastly different heating characteristics could be placed in the same container and left to heat for the time required by the slowest food. As a food temperature approached 190°F, the heat flow would automatically stop.
- Low temperature oven and container materials could be used.
- Heat losses to the kitchen would be reduced.

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* Excluding microwave heating.

It is not possible to achieve zero thermal resistance, but it is possible to achieve significant reductions. The thermal resistance in steam heating is one two-hundredth* of the thermal resistance to hot air convection heating. This explains why it takes less time to heat food in a steamer, despite the fact that the steam is about 150°F cooler than the air temperature in a convection oven. It is possible to decrease the thermal resistance to hot air convection heating by increasing air velocity and turbulence.

A series of tests were conducted to determine the magnitude of improvement which could be accomplished by increasing convection air velocity. The results of these tests are shown in Exhibit E-2. The feasibility of the concept of using high velocity, low temperature air for the field reconstitution system is indicated by these data.

Servings of Salisbury steak in gravy and mashed potatoes in an aluminum foil container were used in the tests. Initial food temperatures in each case were approximately 20°F. Thermocouples were placed in the center of the food portions to measure the temperature.

Two types of tests were conducted. The first series was conducted with air at a constant input temperature of 200°F while the velocity was varied in steps from zero to 40 feet per second. The second series was conducted at constant air velocity of 40 feet per second, while the air temperature was varied. The results are shown in Exhibit E-2.

The first constant temperature test was conducted using a large laboratory oven. Exhibit E-2(1) indicates it required between 52 and 57 minutes to heat the frozen food to 165°F at an air velocity of 20 feet per second and approximately 35 minutes with an air velocity of 40 feet per second. This test indicated the high velocity air concept had validity.

The test was then refined by fabricating a box oven much smaller than the laboratory oven. The box oven fit the food containers closely, thus forcing more of the air to pass over the containers than with the larger oven. Too much air passed along the side of the food shelves without contacting the food in the laboratory oven. The results of the tests using the box oven are shown in Exhibit E-2(1). The food was heated to 165°F in 46 to 50 minutes with air at 200°F moving at 10 feet per second and in 30 to 33 minutes with an air velocity of 20 feet per second.

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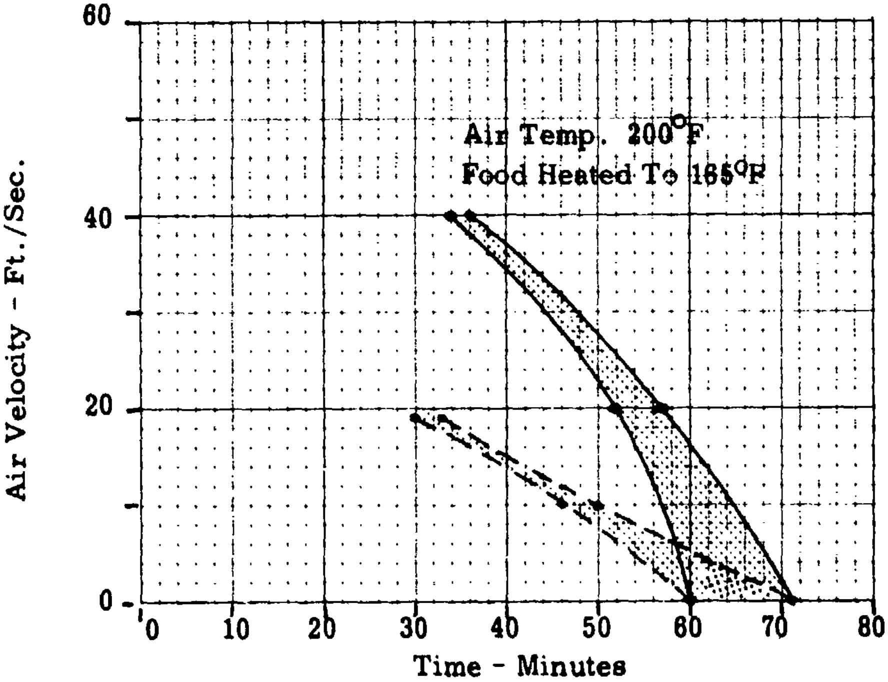
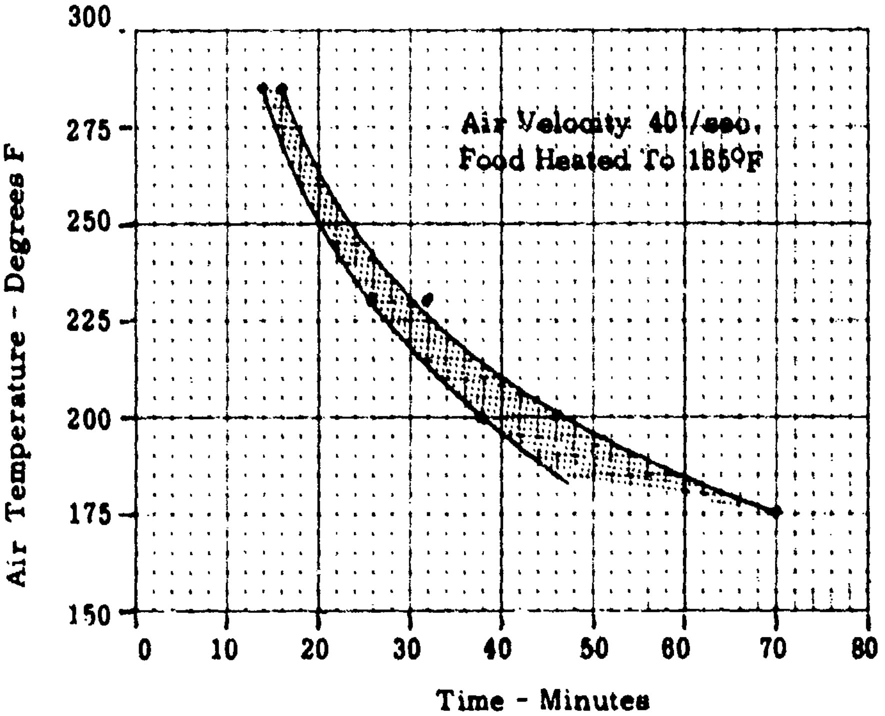
* Frank Krieth, Principles Of Heat Transfer, 1961, International Textbook Company, Scranton, Pennsylvania.

EXHIBIT E-2
U.S. Army Natick Laboratories
HIGH VELOCITY AIR
CONVECTION TESTS



(1)

——— Tests in large laboratory oven
– – – – Tests in smaller close-fitting oven



(2)

In the second series of tests, the air velocity was maintained at 40 feet per second. The box oven was used and the air temperature varied in steps. The results, shown in Exhibit E-2 (2), indicate the heating times are reduced with increasing air temperature as was expected. As shown, the heating time becomes 14 to 16 minutes when the air temperature is raised to 285^{o}F. These tests indicate that the high velocity, low temperature convection heating concept is feasible and has advantages in the field kitchen. Some of the advantages are:

- A wider selection of packaging materials because of the low temperature.
- Less heating of the field kitchen environment than with other convection ovens.
- Little likelihood of overcooking or spoiling the food.

APPENDIX F

DESCRIPTION OF TEST APPARATUS AND METHODS

APPENDIX F

DESCRIPTION OF TEST APPARATUS AND METHODS

The food heating tests discussed in this report were conducted in the food laboratories of Foster D. Snell, Inc., Florham Park, New Jersey. The apparatus and test methods used are described in this appendix.

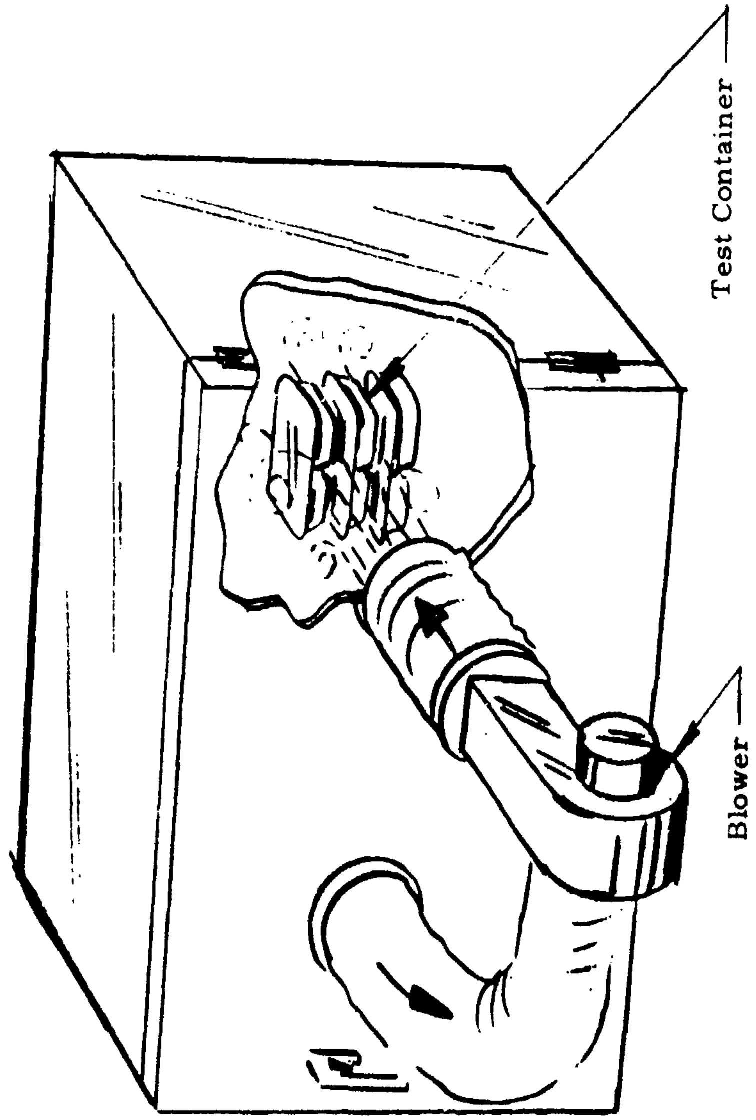
Care was taken to generate accurate data. Whenever data obtained were of questionable accuracy, experimental details were checked, corrections were made, and the experiment was repeated. Nevertheless, the scope of these tests was quite limited, and the test apparatus consisted of readily available equipment. Thus, the test data should be regarded as preliminary.

All food samples were treated in the following manner. The food was removed from the frozen storage cabinet and allowed to thaw to a point where a thermocouple could be inserted into the approximate center of the food item. All thermocouples used in these tests were sheathed in 0.06" diameter stainless steel probes. The food in the container with the thermocouples inserted was then covered with aluminum foil and refrozen. The food was then reconstituted. After each heating experiment, a judgment of the food quality was made by a food technologist based upon visual observations and taste sampling.

Steam heating experiments were conducted in an autoclave. Thermocouples were used with a multipoint recorder to measure and record steam temperature around the food, and the resulting food temperature transient. Steam temperature was manually controlled. The time required to heat the food to 165°F was determined from the strip chart record.

Hot air convection heating experiments were performed using two configurations. Both of these setups used a laboratory oven with two 6" diameter instrument ports as the source of hot air at controlled temperature. In configuration I, shown in Exhibit F-1, the container to be heated was placed in the oven compartment. Two other containers full of frozen food were positioned above and below the test container to form air passages.

EXHIBIT F-1
U.S. Army Natick Laboratories
CONVECTION HEATING TEST
CONFIGURATION I



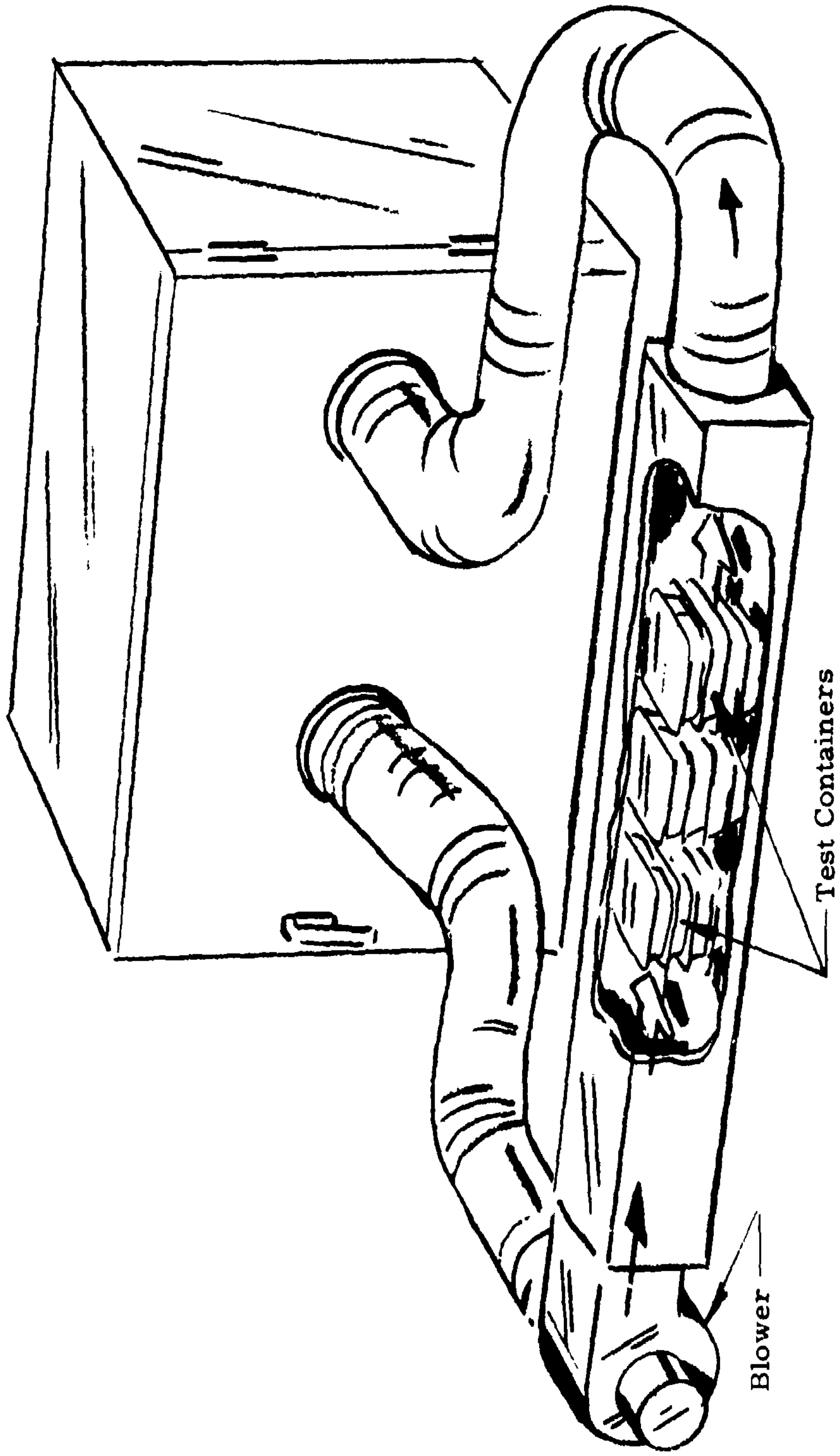
A blower was connected to the instrument ports with flexible tubing. This blower pulled the heated air from the oven and caused it to flow around the test food container. Two different blowers were used to cause two different air velocity conditions. Thermocouples were used with a multipoint recorder to measure and record the temperature of the air around the food container and the resulting food temperature transients. The velocity of the air in the passages above and below the test food container was measured using a Pitot tube and manometer. The food heating time was determined from the strip chart temperature records.

In Configuration II, shown in Exhibit F-2, the test food containers were positioned in a specially constructed box. The blower and flexible tubing were connected to the oven and box. The blower caused hot air to flow through the box and around the test food containers. Thermocouples were used with a multipoint recorder to measure and record the inlet and discharge air temperature, and the resultant food temperature transients. The pressure drop across the food containers was measured with a manometer. The velocity of air flow around the food containers was determined from hot wire anemometer measurements of the average air flow velocity in the discharge area of the box. The food heating time was determined from the recorded temperature transients.

Another test series was conducted to evaluate an electrical resistance method of heating. Thawed food, held in a glass dish, was heated by passing an electrical current through it. The tests indicated the method was too slow for use in the field kitchen. Following is a description of the tests.

- Two #12 copper wire probes were inserted into opposed edges of a sirloin beef patty.
    - At 100 volts the temperature rose from 47°F to 57°F in three minutes. Heating stopped because the probes became insulated by charred meat.
    - At 50 volts the temperature rose from 60°F to 71°F in six minutes when charring occurred and heating stopped.
    - At 25 volts the temperature rose very slowly from 72°F to 76°F in eight minutes when the test was discontinued.

EXHIBIT F-2
U.S. Army Natick Laboratories
CONVECTION HEATING TEST
CONFIGURATION II



- Two #12 copper probes were inserted in the gravy surrounding a beef patty but just touching the patty with the following results.

  - At 100 volts the gravy boiled and caused surface drying without appreciable heating of the patty.

  - At 75 volts the gravy was heated without boiling and the patty was heated from 50°F to 130°F in 30 minutes.

No further tests were conducted because the method was shown to be too slow.

APPENDIX G

EXAMPLES OF CALCULATIONS

APPENDIX G

EXAMPLES OF CALCULATIONS

This appendix contains typical calculations which identify the methods used to determine the quantities used in this evaluation. Footnotes in the text reference the appropriate calculation number.

1. DIESEL FUEL SUPPLY, ELECTRICAL HEATING CONCEPTS

To determine the fuel supply required, it is necessary to calculate the energy used by the system over a typical three day period. The calculation for reconstitution system Concept No. 1, Convection Oven, Electric, Preplated Food is shown here.

- Assumptions used in this calculation are as follows:
  - Ovens and wire baskets are mainly steel and are preheated to an average temperature of 250°F from an initial temperature of 70°F.
  - Oven outside surface temperature is 140°F and the air around the oven is at 70°F. Further, the heat transfer coefficient to the air is $5 \frac{\text{Btu}}{\text{ft}^2\ {}^{\circ}\text{F}}$

    Average time these conditions exist is 50 minutes per oven per meal.
  - Frozen food is loaded at 0°F and is heated to 165°F.
  - Average food heat absorption is as follows:

*0.4	$\frac{\text{Btu}}{\text{lb}\ {}^{\circ}\text{F}}$	from 0 to 30°F
*100	$\frac{\text{Btu}}{\text{lb}}$	latent heat of fusion
*0.8	$\frac{\text{Btu}}{\text{lb}\ {}^{\circ}\text{F}}$	from 30 to 165°F

  - Weights of food to be heated are as shown in Exhibit B-1.

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* ASHRAE, Guide and Data Book, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York (1965).

- Conversion of electrical energy to heat is 100 percent efficient

- Energy required by mechanical refrigeration system is insignificant in a three day period

- Preheat energy, $Q_1 = m_1 c_1 \Delta T$

Where $m_1 = 600$ lbs. per oven

$c_1 = 0.11 \frac{\text{Btu}}{\text{lb-}^{\circ}\text{F}}$

$\Delta T = (250 - 70) = 180^{\circ}\text{F}$

Then $Q_1 = 600 \times 0.11 \times 180 = 11{,}880$ Btu

Each oven is preheated three times per day. Thus, in the three day resupply period the preheat energy used = 2 x 3 x 3 x 11,880 = 213,840 Btu

- Energy absorbed by food,

$$Q_2 = m_2 (C_2 \Delta T_2 + H_2 + C_3 \Delta T_3)$$

Where m_2 = 1790 lbs of food for 3 days

$C_2 = 0.4 \frac{\text{Btu}}{\text{lb}^{\circ}\text{F}}$

$\Delta T_2 = 30^{\circ}\text{F}$

$H_2 = 100 \frac{\text{Btu}}{\text{lb}}$

$C_3 = 0.8 \frac{\text{Btu}}{\text{lb}^{\circ}\text{F}}$

$\Delta T_3 = (165 - 30) = 135^{\circ}\text{F}$

Then $Q_2 = 1790\ (0.4 \times 30 + 100 + 0.8 \times 135) = 393{,}800$ Btu

- Energy lost through oven walls,

$$Q_3 = t\ h\ A\ (T_S - T_A)$$

Where, $t = 50$ minutes $= .83$ hrs per oven

$h = 5 \frac{\text{Btu}}{\text{ft}^2\text{-}^\circ\text{F}}$

$A = 60$ ft^2 surface area per oven

$T_S = 140^\circ F$

$T_A = 70^\circ F$

Then, $Q_3 = .83 \times 5 \times 60\ (140-70) = 17{,}430$ Btu per oven

Each oven would be operated three times per day. Thus, in the three day resupply period, the energy lost through oven walls = 2 x 3 x 3 x 17,430 = 313,740 Btu

- Total heat energy required in three day period = 921,400 Btu

- Equivalent electrical energy required

  $= 921{,}400 \div 3{,}413$

  $= 270$ KW hrs

- The controls and blower of each convection oven consume about 1 KW of power during operation. Thus, the electrical power consumed by two ovens operating for .83 hours three times a day for three days would be,

  $1 \times 2 \times 3 \times .83 \times 3 = 14.9$ KW hrs

- Then the total electrical energy consumed in three days is,

  $270 + 14.9 = 285$ KW hrs

- Using performance data for the 40 KW commercial diesel electric generator, the diesel fuel consumption rate was found to be 0.093 gallons per KW hr.

Then fuel consumption is :

$285 \times .093 = 26.5$ gallons in three days

2. DIESEL FUEL SUPPLY, FUEL FIRED CONCEPTS

In the case of fuel fired concepts, the diesel fuel supply required is calculated by assuming that heat energy is supplied by burning of diesel fuel at 60 percent efficiency. The calculation for reconstitution system Concept No. 3, Convection Oven, Diesel Fuel Fired, Preplated Food is shown here.

- From example calculation 1, the total heat energy required in three days is 921,400 Btu.

- Using a heating value of 135,000 Btu per gallon of fuel* and 60 percent efficiency, the fuel required for heating is calculated to be,

  W = 921,400 ÷ 135,000 ÷ 0.60 = 11.4 gallons

- The controls, blowers and power pack used in this concept consume about 3.5 KW per hour of operation. Thus, over the three day supply period, electrical power consumption would be,

  3.5 x .83 x 3 x 3 = 26.1 KW hrs

- Using the performance data for the 5.5 KW commercial diesel electric generator, the diesel fuel consumed by the generator in three days is found to be,

  26.1 x 0.09 = 2.4 gallons in 3 days

- Then total fuel consumed in three days is,

  11.4 + 2.4 = 13.8 gallons

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* ASHRAE, Guide and Data Book, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York (1965).

3. ALLOWABLE FOOD STORAGE TIME IN INSULATED CASE

To determine the length of time frozen food may be stored in insulated cases, it is necessary to determine the quantity of heat which may be absorbed by the frozen food and the rate at which heat flows through the insulation.

. Assumptions used in this calculation are as follows:

- Fifty-four 17 ounce hot packs at 0°F are loaded into the insulated case.
- The temperature of food may be allowed to rise to 40°F.
- Average rate of food heat absorption is as follows:

*0.4	$\frac{\text{Btu}}{\text{lb }^\circ\text{F}}$	from 0 to 30°F
*100	$\frac{\text{Btu}}{\text{lb}}$	latent heat of fusion
*0.8	$\frac{\text{Btu}}{\text{lb }^\circ\text{F}}$	above 30°F

- Insulated container effective area of 13.7 square feet with 2" thick polyurethane foam walls.
- Inside wall temperature is 30°F and outside is 100°F.

. Heat which may be absorbed by the food,

$$Q_4 = m_4 \ (C_4 \Delta T_4 + H_4 + C_5 \Delta T_5)$$

Where

$m_4 = 54 \times 17 : 16 = 57.4 \text{ lbs.}$

$C_4 = 0.4 \ \frac{\text{Btu}}{\text{lb}^\circ\text{F}}$

$\Delta T_4 = 30^\circ\text{F}$

$H_4 = 100 \ \frac{\text{Btu}}{\text{lb}}$

$C_5 = 0.8 \ \frac{\text{Btu}}{\text{lb}^\circ\text{F}}$

$\Delta T_5 = (40 - 30) = 10^\circ\text{F}$

Then $Q_4 = 57.4 \ (0.4 \times 30 + 100 + 0.8 \times 10) = 6888 \text{ Btu}$

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* ASHRAE, Guide and Data Book, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., New York.

- Rate of heat flow through the insulated case walls,

$$q_5 = \frac{Ak}{t} \ (T\ out - T\ in)$$

Where,

$A = 13.7$ square feet

$k = 0.12 \ \frac{Btu\text{-}in}{hr\text{-}ft^2\text{-}^{\circ}F}$

$t = 2''$

$T\ out = 100^{\circ}F$

$T\ in = 30^{\circ}F$

Then $q_5 = \frac{13.7 \times 0.12}{2} \ (100 - 30) = 57.5 \ \frac{Btu}{Hr}$

- Allowable storage time,

$$t = \frac{Q_4}{8_5} = \frac{6888}{57.5} = 119.8 \text{ Hrs or 5 Days}$$

APPENDIX H

LIST OF ORGANIZATIONS INTERVIEWED

APPENDIX H

LIST OF ORGANIZATIONS INTERVIEWED

1. EQUIPMENT MANUFACTURERS

Aladdin Synergetics, Inc.
703 Murfreesboro Road
P. O. Box 7222
Nashville, Tennessee 37210

Alto-Shaam, Inc.
6040 N. Flint Road
Milwaukee, Wisconsin 53209

Associated Food Equipment Co.
2051 Valley View Lane
P. O. Box 34568
Dallas, Texas 75234

Avery Products Corporation
415 Huntington Drive
San Marino, California 91108

The Cleveland Range Company
971 East 63rd. Street
Cleveland, Ohio 44103

Crown-X, Inc.
12711 Taft Avenue
Cleveland, Ohio 44108

Despatch Oven Co.
P. O. Box 1320
Minneapolis, Minnesota 55440

Foster Refrigeration Corporation
Hudson, New York 12534

General Electric Co.
Commercial Equipment Department
14th and Arnold Street
Chicago Heights, Illinois 60411

The Hobart Manufacturing Co.
Food Service Equipment Dealer Division
Troy, Ohio 45373

Lincoln Food Service Systems
Division Of Lincoln Manufacturing Co., Inc.
1111 N. Hadley Road
Fort Wayne, Indiana 46801

Litton Microwave Cooking
400 Shelard Plaza South
Minneapolis, Minnesota 55426

Market Forge
35 Garvey Street
Everett, Massachusetts 02149

Minnesota Mining and Manufacturing Co.
3M Center, Building 551-2
St. Paul, Minnesota 55101

The Montague Co.
1830 Stearman Avenue
Hayward, California 94545

Raytheon Co.
Microwave and Power Tube Division
Foundry Avenue
Waltham, Massachusetts 02154

South Bend Range Corporation
201 South Cherry Street
South Bend, Indiana 46621

Varian Associates
611 Hansen Way
Palo Alto, California 94303

Votator Division of Chemetron
P. O. Box 43
Louisville, Kentucky 40201

Vulcan-Hart Corp.
P. O. Box 696
Louisville, Kentucky 40201

2. EQUIPMENT USERS

ARA Food Service Co.
Independence Square, West
Philadelphia, Pennsylvania 19106

ARA Food Service Co.
Southern Connecticut State College
New Haven, Connecticut

Fairfield Farm Kitchens
Division of Marriott
5200 Addison Road, N.E.
Washington, D.C. 20027

Hennepin County General Hospital
Fifth and Portland South
Minneapolis, Minnesota 55415

United Air Lines
Flight Kitchen
Logan International Airport
Boston, Massachusetts 02128

3. FOOD PACKERS

Campbell Soup Company
Food Service Products Division
Campbell Place
Camden, New Jersey 08101

Culinary Technology, Inc.
4620 West 77th Street
Minneapolis, Minnesota 55435

Glidden-Durkee
Division of SCM Corporation
900 Union Commerce Building
Cleveland, Ohio 44115

Green Giant Company
Food Service Division
5601 Green Valley Drive
Minneapolis, Minnesota 55437

4. DEVELOPMENT LABORATORIES

United States Army
Natick Laboratories
Food Laboratory
Natick, Massachusetts 01760

United States Army
Natick Laboratories
General Equipment and Packaging Lab
Natick, Massachusetts 01760

United States Army
Natick Laboratories
Pioneering Research Laboratory
Natick, Massachusetts 01760

Purdue University
Institutional Management Research
Home Economics Building
West Lafayette, Indiana 47907

United States Army
Natick Laboratories
Operations Research
Systems Analysis Office
Natick, Massachusetts 01760