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31 DECEMBER 1970

NASA APPROVED

FINAL REPORT
SPACE STATION/BASE FOOD SYSTEM STUDY
VOLUME I
SYSTEMS DESIGN HANDBOOK

Prepared for
NATIONAL AERONAUTICS and SPACE ADMINISTRATION
Manned Spacecraft Center
Houston, Texas 77058

Contract NAS9-11139
DRL Line Item No. 6

Prepared by
Manned Space Systems

FAIRCHILD HILLER
FAIRCHILD REPUBLIC DIVISION
FARMINGDALE, NEW YORK 11735

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ABSTRACT

The Fairchild Hiller Corporation, Republic Aviation Division, performed a seven-month study under Contract Number NAS9-11139 entitled "Space Station/Base Food System Study" for the National Aeronautics and Space Administration, Manned Spacecraft Center. The study was conducted so as to identify and define engineering data for a spectrum of possible items and equipment comprising potential food systems for use on manned spacecraft and assemble these data in a Final Report and Data Book.

This document is Volume I of the Final Report. The Final Report summarizes the results of this study and has been prepared in two volumes:

Final Report - Volume I - Systems Design Handbook

This volume contains the study approach used in performance of the contract effort; the study results containing the candidate concepts considered and technical data, performance characteristics, and sketches for each of the concepts by functional area; human factors considerations for crew tasks; shuttle supply interface requirements; special food system study areas; and recommendations/conclusions based on the study results.

Final Report - Volume II - Systems Assessment

This volume describes the evaluation modeling technique used to combine the candidate element concepts into systems that meet mission requirements. Results of this assessment are presented in terms of systems performance data and plots of system trade-off data by highest ranking variable. Note: Section IV of Volume II is bound under separate cover.

The engineering Data Book supplements the Final Report and includes the detailed technical data sheets, supporting analysis and selection rationale for each of the concepts considered in the final study.

The contract effort was performed under the technical direction of Mr. Dean Glenn, Habitability Technology/Spacecraft Design Office of the Manned Spacecraft Center.

SECTION I

INTRODUCTION AND SUMMARY

The problems of confinement and stress may well prove to be limiting factors in long-duration manned space flight. A significant input can be made in minimizing these problems by changing the present barely tolerable, confined environment to a more spacious, comfortable, earth-like habitable environment in which man can work, sleep, eat and relax, and attend to personal needs over extended periods of time. The intent of this study was to investigate one of the primary task areas associated with sustaining the crew; the development of food systems concepts for multi-manned space missions.

Since man's first suborbital mission, space feeding systems have provided dry, bite-sized foods plus only a limited selection of rehydratable food items. These rations, although nutritionally adequate, are not satisfactory for long-term crew acceptance. From the standpoint of acceptability and its relationship to individual performance it is, therefore, imperative that a long-term space mission incorporate a vastly superior feeding system based on an earth-like one-gravity environment. To accomplish this objective, certain basic requirements must be established; for example, the system should:

- Provide a sufficient variety of food to meet the anticipated demands of large crew sizes.
- Provide a capability to store, prepare, serve, and allow for consumption of this food by employing essentially conventional earth-like techniques onboard the orbital vehicle.
- Provide a capability to clean equipment and facilities and dispose of resulting debris.
- Provide facilities to store required consumables and expendables.
- Provide for logistics and inventory control.

The purpose of the study conducted by Fairchild Hiller was to identify and define concepts and engineering data for food systems fulfilling the above requirements, evaluate and assess these concepts placing emphasis on the mechanics of food systems rather than the nutritional/caloric requirements, and produce documentation of the study results that can be utilized in a source manual.

A food system that will sustain a crew for extended periods of time must consider all the elements of food equipment and techniques that interface with the spacecraft missions. In addition, crew size and resupply cycles impact on the applicability of concepts as well as the associated penalties. Recognizing the spectrum of systems that could be conceived to fulfill the number of variables involved, the study was directed to; constrain the variables and develop mission models against which concepts could be conceived; produce technology data by analyzing and evaluating resulting concepts; and finally assessing these data in terms of system performance characteristics.

The mission model data is presented in Section II of this report which contains the guidelines, assumptions, study limits, and methodology utilized in the study. The results of the study are presented in Section III of this report which contains the evaluation critique, technical data, and sketches for each of the concepts considered. The detailed concept data sheets applicable to each mission, the supporting technical analysis and rationale are presented in Books I, II, and III of the Data Book. The balance of this volume of the Final Report contains discussions and data pertaining to human factors, crew time/task analysis, shuttle equipment interface requirements, special study considerations including the effects of multi-national crews on the food system, and recommendations for future development. The final assessment of the technology concepts is the overall impact when each element is combined into a system to fulfill the mission definition. The performance characteristics and parametric analysis are presented in Volume II of the Final Report.

SECTION II

STUDY APPROACH

A. OBJECTIVE

The food system required to sustain the crew of a Space Station/Base for extended periods of time consists of a particular concept of techniques, equipment elements, and functional arrangements. Fairchild Hiller studied various concepts of food systems for use on manned spacecraft emphasizing the mechanics of these systems in performing specific tasks on a spectrum of possible systems.

B. PURPOSE

The study was conducted to achieve the following results:

- Identify and define system concepts.
- Identify and define performance and quantitative requirements.
- Determine functional features and engineering data for system elements.
- Evaluate concepts.
- Perform parametric studies.
- Assess relative merits and/or deficiencies of each concept.
- Assemble data into a data book and final report.
- Provide a basis for the determination of future development areas.

C. MISSION MODEL GUIDELINES

The basis for the study was within the guidelines of a post-Apollo mission. The generalized parameters to be considered were:

- Gravity - Zero to one earth gravity.
- Radiation - Spacecraft structure provides required protection.
- Atmosphere

Pressure	10 to 14.7 psia
Composition	The partial pressure of oxygen will always be 3.5 psi; nitrogen and other atmosphere constituents partial pressures will compose the remainder.

Temperature	Range:	65°F to 75°F
	Nominal:	72°F
Dew Point	Preferred Range:	41°F to 46°F
	Nominal:	44°F
	Maximum:	60°F
	Minimum partial water pressure: 4 MM Hg	

- Crew - Number of crewmen (all male) ranges from 6 to 100.
- Water System - 155°F and 50°F water will be available for the food system.
- Nominal Duty Cycle

Duty in orbit	Ten years with 14 days to 6-month resupplies.	
Nominal duty day	Work	- 8 hours
	Eat	- 3 hours
	Sleep	- 8 hours
	Off Duty	- 5 hours

- Nutrition

2800 calories per man per day

2 to 3 pounds per man per day

250 cubic inches per man per day

- Equipment Lifetime - The operational lifetime will be 10 years.
- Operation - Kitchen operations shall be performed by personnel assigned specifically to this work area.
- Assumptions

In order to constrain detail requirements, the following assumptions were made and considered as part of the study limits:

a) No backup provisions in the food system are required to handle a failure of the environmental control system. This applies primarily to ambient storage requirements that are dependent on maintenance of vehicle atmosphere.

b) Food supplies are based on normal operations and contingency provisions are not included in sizing of equipment or facilities.

c) Water consumption requirements will be determined for reconstituting foods; however, based on a 90% efficient onboard urine reclamation system, sufficient water will be available for the food system since the maximum dry food percentage of food onboard does not exceed the recovery efficiency.

d) An ideal food system would be as nearly balanced as possible regarding water consumption requirements with respect to urine reclamation efficiency. Although it is recognized that this approach utilizing a high percentage of dry foods may result in an unacceptable food type selection, a design goal should be to minimize launch and return weights by reducing the net amount of onboard water generated by the food system.

- Study Limits

To define actual systems in terms of quantified requirements, a mission model matrix as depicted in Figures II-1, II-2, and III-3 was developed to cover a spectrum of mission alternatives or options to be studied. The parameters considered as variables were resupply times, crew size, number of meal sittings, and crewmen per meal sitting. For each of the resupply missions, a range of food type mix by percentage was used to generate concepts and equipment to fulfill each functional area of the total system.

The rationale used for the parameters selected was as follows:

a) All numbers chosen are nominal values and have some arbitrary tolerance range to permit flexibility of selection and arrangements.

b) Resupply periods were selected jointly by NASA and Fairchild Hiller to be 14 days and 90 days as most representative data points. The six-month resupply point was dropped as an unlikely candidate so as to permit more detailed data generation for the selected periods.

c) The original crew size range of 10 - 100 men was modified in meetings with NASA to reflect more realistic crew sizes. Data points of a 6-man, 12-man, and 25-man crew were ultimately selected to define mission model planning.

d) The number of sittings and men/sitting were selected in order to define basic equipment sizes for preparation and serving devices; storage and dispensing sizing; and consumption and clean-up devices.

e) The water balance and wet food mix percentages are explained in Functional Subsystem Area 1.0 - Provide For Food, in Section III - Study Results.

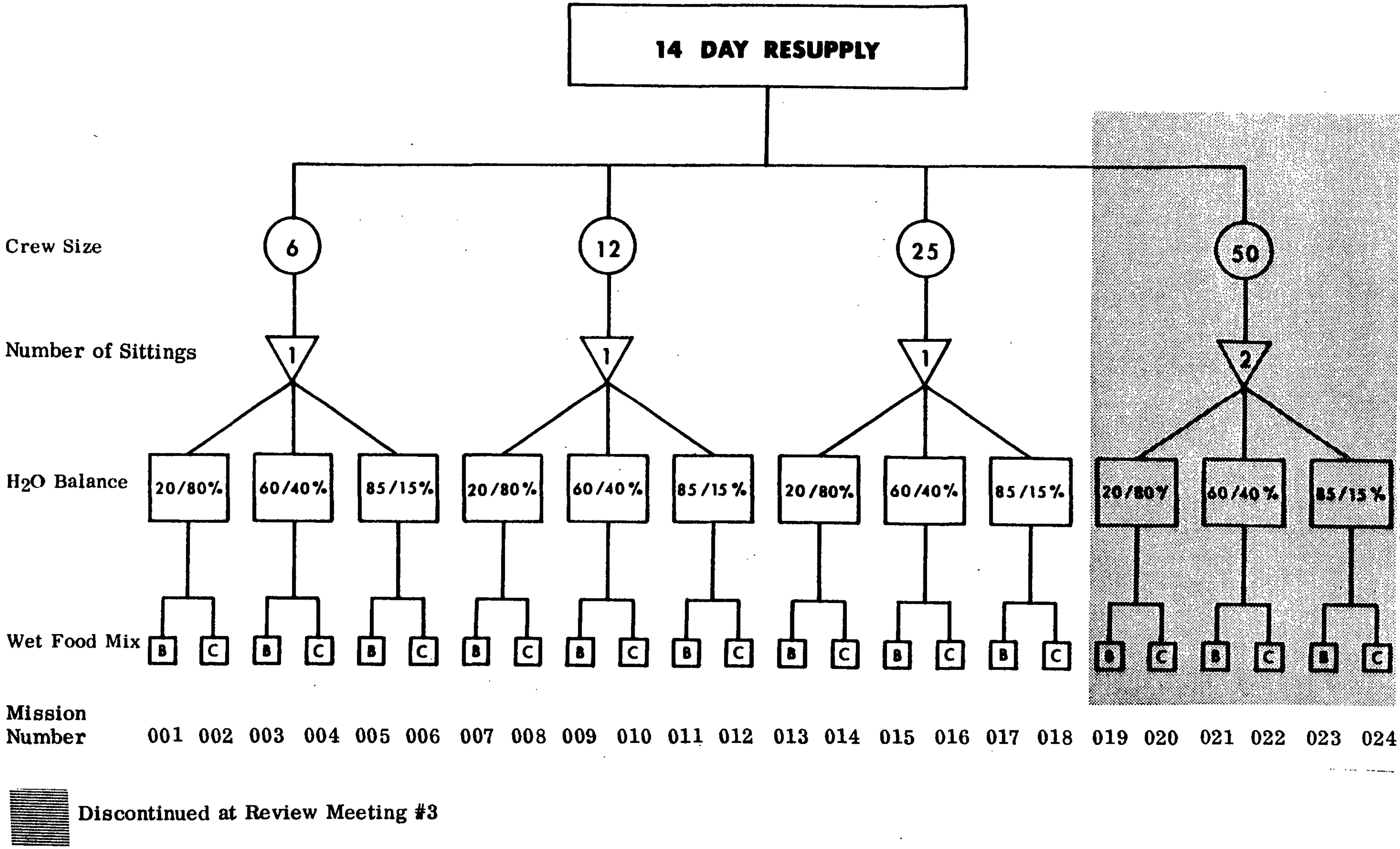

Figure II-1. Mission Model Matrix - 14-Day Resupply

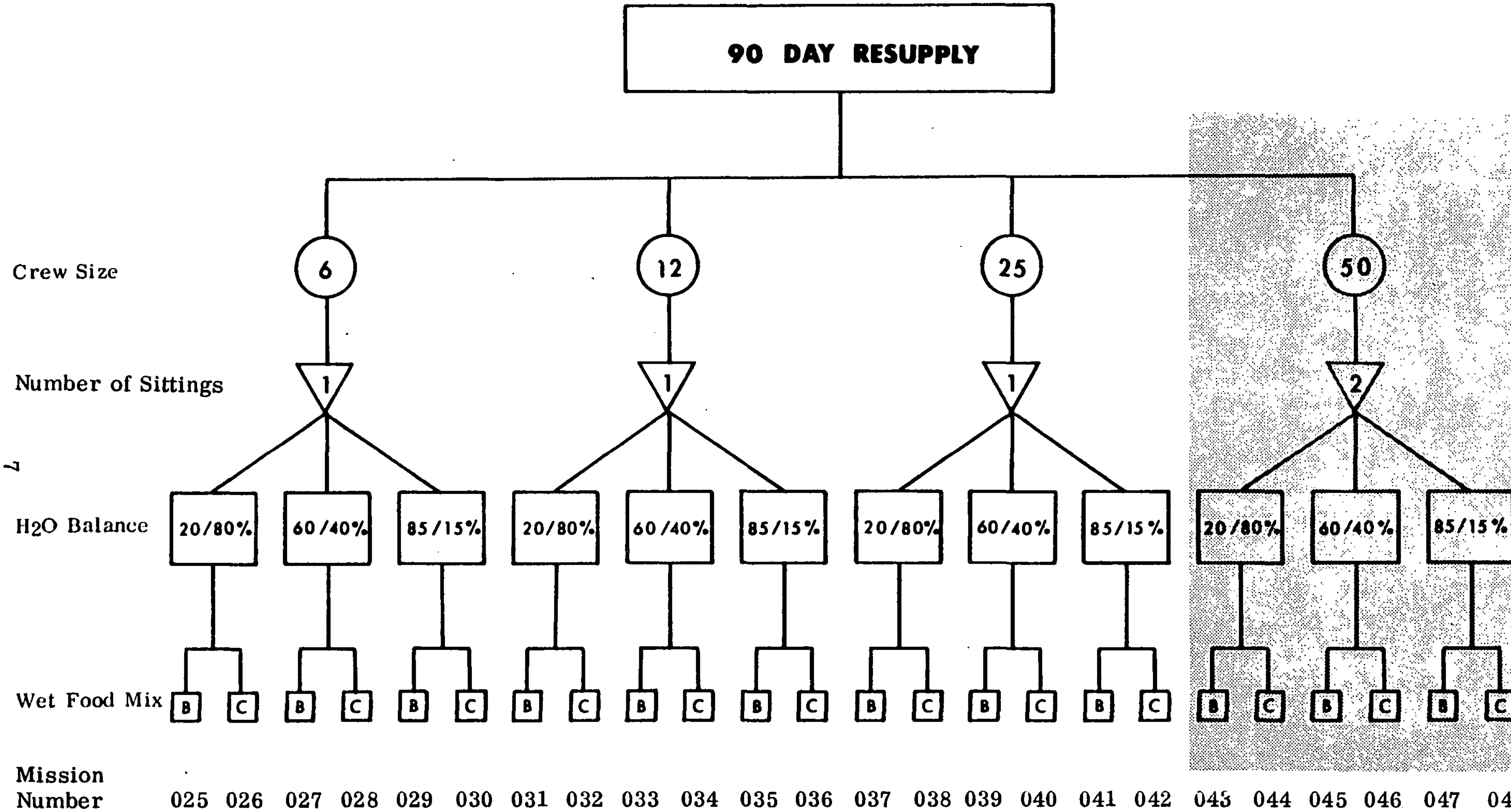

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Figure II-2. Mission Model Matrix - 90-Day Resupply

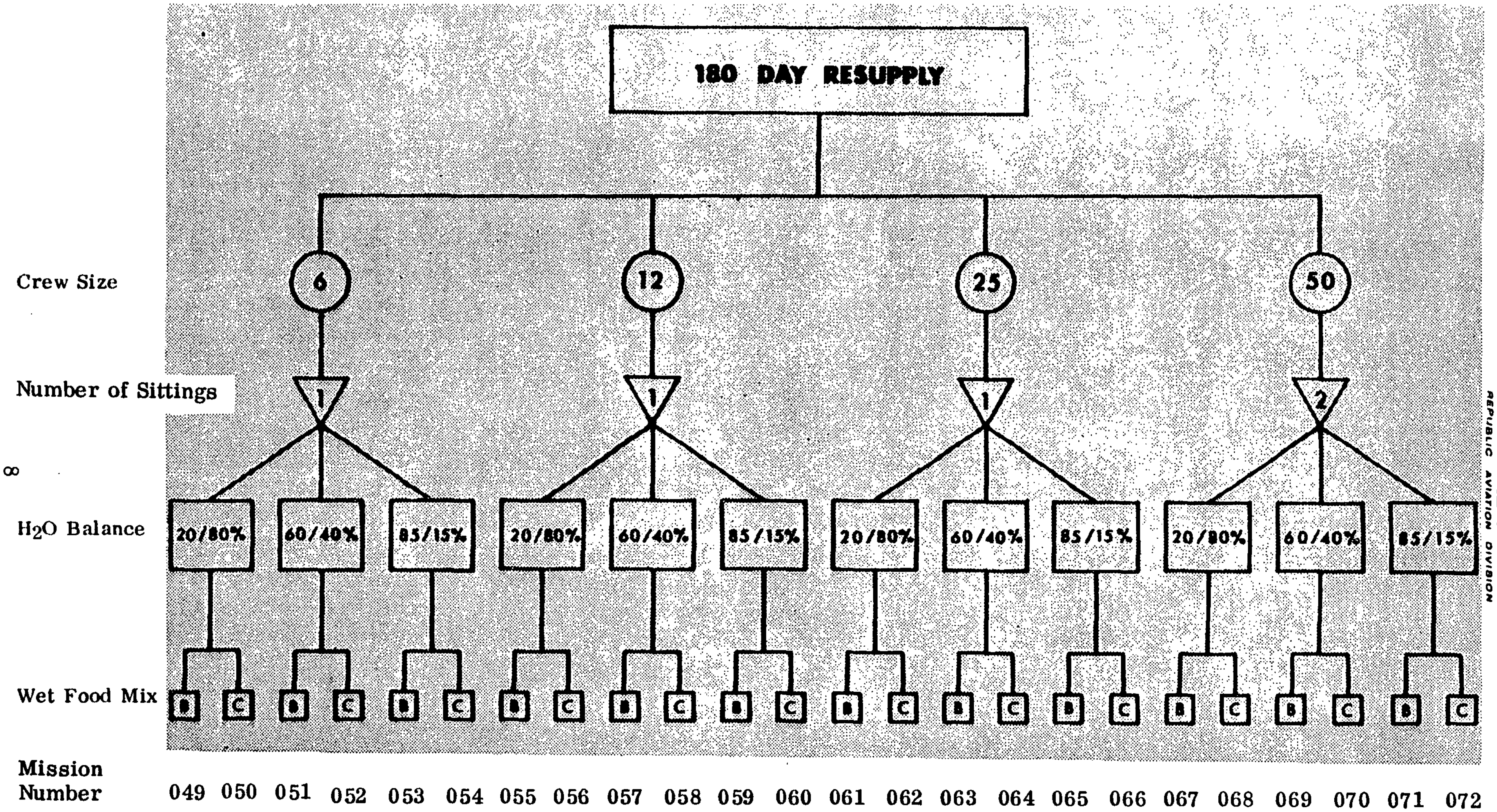

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Figure II-3. Mission Model Matrix - 180-Day Resupply

f) Mission model numbers were originally assigned for all combinations of the parameters considered. During the course of the study certain mission numbers were dropped as the study limits became more defined. Therefore, only mission numbers representative of the final phase of the study are depicted in Figures II-1 and II-2.

- Systems Consideration

The requirements for a total food system were defined by considering the system to be comprised of seven (7) primary functional subsystem areas as shown in Figure II-4. By developing equipment concepts to meet the requirements of each functional area, a spectrum of possible system concepts were derived.

D. METHODOLOGY

A study task flow diagram, depicted in Figure II-5, outlines the tasks performed within the four phases of the study. A description of the effort and results obtained are summarized below. Task numbers are in accordance with the detailed task outline defined in the Study Plan (Document Number MS128W0001).

1.0 Survey/Literature Search/Bibliography Report (Tasks 1, 2, 3)

Fairchild Hiller surveyed industrial, governmental, and university food research and equipment organizations by personal contact, form letters, visits, and meetings. A Team Study Panel was created consisting of representatives of diverse organizations in food technology. The Panel consisted of:

Swift and Company	-	Dr. R. Pavey
General Foods Corporation	-	Dr. B. Buchanon
Litton Systems, Inc.	-	Mr. P. Pederson
American Can Company	-	Mr. H. Bardwell
Pillsbury Company	-	Mr. P. Sams
Sky Chefs, Inc.	-	Mr. A. D'Agostino
Rutgers University	-	Dr. P. Lachance

Meetings were held with this panel at the Fairchild Hiller facility. Notes of the meetings were submitted to NASA in Monthly Progress Reports.

The literature search was conducted during the Initial Research Phase. Services utilized included the Defense Documentation Center (DDC), National Library of Medicine (MEDLARS), and the NASA Computerized Literature Search data tapes.

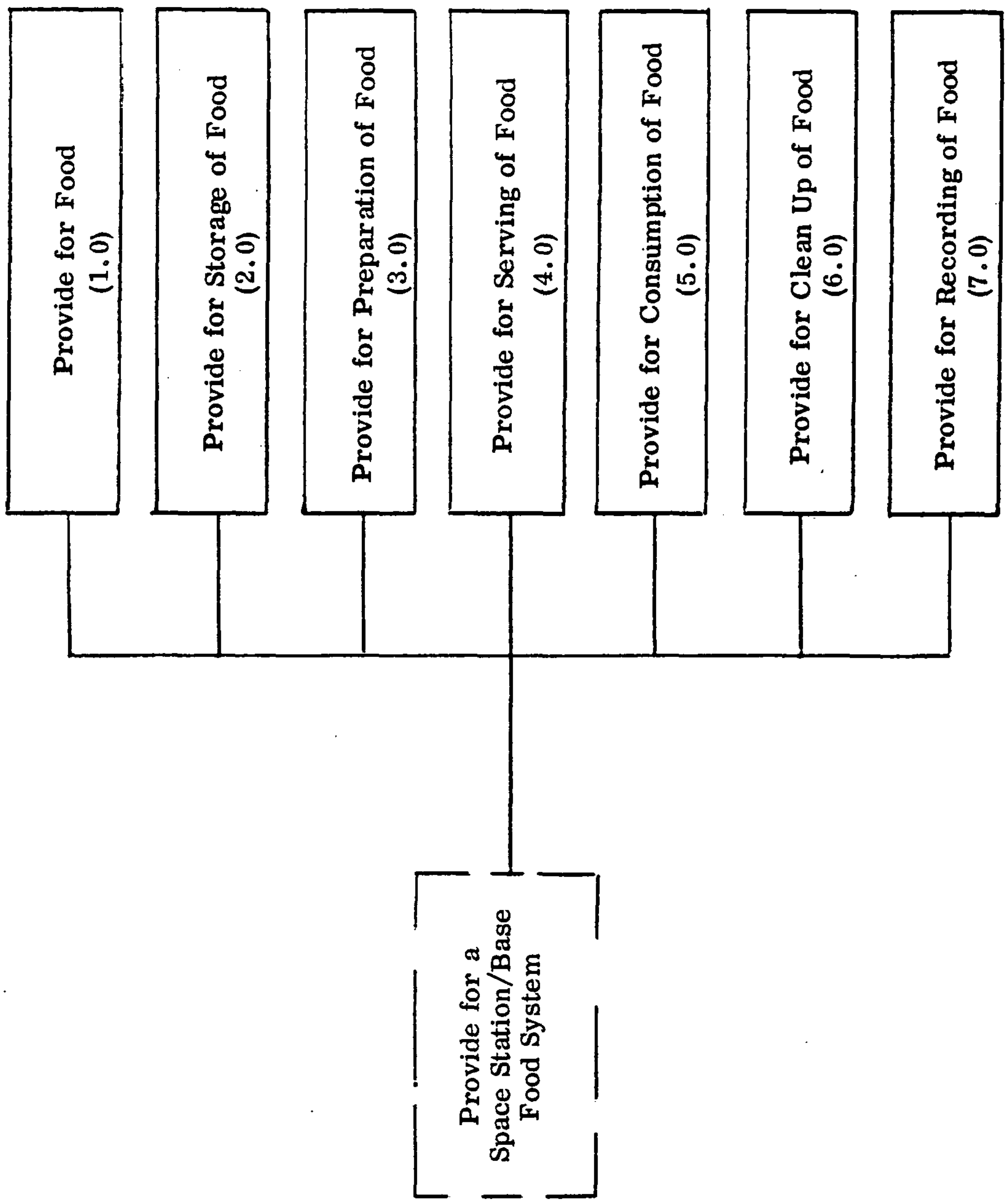


Figure II-4. Food System Functional Subsystem Areas

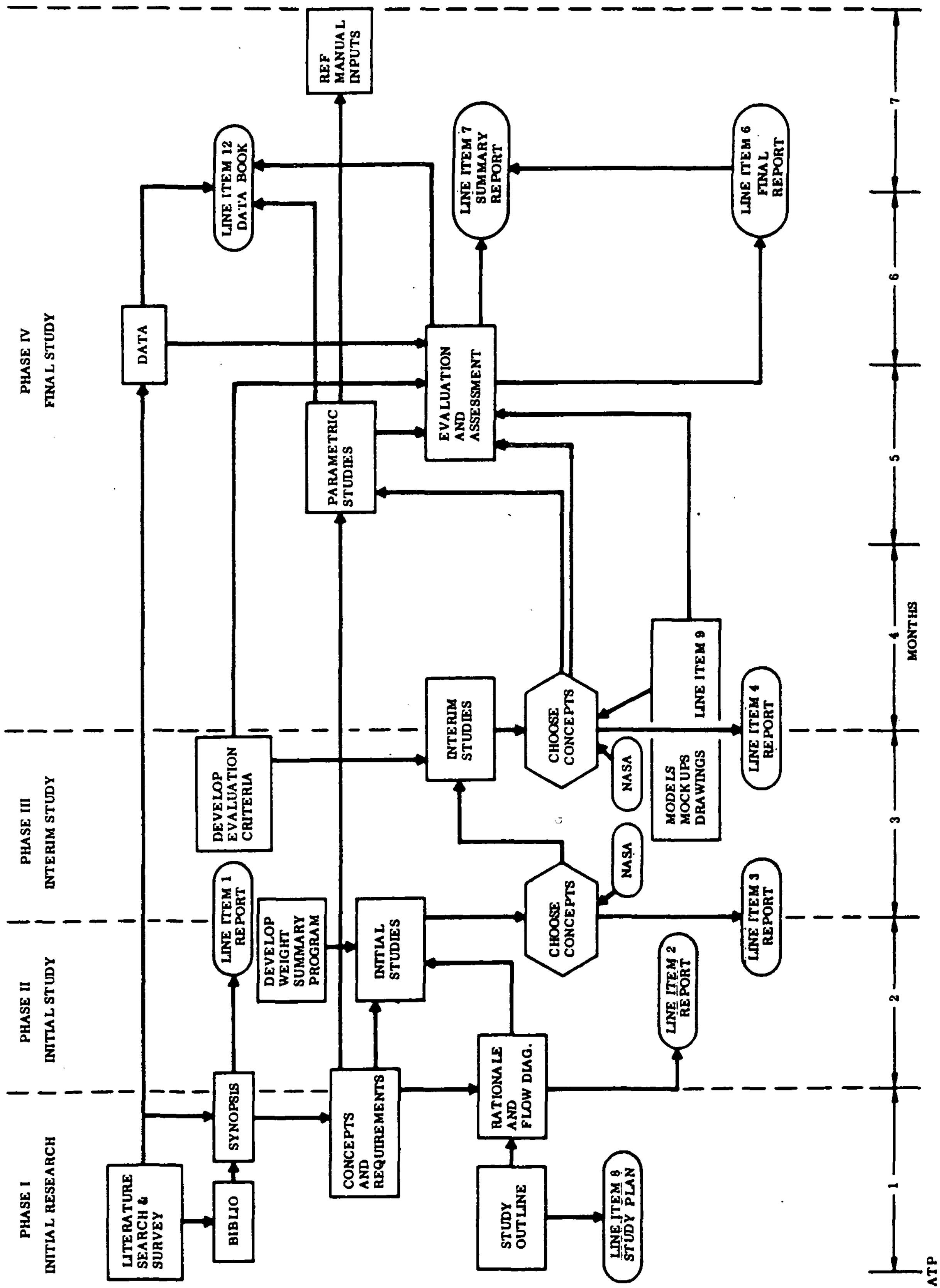


Figure II-5. Food System Study Task Flow Diagram

A Bibliography/Synopsis Report (Document Number MS128Y0002 dated 28 August 1970) was prepared and submitted to NASA summarizing the results of the literature search.

2.0 Logic Flow/Evaluation Criteria/Modeling Technique (Tasks 4, 9, 13)

A model logic (Figure II-6) was developed to assess inputs, establish requirements for evaluation criteria, and present the primary computational steps that were utilized. Evaluation criteria utilized during the Initial and Interim phases of the study are presented in Document Number MS128Y0004 dated 26 October 1970/ Volume II - Study Selection Rationale Sheets.

3.0 Concepts and Requirements (Task 5)

The requirements for a total system concept, functional characteristics, and identification of preliminary equipment concepts were prepared and submitted in Document Number MS128Y0001 dated 7 August 1970/Requirements Report.

4.0 Weight Summary (Task 6)

The requirement for completing and submitting weight data on NASA/MSC Form 1522 were deleted. The data required by this form as well as complete physical and technical data for each element concept are included on the Element Concept Data Sheets appearing in the Data Book, Book I, Document Number MS128W0002 dated 31 December 1970.

5.0 Assessments/Concept Evaluation/Selection (Tasks 7, 8, 10, 12)

The generation of equipment concepts to meet the functional requirements, their evaluation and selection for detailed study in the Final Phase of the contract are detailed in the Initial Report (Document Number MS128Y0003 dated 28 August 1970) and the Interim Report (Document Number MS128Y0004, Volumes I, II, and III, dated 26 October 1970).

6.0 Mock-Up/Models/Drawings (Task 11)

Due to the large number of concepts that were developed to fit the spectrum of missions considered and the decision to carry them into the final study phase utilizing the evaluation model as the assessment tool, no mock-ups or models were constructed.

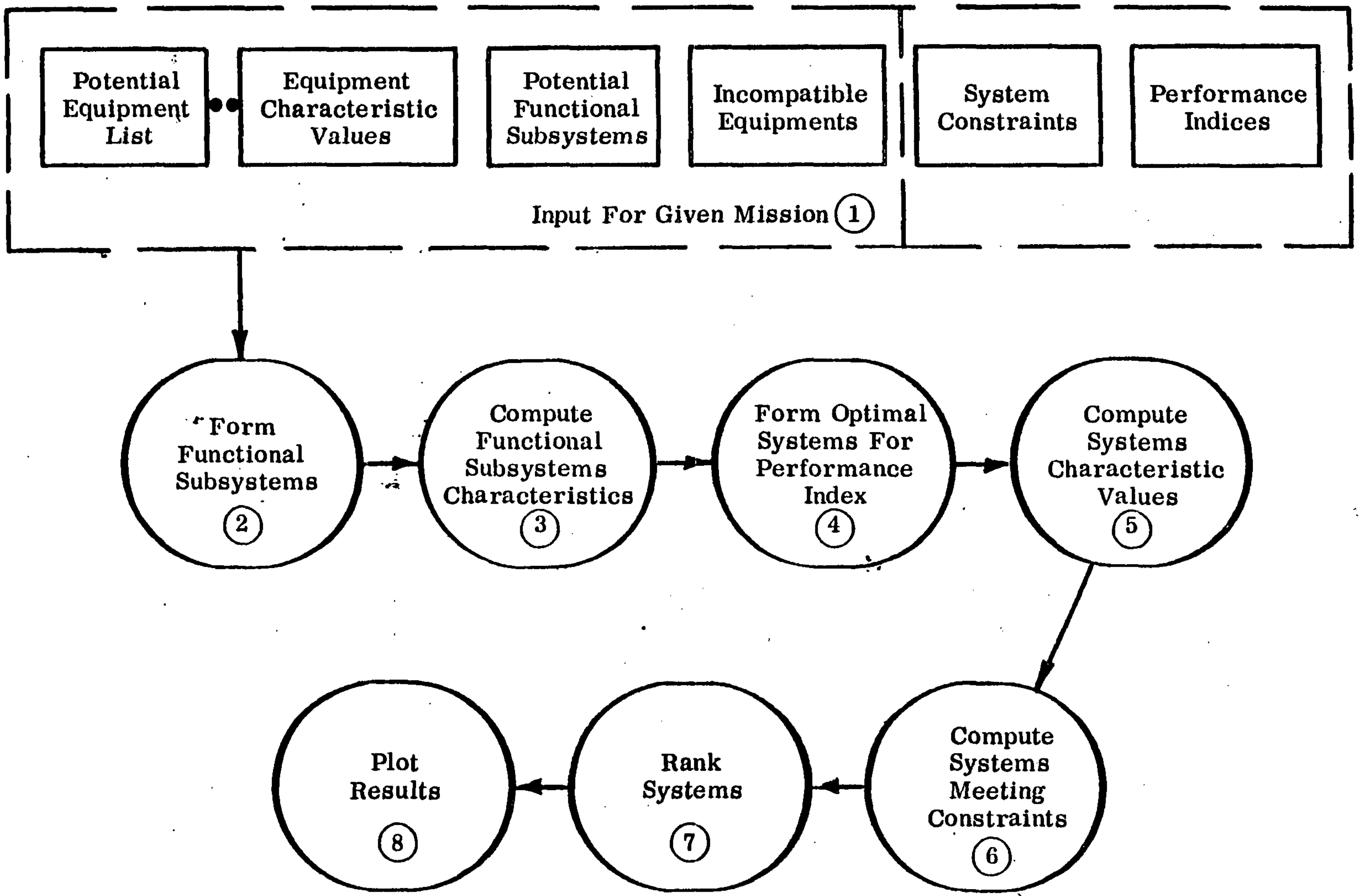


Figure II-6. Food System Evaluation Model - Model Description

Sketches and drawings depicting each equipment concept were prepared and included in this volume of the Final Report.

7.0 System Parametric Studies (Task 14)

The computer model was used to generate parametric studies and analysis of the key parameters of the mission models and to provide comparative evaluations of system concepts for various input variables. These data are presented in the Final Report, Volume II - Systems Assessments.

8.0 Data Book and Design Manual (Tasks 15 and 16)

Detailed data and design factors are included in the Data Book (Document Number MS128W0002 dated 31 December 1970, Book I - Element Concept Data Sheets and Book II - Supporting Technical Data) as well as the Final Report, Volumes I and II. In addition, the Interim Report (Document Number MS128Y0004 dated 26 October 1970) lists preliminary technical data for those concepts not carried into the final study phase.

9.0 Contract Data (Tasks 17-26)

Reports and Data as shown in Figure II-7 were prepared and delivered to NASA in accordance with the Data Requirements List (DRL) and Data Requirements Descriptions (DRD) contained in the Contract.

Task Number	Title	DRL Number	DRD Number	Document Number	Date
17	Bibliography/Synopsis Report	1	4.1, 4.2	MS128Y0002	28 August 1970
18	Requirements Report	2	4.3	MS128Y0001	7 August 1970
19	Initial Study Report	3	4.4	MS128Y0003	28 August 1970
20	Interim Study Report	4	4.5	MS128Y0004	20 October 1970 (preliminary) 26 October 1970 (approved)
21	Monthly Reports	5	4.6	MS128V0001-0007	End of Month
22	Final Report	6	4.7	MS128V0010	31 December 1970
23	Summary Report	7	4.8	MS128V0011	31 December 1970
24	Study Plan	8	4.9	MS128W0001	8 July 1970 (preliminary) 19 October 1970 (approved)
25	Visits/Presentation (NASA/MSC)	9, 10, 11	3.5	(none) FS/DRL 10-1 FS/DRL 10-2 FS/DRL 10-3 FS/DRL 10-4 FS/DRL 10-5	14 July 1970 18 August 1970 10 September 1970 20 October 1970 8 December 1970 26 January 1970
26	Data Book and Cards	12	4.11	MS128W0002	31 December 1970

Figure II-7. Contract Data Summary

SECTION III

STUDY RESULTS

A. GENERAL

The technical analysis of the concepts studied for each functional area of the food system are presented in this section of the Final Report and the Data Book. The data is compiled by functional subsystem area and includes performance characteristics of equipment items; tables, charts and graphs of weight, power and volume comparisons for various options of equipment or techniques; photographs and sketches of packaging techniques; and drawings depicting each of the equipment concepts discussed. In addition, reference is made to the applicable element concept data sheets contained in Book I of the Data Book, where all pertinent engineering information is summarized for each concept option or variation based on the mission requirement.

For functional subsystem area 1.0 - "Provide For Food", 2.0 - "Provide For Food Storage", and 3.0 - "Provide For Food Preparation", the primary technical data are presented in this section, supplemented by the detail data sheets in the Data Book. Since functional subsystem areas 4.0 - "Provide For Food Serving" and 5.0 - "Provide For Food Consumption" are primarily optional technique assessments, the basic data are more mission oriented and as such are presented on the detail data sheets and supplemented in this section under the appropriate paragraph. Trade-off data for area 6.0 - "Provide For Food Clean-Up" are presented in this section, while more detailed engineering data are tabulated on the applicable data sheets in the Data Book.

During the course of the study, it was mutually agreed that efforts in functional subsystem area 7.0 - "Provide For Recording of Food" would be oriented to defining possible inventory, logistics, and quality control procedures rather than toward developing equipment concepts for recording and/or transmitting accumulated data. Existing onboard systems would be utilized for these tasks. Consequently, no detailed data sheets were prepared for this area, and the study results are presented in narrative form in this section of the Final Report.

1.0 Provide For Food - Functional Subsystem Area 1.0

1.1 Food Type Selection

a. Candidate Concepts and Summary

1. Concept: Fresh Perishable (1.1.1)

Concept Description: Living fruits, vegetables, and meats suitable as primary or secondary menu items or snacks. Types selected for inclusion into spacecraft provisioning would be those having the most universal acceptance but would not require high crew time expenditure prior to consumption.

Technical Analysis: This concept will be studied since fresh fruits and vegetables provide a relationship with normal earth foods and dining conditions. Furthermore, the concept satisfies the additional requirements of crew acceptability, safety, and availability.

2. Concept: Frozen Unprocessed (1.1.2)

Concept Description: Fresh food which, except for blanching of vegetables and fruits, has not had any pretreatment. Only edible parts of these foods are packaged and they require cooking rather than reheating. Sauces and gravies are not part of the unprocessed packaged food. Recipes would be required to develop these foods into acceptable meals.

Technical Analysis: A very wide variety of foods can be made available in this category and unprocessed food permits great latitude in preparation techniques. Additionally, certain food items are preferable in the unprocessed state; e.g., berries, fruits. However, the concept is discarded from further study for the following reasons: (a) high crew time for preparation, (b) shrinkage weight carried aboard unnecessarily, and (c) high ECS interface.

3. Concept: Frozen Processed (1.1.3)

Concept Description: Fresh foods which are available as single menu items or in combinations that provide an entire meal consisting of several courses. The items or their combinations are usually precooked and are provided with sauces, gravies, and seasoning as required.

Technical Analysis: A very wide variety of food types and combinations are available in this category. Only the edible portions of these foods are packaged, and they require only heating to acceptable levels rather than cooking. The preprocessing of these foods prior to supplying or resupplying the spacecraft results in lower weight and volume due to the shrinkage in preparation.

4. Concept: Intermediate Moisture (1.1.4)

Concept Description: These are essentially dried foods, but have a water content of 15% to 30% and include such items as sausage, fruits, candies, and filled pastries. Solutes such as sugars, salt, or glycerine are added to these foods to maintain the desired water activity; sorbic acid or potassium sorbate is added to inhibit mold growth and propylene glycol contributes to water absorption and the formation of the desired plastic texture.

Technical Analysis: These food items are attractive since they are lighter in weight than conventional wet foods and present an acceptable texture and taste without the sensation of dryness. Shelf life is excellent when stored in ambient space cabin temperatures. Since sufficient water is present in these foods, rehydration is unnecessary.

5. Concept: Thermo Stabilized (1.1.5)

Concept Description: Foods which are heat processed (1) prior to canning and then canned under sterile conditions, or (2) canned and then heat processed by retorting as in the "Flash-18" process. All current, commercially available, canned foods can be listed in this category.

Technical Analysis: These foods will be continued as part of the study for the following reasons: (a) high crew acceptability and safety, (b) wide variety of foods available, (c) extremely long shelf life at ambient temperatures, (d) capable of providing extensive menu variety, and (e) regular geometric shaped packages permit easy storage.

6. Concept: Air Dehydrated (1.1.6)

Concept Description: Meat, vegetables, and fruits which have been reduced in volume by any of several air drying techniques. The products are packaged as powders, flakes, crystals, and cubes and can be utilized directly upon rehydration or can become part of a classical meal menu.

Technical Analysis: Advances in dehydration techniques and quality control have resulted in a significant improvement in the hedonic ratings of many dehydrated products. Shelf life at ambient temperatures is excellent and assuming package integrity, crew safety is assured due to the low water content which precludes bacterial activity. Reduced food volume due to dehydration will contribute to a lower total volume of food onboard a spacecraft.

7. Concept: Compressed (1.1.7)

Concept Description: Meats, vegetables, and fruits which have been dehydrated by one of several dehydration methods (including freeze drying) and then compressed at 1000-2500 psi. Reduction in food volumes ranges from ratios of 1:4 to 1:6. These foods require rehydration in order to assume the original configuration. Shelf life is excellent at ambient temperatures.

Technical Analysis: Certain items so processed have been panel tested on a number of occasions and were found to be organoleptically acceptable. They have excellent shelf life in ambient storage and can contribute to a reduction in the total volume of food onboard a spacecraft.

8. Concept: Freeze Dehydrated (1.1.8)

Concept Description: Meats, vegetables, and fruits which are dehydrated in a vacuum chamber. The pressure is lowered until the food freezes and as pumping continues the water is removed by sublimation (liquid to gas transition). The product has excellent storage at ambient temperatures and essentially retains its original configuration since tissue deformation or destruction does not occur.

Technical Analysis: This process results in food items which are generally more acceptable than air dehydrated foods and, in some items, indistinguishable from fresh products. When rehydrated, they can form the primary ingredient(s) in a classical meal, and can be prepared using recipes applicable to their fresh counterparts.

9. Concept: Dehydrofrozen (1.1.9)

Concept Description: Foods which are dehydrated in a vacuum chamber until atmospheric pressure is lowered sufficiently to cause freezing of the product. At this point, the process is terminated and the food is then treated as normal frozen food. Although many meats, vegetables, and fruits lend themselves to this process, a commercially attractive position has not yet been achieved. For space utilization, food processors can provide the required quantity and variety.

Technical Analysis: With the reduced water content, these foods are attractive from the weight storage considerations. They have a freezer shelf life common with standard frozen foods and can be packaged in a similar manner. They are highly acceptable to the crew and can provide a large variety of menu items.

10. Concept: Irradiated (1.1.10)

Concept Description: Exposure of food products to high energy radiation in order to destroy microorganisms. Foods are usually blanched to control proteolytic enzyme activity, flash frozen to -320°F, then exposed to radiation sources, usually less than 4.5 megarads.

Technical Analysis: Although the Food and Drug Administration has given approval to the irradiation of wheat and potatoes only, very significant research has been conducted both by the U.S. Government, universities, and industry and it is felt that the wide variety of products which have been developed using this technique may be cleared in the near future.

11. Concept: Algae (1.1.11)

Concept Description: Numerous species of algae have been investigated as potential food sources. Among these are (a) Chlorella sp. - a microscopic chlorophyte which yields principally protein, and (b) several species of phaeophytes and rhodophytes which yield principally carbohydrates. These are grown hydroponically in nutrient solutions of mineral salts and simple organic molecules.

Technical Analysis: This concept has been discarded from further study for the following reasons: (a) unacceptable hedonically to humans or animals, (b) growth systems not fully developed, (c) nutritional characteristics uncertain, (d) system weight and volume appear to be prohibitive, (e) reliability factor indicates high risk, (f) minimum crew acceptability, (g) processing to final food is complicated, (h) high level crew training required, (i) supplementary food required for proper diet, (j) equipment characteristics for zero-g operation undefined, and (k) gastrointestinal toxicity.

12. Concept: Live Animal (1.1.12)

Concept Description: A food system composed of living vertebrates and the equipment necessary to raise, feed, and process the animals into an acceptable source of nutrition. Animal species could include Japanese quail, chickens, ducks, rabbits, etc.

Technical Analysis: This concept has been discarded from further study for the following reasons: (a) systems not fully developed, (b) insufficient data on nutritional characteristics, (c) housekeeping and waste disposal are major problems, (d) waste management systems not developed, (e) particulate matter (hair, feathers, etc.) not compatible with ECS, (f) animal feeding characteristics (nutrition) and equipment poorly defined, (g) man/animal biologic compatibility poorly defined, (h) supplementary food required for proper diet, (i) animal behavior in zero-g not defined, and (j) mating behavior in zero-g not defined.

13. Concept: Formula (1.1.13)

Concept Description: A nutrient defined formulation which may be structured as liquid; powdered dry diet; compressed tablet; chewable candy or a baked cookie product. Guarantees specific calories, vitamins, minerals, amino acids, etc.

Technical Analysis: Formula diets may have application in conducting metabolic experiments during flight. This concept has been discarded from further study because: (a) low crew acceptability, (b) requires supplementary foods for proper nutritional balance and to relieve monotony, and (c) previous research indicates potential gastrointestinal distress factors when food supply is limited to formulation diet.

14. Concept: Bioregenerative (1.1.14)

Concept Description: A bioregenerative system is based on the unbroken rule that if an organic compound is made by one form of life, another form of life uses it for carbon and energy. The conversion of human waste products to nutrients suitable for the production of autotrophic and/or auxotrophic organisms which can serve as a food supply satisfies this rule. Mixed populations of micro-organisms degrade human waste to molecules which are assimilated by higher plants that can be consumed directly and/or used as feed to nourish animals.

Technical Analysis: This concept has been discarded from further study for the following reasons: (a) unacceptable hedonically to humans or animals, (b) systems not fully developed, (c) nutritional characteristics uncertain, (d) weight and volume appear to be prohibitive, (e) reliability factor indicates high risk, (f) minimum crew acceptability, (g) processing to final food is complicated, (h) high level crew training required, and (i) crew safety.

15. Concept: Live Plant (Photosynthetic) (1.1.15)

Concept Description: Utilization of multicellular (broad-leaf) plants to provide basic caloric requirements and most or all of the essential vitamins, amino acids, and nutrients. Several desirable species have been investigated, among them were Chinese cabbage, endive, and tampala.

Technical Analysis: This concept has been discarded from further study for the following reasons: (a) systems not fully developed, (b) nutritional characteristics uncertain, (c) weight and volume appear to be prohibitive, (d) reliability factor indicates high risk, (e) minimum crew acceptability, (f) processing to final food is complicated, (g) high level crew training required, (h) supplementary food required for proper diet, and (i) crew safety.

16. Concept: Live Fish and Shellfish (1.1.16)

Concept Description: The management of marine animals in aquaria designed to breed, spawn, and promote the growth of these animals for use as a food supply. Previously researched species include Talapia fish, Artemia salina L. (mollusk), other sessile animals and crustacea.

Technical Analysis: This concept has been discarded from further study for the following reasons: (a) systems not fully developed, (b) nutritional characteristics uncertain, (c) weight and volume appear to be prohibitive, (d) reliability factor indicates high risk, (e) minimum crew acceptability, (f) processing to final food is complicated, (g) high level crew training required, (h) supplementary food required for proper diet, and (i) housekeeping and waste disposal are major problems.

17. Concept: Intravenous (1.1.17)

Concept Description: Utilization of formula and/or chemical diets injected directly into bloodstream.

Technical Analysis: This concept has been discarded from further study for the following reasons: (a) low crew acceptability, (b) crew safety (potential infection), (c) require supplementary foods for proper diet and to relieve monotony, and (d) uncertain operability in zero-g.

18. Concept: Crewman Modification (1.1.18)

Concept Description: Would include stomach resection, overfeeding prior to flight, utilization of undersized crewmen, etc.

Technical Analysis: This concept has been exluded from further study for the following reasons: (a) certain techniques are only temporary in nature; e.g., stomach resection (elasticity of this organ will result in increased size in relatively short period of time), (b) low crew acceptability, (c) crew safety, (d) compromise in crew selectivity, and (e) approach to solution is inherently from the wrong direction; e.g., solution to the problem of a leaking ink pen is not to wear rubber gloves.

19. Concept: Edible Structure and/or Equipment (1.1.19)

Concept Description: Providing certain items of structure or equipment, which can be discarded during the flight plan, as an edible material. For example, hot melts of acetoglycerides, mixtures of monoglycerides and polyglycolesters, protein film, fatty esters of amylose, hard fats, and combinations of these materials as mixtures, laminates, or castings.

Technical Analysis: This concept has been excluded from further study for the following reasons: (a) techniques are not fully developed, (b) low crew acceptability, and (c) crew safety.

20. Concept Evaluation Summary and Technical Data

The concepts are summarized in Table III-1 below with the rating factors and study/discard decision as derived on the Selection Rationale Sheets of Data Book - Book III. Those types of food to be studied comprise the food mixes for which data are presented in this study.

TABLE III-1

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 1.1	SUB-FUNCTION TITLE: Food Types	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
1.1.1	Fresh Perishable (Refrigerated)	6.0		X	-		X
1.1.2	Frozen Unprocessed	(9.8)	X		-		
1.1.3	Frozen Processed	11.8		X	-		X
1.1.4	Intermediate Moisture	13.0		X	-		X
1.1.5	Thermo Stabilized	12.1		X	-		X
1.1.6	Air Dehydrated	14.1		X	-		X
1.1.7	Compressed	13.7		X	-		X
1.1.8	Freeze Dehydrated	14.0		X	-		X
1.1.9	Dehydrofrozen	10.3		X	-		X
1.1.10	Irradiated	10.7		X	-		X
1.1.11	Algae	1.7	X		-		
1.1.12	Live Animal	5.6	X		-		
1.1.13	Formula	(10.1)	X		-		
1.1.14	Bioregenerative	3.5	X		-		
1.1.15	Live Plant (Photosynthetic)	4.1	X		-		
1.1.16	Live Fish and Shellfish	3.4	X		-		
1.1.17	Intravenous	7.3	X		-		
1.1.18	Crewman Modification	(10.2)	X		-		
1.1.19	Edible Structure and/or Equipment	(9.5)	X		-		

b. Food Mix Ratios

The types of food chosen for study in section (a.) above can be divided according to moisture content into dry and wet. Dry food is defined as containing less than 5% moisture, and wet food is defined as containing more than 5% moisture. The wet food is further subdivided according to storage requirement; i.e., frozen, shelf stable, and refrigerated. The dry food is considered shelf stable. The ratio of dry to wet food types studied are defined in Figure III-1 below.

	Percentage 1	Percentage 2	Percentage 3
Dry	20	60	85
Frozen, Shelf Stable, Refrigerated } Wet	80	40	15

Figure III-1. Food Type Selection

The three mixes (1, 2, and 3) represent two rationalized extremes with a "more likely" middle mix. The wet percentage of each mix will be applied as follows:

	B	C
Frozen	55%	35%
Shelf Stable	20%	55%
Perishable	25%	10%

In order to size storage and preparation equipment, it was necessary to analyze each proposed diet mix for actual food weight and cubic volume in the unpackaged condition. To accomplish this task, the following data and definitions were utilized:

- The nutritionally dry food weight per man per day is 1.5 lb.
- The percentage numbers applied to dry and wet food types are percent of nutritionally dry food weight.
- The average water content of each food type is expressed as the percentage of total wet weight as follows:

Food Type	Water Content	Dry Food Content	Average Density (lbs per ft^3)
Dry	4%	96%	25
Frozen	66%	34%	50
Shelf Stable	66%	34%	50
Perishable	60%	40%	30

This data is in accordance with the food mix percentages, water contents, and densities advised by the Food System Study Panel Meeting #2, September 17, 1970.

With the information listed above and the diet mix definitions cited previously, the following data are derived.

- Percent Dry Weight of each food type given
- Dry Weight of Food (nutritional value)
  % Food Type x 1.5 lb
- Wet Weight of Food

  $$\frac{\text{Dry Weight}}{1 - \%\ \text{Water Content}}$$
- Water Weight in Wet Food Total
  Wet Weight of Food x % Water Content
- Cubic Volume
  Wet Weight x Average Density

A typical chart of data generated from the above information is presented in Figure III-2.

From Figure III-2 and similar data sheets developed for the other diet mixes, the wet weight percent of the total food supply can be derived. Figure III-3 presents the percentage by wet weight or launch percentage of each food type.

c. Food Requirements Per Man

Analyses of representative 2800 Kcal menus were made to determine average percentage weights for breakfast, lunch, and supper portions. The results of these analyses are presented in Figure III-4.

MISSION: 12 Men; Resupply - 90 Days
or 6 Men; Resupply - 180 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Average Density (Lb/Ft^3)	Estimated Cubic Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	324.0	4	14.04	338.0	25	13.50
FROZEN Frozen Dehydrofrozen	44	712.8	66	1,383.	2,096.	50	41.93
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	16	259.2	66	503.3	762.5	50	15.24
PERISHABLE Refrigerated	20	324.0	60	486.0	810.0	30	27.00
TOTAL	100%	1,620.	--	2,386.	4,006.	41.02	97.67

Figure III-2. Examples of Food Type Weights, Water Content, and Volume By Mission For A 20/80 Food Mix Using Wet Percentage B

	Mix 20/80		Mix 60/40		Mix 85/15	
	Wet Mix		Wet Mix		Wet Mix	
Food Type	B	C	B	C	B	C
Dry	8.44	8.26	35.58	35.05	67.58	67.07
Frozen	52.32	32.59	36.82	23.08	18.58	11.72
Shelf Stable	19.03	51.23	13.38	36.27	6.72	18.44
Perishable	20.21	7.92	14.22	5.60	7.12	2.77
TOTAL	100%	100%	100%	100%	100%	100%

Figure III-3. Launch Percentage of Each Food Type

Food Mix	Breakfast	Lunch	Dinner	TOTAL
20/80	23%	42%	35%	100%
60/40	28%	34%	38%	100%
85/15	30%	30%	40%	100%

Figure III-4. Percentage by Wet Weight of Total Menu Applied to Each Meal

Figure III-5 is a summary of the one man one day food weights by diet mix and meal portion.

Food Mix		Food Lbs/Man/Day	Breakfast (Lbs)	Lunch (Lbs)	Dinner (Lbs)
20/80	B	3.710	.853	1.558	1.299
	C	3.789	.872	1.591	1.326
60/40	B	2.637	.738	.897	1.002
	C	2.677	.750	.910	1.017
85/15	B	1.965	.5895	.5895	.786
	C	1.980	.594	.594	.792

Figure III-5. Wet Weight of Each Meal One Man/One Day

Figures III-6, III-7, and III-8 indicate weight and volume of one man/one day meals; i.e., breakfast, lunch, and dinner according to frozen, refrigerated, and ambient storage food type components.

d. Food Requirements By Mission

Figure III-9 on succeeding pages is a summary tabulation of unpackaged food weight and its cubic volume for each of the original 72 missions considered. It should be noted that as defined in Section II, paragraph C - Mission Model, only missions 001 through 018 and 025 to 042 were selected for detail analysis in the Final phase of the study.

Figures III-10 through III-45 each present a detailed composition of food weight, volume, and water content for each mission studied in the Final phase.

Figure III-46 is a summary tabulation of packaged food weight and volume for each mission. These values are representative of packaged food for bulk meal packaging of 6-man meal components according to best commercial practice and engineering judgment.

e. Weight and Volume Requirements

1) Figure III-47 depicts the weight of unpackaged food for each diet mix as a function of man days.

2) Figure III-48 depicts the volume of unpackaged food for each diet mix as a function of man days.

3) The effects of Kcal requirements on food weight and volume are shown according to mission size and resupply time in Figures III-49 through III-54.

4) The weight of packaged food for each diet mix as a function of man days is depicted in Figure III-55.

5) The volume of packaged food for each diet mix as a function of man days is depicted in Figure III-56.

f. Water Requirements

Metabolic water requirements per man per day are established as 5.5 pounds (Bioastronautics Data Book, NASA SP-3006).

Food Mix		Freezer Pounds	Freezer Volume (In^3)	Refrigerator Pounds	Refrigerator Volume (In^3)	Ambient Pounds	Ambient Volume (In^3)	TOTAL Pounds	TOTAL Volume (In^3)
20/80	B	.446	15.42	.173	9.96	.234	10.58	.853	35.96
	C	.284	9.82	.069	3.98	.519	20.41	.872	34.21
60/40	B	.272	9.39	.105	6.04	.361	21.56	.738	36.99
	C	.173	5.98	.042	2.42	.535	27.56	.750	35.96
85/15	B	.1095	3.78	.042	2.42	.438	28.91	.5895	35.11
	C	.070	2.41	.016	0.95	.508	31.32	.594	34.68

Figure III-6. One Man - One Day Breakfast (Weight and Volume Do Not Include Packaging)

Food Mix		Freezer Pounds	Freezer Volume (In^3)	Refrigerator Pounds	Refrigerator Volume (In^3)	Ambient Pounds	Ambient Volume (In^3)	TOTAL Pounds	TOTAL Volume (In^3)
20/80	B	.815	28.17	.315	18.14	.428	19.33	1.558	65.64
	C	.519	17.92	.126	7.25	.946	37.25	1.591	62.42
60/40	B	.330	11.41	.128	7.35	.439	26.20	.897	44.96
	C	.210	7.26	.051	2.94	.649	33.45	.910	43.65
85/15	B	.1095	3.78	.042	2.42	.438	28.91	.5895	35.11
	C	.070	2.41	.016	0.95	.508	31.32	.594	34.68

Figure III-7. One Man - One Day Lunch (Weight and Volume Do Not Include Packaging)

Food Mix		Freezer		Refrigerator		Ambient		TOTAL	
		Pounds	Volume (In^3)	Pounds	Volume (In^3)	Pounds	Volume (In^3)	Pounds	Volume (In^3)
20/80	B	.680	23.49	.262	15.09	.357	16.12	1.299	54.70
	C	.432	14.94	.105	6.05	.789	31.05	1.326	52.04
60/40	B	.369	12.75	.142	8.21	.491	29.27	1.002	50.23
	C	.235	8.11	.057	3.28	.725	37.38	1.017	48.77
85/15	B	.146	5.05	.056	3.22	.584	38.54	.786	46.81
	C	.093	3.21	.022	1.27	.677	41.76	.792	46.24

Figure III-8. One Man - One Day Dinner (Weight and Volume Do Not Include Packaging)

	Dry		Frozen		Shelf Stable		Perishable		TOTALS	
Mission Number	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)
001	26.29	1.05	163.0	3.26	59.30	1.19	63.00	2.10	311.6	7.60
002	26.29	1.05	103.7	2.07	163.0	3.26	25.20	0.84	318.3	7.22
003	78.79	3.15	81.56	1.63	29.65	0.59	31.50	1.05	221.5	6.42
004	78.79	3.15	51.91	1.04	81.56	1.63	12.60	0.42	224.9	6.24
005	111.6	4.46	30.66	0.61	11.09	0.22	11.76	0.39	165.1	5.68
006	111.6	4.46	19.49	0.39	30.66	0.61	4.62	0.15	166.3	5.61
007	52.58	2.10	326.1	6.52	118.6	2.37	126.0	4.20	623.3	15.19
008	52.58	2.10	207.5	4.15	326.1	6.52	50.40	1.68	636.6	14.45
009	157.6	6.30	163.1	3.26	59.30	1.19	63.00	2.10	443.0	12.85
010	157.6	6.30	103.8	2.08	163.1	3.26	25.20	0.84	449.7	12.48
011	223.1	8.92	61.32	1.23	22.18	0.44	23.52	0.78	330.1	11.38
012	223.1	8.92	38.98	0.78	61.32	1.23	9.24	0.31	332.6	11.24
013	109.6	4.37	679.4	13.59	247.1	4.94	262.5	8.75	1,298.	31.65
014	109.6	4.37	432.2	8.64	679.4	13.59	105.0	3.50	1,326.	30.10
015	328.3	13.13	339.9	6.80	123.6	2.47	131.2	4.37	923.0	26.77
016	328.3	13.13	216.3	4.33	339.8	6.80	52.5	1.75	937.0	26.01
017	464.8	18.59	127.8	2.55	46.20	0.92	49.00	1.63	687.8	23.69
018	464.8	18.59	81.2	1.62	127.6	2.55	19.25	0.64	693.0	23.40
019	219.1	8.75	1,359.	27.18	494.2	9.88	525.0	17.50	2,597.	63.31
020	219.1	8.75	864.5	17.29	1,358.	27.18	210.0	7.00	2,652.	60.21

Figure III-9. Tabulation of Food Weight and Volume (Unpackaged) By Mission

	Dry		Frozen		Shelf Stable		Perishable		TOTALS	
Mission Number	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)
021	656.6	26.26	679.7	13.59	247.1	4.94	262.5	8.75	1,846.	53.54
022	656.6	26.26	432.6	8.65	679.7	13.59	105.0	3.50	1,874.	52.00
023	929.6	37.18	255.5	5.11	92.40	1.85	98.00	3.27	1,376.	47.41
024	929.6	37.18	162.4	3.25	255.5	5.11	38.50	1.28	1,386.	46.82
025	169.0	6.75	1,048.	20.97	381.2	7.62	405.0	13.50	2,003.	48.84
026	169.0	6.75	666.9	13.34	1,048.	20.97	162.0	5.40	2,046.	46.45
027	506.5	20.26	524.3	10.49	190.6	3.81	202.5	6.75	1,424.	41.31
028	506.5	20.26	333.7	6.68	524.3	10.49	81.00	2.70	1,446.	40.13
029	717.1	28.68	197.1	3.94	71.28	1.43	75.60	2.52	1,061.	36.57
030	717.1	28.68	125.2	2.51	197.1	3.94	29.70	0.99	1,069.	36.12
031	338.0	13.50	2,096.	41.93	762.4	15.24	810.0	27.00	4,006.	97.67
032	338.0	13.50	1,334.	26.68	2,096.	41.93	324.0	10.80	4,092.	92.91
033	1,013.	40.52	1,047.	20.98	381.2	7.63	405.0	13.50	2,846.	82.63
034	1,013.	40.52	667.4	13.35	1,049.	20.98	162.0	5.40	2,891.	80.25
035	1,434.	57.37	394.2	7.88	142.5	2.85	151.2	5.04	2,122.	73.14
036	1,434.	57.37	250.6	5.01	394.2	7.88	59.40	1.98	2,138.	72.24
037	704.2	28.12	4,367.	87.36	1,588.	31.76	1,688.	56.25	8,347.	203.5
038	704.2	28.12	2,779.	55.57	4,367.	87.36	675.0	22.50	8,525.	193.5
039	2,110.	84.41	2,185.	43.70	794.2	15.89	843.8	28.12	5,933.	172.1
040	2,110.	84.41	1,390.	27.81	2,185.	43.70	337.5	11.25	6,022.	167.2

Figure III-9. Tabulation of Food Weight and Volume (Unpackaged) By Mission (cont'd)

Mission Number	Dry		Frozen		Shelf Stable		Perishable		TOTALS	
	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)
041	2,988.	119.5	821.2	16.42	297.0	5.94	315.0	10.49	4,421.	152.4
042	2,988.	119.5	522.0	10.44	821.2	16.42	123.8	4.13	4,455.	150.5
043	1,408.	56.25	8,734.	174.7	3,177.	63.52	3,375.	112.5	16,694.	406.9
044	1,408.	56.25	5,557.	111.2	8,734.	174.7	1,350.	45.00	17,049.	387.1
045	4,221.	168.8	4,370.	87.40	1,588.	31.77	1,688.	56.25	11,867.	344.2
046	4,221.	168.8	2,781.	55.62	4,370.	87.40	675.0	22.50	12,047.	334.4
047	5,976.	239.0	1,642.	32.84	594.0	11.87	630.0	20.99	8,842.	304.7
048	5,976.	239.0	1,044	20.89	1,642.	32.84	247.5	8.26	8,910.	301.0
049	338.0	13.50	2,096.	41.93	762.5	15.24	810.0	27.00	4,006.	97.67
050	338.0	13.50	1,334.	26.68	2,096.	41.93	324.0	10.80	4,092.	92.91
051	1,013.	40.52	1,049.	20.98	381.2	7.63	405.0	13.50	2,848.	82.63
052	1,013.	40.52	667.4	13.35	1,049.	20.98	162.0	5.40	2,891.	80.25
053	1,434.	57.37	394.2	7.88	142.6	2.85	151.2	5.04	2,122.	73.14
054	1,434.	57.37	250.6	5.01	394.2	7.88	59.40	1.98	2,138.	72.24
055	676.1	27.00	4,193.	83.86	1,525.	30.49	1,620.	54.00	8,014.	195.4
056	676.1	27.00	2,668.	53.35	4,193.	83.86	648.0	21.60	8,185.	185.8
057	2,026.	81.04	2,097.	41.95	762.5	15.25	810.0	27.00	5,696.	165.2
058	2,026.	81.04	1,335.	26.70	2,097.	41.95	324.0	10.80	5,782.	160.5
059	2,868.	114.7	788.4	15.76	285.1	5.70	302.4	10.08	4,244.	146.2
060	2,868.	114.7	501.1	10.03	788.4	15.76	118.8	3.96	4,276.	144.4

Figure III-9. Tabulation of Food Weight and Volume (Unpackaged) By Mission (cont'd)

Mission Number	Dry		Frozen		Shelf Stable		Perishable		TOTALS	
	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)	Weight (Lbs)	Volume (Ft^3)
061	1,408.	56.25	8,734.	174.7	3,177.	63.52	3,375.	112.5	16,694.	406.9
062	1,408.	56.25	5,558.	111.2	8,734.	174.71	1,350.	45.00	17,050.	387.1
063	4,221.	168.8	4,370.	87.40	1,588.	31.77	1,688.	56.25	11,867.	344.2
064	4,221.	168.8	2,781.	55.62	4,370.	87.40	675.	22.50	12,047.	334.4
065	5,976.	239.0	1,642.	32.84	594.0	11.87	630.0	20.99	8,842.	304.7
066	5,976.	239.0	1,044.	20,89	1,642.	32.84	247.5	8.26	8,910.	301.0
067	2,817.	112.5	17,469.	349.4	6,354.	127.0	6,750.	225.0	33,390.	813.9
068	2,817.	112.5	11,115.	222.3	17,469.	349.4	2,700.	90.00	34,101.	774.2
069	8,442.	337.7	8,739.	174.8	3,177.	63.54	3,375.	112.5	23,733.	688.5
070	8,442	337.7	5,562.	111.2	8,739.	174.8	1,350.	45.00	24,093.	668.7
071	11,952.	478.1	3,285.	65.68	1,188.	23.75	1,260.	41.98	17,685.	609.5
072	11,952.	478.1	2,088.	41.77	3,285.	65.68	495.0	16.51	17,820.	602.0

Figure III-9. Tabulation of Food Weight and Volume (Unpackaged) By Mission (concluded)

Figure III-10

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage B

MISSION: 001 ; Men - 6 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	25.20	4	1.092	26.29	29.71	1.60
FROZEN Frozen Dehydrofrozen	44	55.44	66	107.6	163.0	176.4	10.43
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	16	20.16	66	39.14	59.30	75.43	1.36
PERISHABLE Refrigerated	20	25.20	60	37.80	63.00	69.43	4.35
TOTAL	100%	126.0	-	185.6	311.6	351.0	17.74

Functional Subsystem 1.0: Provide For Food

2,9

Figure III-11

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage C

MISSION: 002 ; Men - 6 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	25.20	4	1.092	26.29	29.71	1.60
FROZEN Frozen Dehydrofrozen	28	35.28	66	68.46	103.7	112.2	6.64
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	44	55.44	66	107.6	163.0	207.3	3.75
PERISHABLE Refrigerated	8	10.08	60	15.12	25.20	27.77	1.74
TOTAL	100%	126.0	-	192.3	318.2	377.0	13.73

Functional Subsystem 1.0: Provide For Food

Figure III-12

Examples of Food Type Weights, Water Content, and Volume By Mission For A 60/40 Food Mix Using Wet Percentage B

MISSION: 003; Men - 6; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	75.60	4	3.192	78.79	89.03	4.81
FROZEN Frozen Dehydrofrozen	22	27.72	66	53.84	81.56	88.25	5.22
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8	10.08	66	19.57	29.65	37.71	0.68
PERISHABLE Refrigerated	10	12.60	60	18.90	31.50	34.71	2.17
TOTAL	100%	126.0	-	95.50	221.5	249.7	12.88

Functional Subsystem 1.0: Provide For Food

Figure III-13

Examples of Food Type Weights, Water Content, and Volume By Mission For A 60/40 Food Mix Using Wet Percentage C

MISSION: 004 ; Men - 6 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	75.60	4	3.192	78.79	89.03	4.81
FROZEN Frozen Dehydrofrozen	14	17.64	66	34.27	51.91	56.17	3.32
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	22	27.72	66	53.84	81.56	103.7	1.88
PERISHABLE Refrigerated	4	5.04	60	7.56	12.60	13.89	0.87
TOTAL	100%	126.0	-	98.86	224.9	262.8	10.88

Functional Subsystem 1.0: Provide For Food

Figure III-14

Examples of Food Type Weights, Water Content, and Volume By Mission For A 85/15 Food Mix Using Wet Percentage B

MISSION: 005 ; Men - 6 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	107.1	4	4.452	111.6	126.1	6.81
FROZEN Frozen Dehydrofrozen	8.25	10.42	66	20.24	30.66	33.17	1.96
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	3	3.780	66	7.308	11.09	14.11	0.20
PERISHABLE Refrigerated	3.75	4.704	60	7.056	11.76	12.96	0.81
TOTAL	100%	126.0	-	39.06	165.1	186.3	9.84

Functional Subsystem 1.0: Provide For Food

Figure III-15

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage C

MISSION: 006; Men - 6 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	107.1	4	4.452	111.6	126.1	6.81
FROZEN Frozen Dehydrofrozen	5.25	6.636	66	12.85	19.49	21.09	1.25
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8.25	10.42	66	20.24	30.66	39.00	0.71
PERISHABLE Refrigerated	1.5	1.848	60	2.772	4.620	5.09	0.32
TOTAL	100%	126.0	-	40.31	166.3	191.3	9.09

Functional Subsystem 1.0: Provide For Food

Figure III-16

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage B

MISSION: 007 ; Men - 12 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	50.40	4	2.184	52.58	59.42	3.21
FROZEN Frozen Dehydrofrozen	44	110.9	66	215.2	326.1	352.8	20.87
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	16	40.32	66	78.29	118.6	150.9	2.73
PERISHABLE Refrigerated	20	50.40	60	75.60	126.0	138.9	8.69
TOTAL	100%	252.0	-	371.3	623.3	702.0	35.50

Functional Subsystem 1.0: Provide For Food

Figure III-17

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage C

MISSION: 008 ; Men - 12 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	50.40	4	2.184	52.58	59.42	3.21
FROZEN Frozen Dehydrofrozen	28	70.56	66	136.9	207.5	224.5	13.28
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	44	110.9	66	215.2	326.1	414.8	7.50
PERISHABLE Refrigerated	8	20.16	60	30.24	50.40	55.54	3.48
TOTAL	100%	252.0	-	384.6	636.6	754.3	27.47

Functional Subsystem 1.0: Provide For Food

Figure III-18

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 60/40 Food Mix Using Wet Percentage B

MISSION: 009 ; Men - 12 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	151.2	4	6.384	157.6	178.1	9.61
FROZEN Frozen Dehydrofrozen	22	55.44	66	107.7	163.1	176.5	10.44
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8	20.16	66	39.14	59.30	75.43	1.36
PERISHABLE Refrigerated	10	25.20	60	37.80	63.00	69.43	4.35
TOTAL	100%	252.0	-	191.0	443.0	499.5	25.76

Functional Subsystem 1.0: Provide For Food

Figure III-19

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 60/40 Food Mix Using Wet Percentage C

MISSION: 010 ; Men - 12 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	151.2	4	6.384	157.6	178.1	9.61
FROZEN Frozen Dehydrofrozen	14	35.28	66	68.54	103.8	112.3	6.64
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	22	55.44	66	107.7	163.1	207.5	3.75
PERISHABLE Refrigerated	4	10.08	60	15.12	25.20	27.77	1.74
TOTAL	100%	252.0	-	197.7	449.7	525.7	21.74

Functional Subsystem 1.0: Provide For Food

Figure III-20

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage B

MISSION: 011 ; Men -12 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	214.2	4	8.904	223.1	252.1	13.61
FROZEN Frozen Dehydrofrozen	8.25	20.83	66	40.49	61.32	66.35	3.92
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	3	7.560	66	14.62	22.18	28.21	0.51
PERISHABLE Refrigerated	3.75	9.408	60	14.11	23.52	25.92	1.62
TOTAL	100%	252.0	-	78.12	330.1	372.6	19.66

Functional Subsystem 1.0: Provide For Food

Figure III-21

Examples of Food Type Weights, Water Content, and Volume By Mission For A 85/15 Food Mix Using Wet Percentage C

MISSION: 012 ; Men - 12 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	214.2	4	8.904	223.1	252.1	13.61
FROZEN Frozen Dehydrofrozen	5.25	13.27	66	25.70	38.98	42.18	2.49
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8.25	20.83	66	40.49	61.32	78.00	1.41
PERISHABLE Refrigerated	1.5	3.696	60	5.544	9.240	10.18	0.64
TOTAL	100%	252.0	-	80.63	332.6	382.5	18.15

Functional Subsystem 1.0: Provide For Food

Figure III-22

Examples of Food Type Weights, Water Content, and Volume By Mission For A 20/80 Food Mix Using Wet Percentage B

MISSION: 013 ; Men - 25 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	105.0	4	4.550	109.6	123.8	6.69
FROZEN Frozen Dehydrofrozen	44	231.0	66	448.4	679.4	735.1	43.48
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	16	84.00	66	163.1	247.1	314.3	5.68
PERISHABLE Refrigerated	20	105.0	60	157.5	262.5	289.3	18.11
TOTAL	100%	525.0	-	773.5	1298.	1463.	73.76

Functional Subsystem 1.0: Provide For Food

Figure III-23

Examples of Food Type Weights, Water Content, and Volume By Mission For A 20/80 Food Mix Using Wet Percentage C

MISSION: 014 ; Men - 25 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	105.0	4	4.550	109.6	123.8	6.69
FROZEN Frozen Dehydrofrozen	28	147.0	66	285.2	432.2	467.6	27.66
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	44	231.0	66	448.3	679.4	864.2	15.63
PERISHABLE Refrigerated	8	42.00	60	63.00	105.0	115.7	7.25
TOTAL	100%	525.0	-	801.0	1326.	1571.	57.23

Functional Subsystem 1.0: Provide For Food

Figure III-24

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 60/40 Food Mix Using Wet Percentage B

MISSION: 015 ; Men - 25 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	315.0	4	13.30	328.3	371.0	20.03
FROZEN Frozen Dehydrofrozen	22	115.5	66	224.4	339.9	367.8	21.75
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8	42.0	66	81.55	123.6	157.2	2.84
PERISHABLE Refrigerated	10	52.50	60	78.75	131.2	144.6	9.05
TOTAL	100%	525.0	-	398.0	923.0	1041.	53.67

Functional Subsystem 1.0: Provide For Food

Figure III-25

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 60/40 Food Mix Using Wet Percentage C

MISSION: 016 ; Men - 25 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	315.0	4	13.30	328.3	371.0	20.03
FROZEN Frozen Dehydrofrozen	14	73.5	66	142.8	216.3	234.0	13.84
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	22	115.5	66	224.4	339.8	432.2	7.82
PERISHABLE Refrigerated	4	21.0	60	31.50	52.50	57.86	3.62
TOTAL	100%	525.0	-	412.0	937.0	1095.	45.31

Functional Subsystem 1.0: Provide For Food

Figure III-26

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage B

MISSION: 017 ; Men - 25 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	446.2	4	18.55	464.8	525.2	28.35
FROZEN Frozen Dehydrofrozen	8.25	43.40	66	84.35	127.8	138.3	8.18
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	3	15.75	66	30.45	46.20	58.77	1.06
PERISHABLE Refrigerated	3.75	19.60	60	29.40	49.00	54.00	3.38
TOTAL	100%	525.0	-	162.75	687.8	776.3	40.97

Functional Subsystem 1.0: Provide For Food

Figure III-27

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage C

MISSION: 018 ; Men - 25 ; Resupply - 14 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	446.2	4	18.55	464.8	525.2	28.35
FROZEN Frozen Dehydrofrozen	5.25	27.65	66	53.55	81.20	87.86	5.20
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8.25	43.40	66	84.35	127.8	162.3	2.93
PERISHABLE Refrigerated	1.5	7.700	60	11.55	19.25	21.21	1.33
TOTAL	100%	525.0	-	168.0	693.0	796.6	37.81

Functional Subsystem 1.0: Provide For Food

Figure III-28

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage B

MISSION: 025 ; Men - 6 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	22	162.0	4	7.020	169.0	191.0	10.31
FROZEN Frozen Dehydrofrozen	44	356.4	66	691.7	1048.	1134.	67.07
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	16	129.6	66	251.6	381.2	484.9	8.77
PERISHABLE Refrigerated	20	162.0	60	243.0	405.0	446.3	27.95
TOTAL	100%	810.0	-	1193.	2003.	2256.	114.1

Functional Subsystem 1.0: Provide For Food

Figure III-29

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage C

MISSION: 026; Men - 6 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	162.0	4	7.02	167.02	191.0	10.31
FROZEN Frozen Dehydrofrozen	28	226.8	66	440.1	666.9	721.6	42.68
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	44	356.4	66	691.7	1048.	1333.	24.10
PERISHABLE Refrigerated	8	64.80	60	97.20	162.0	178.5	11.18
TOTAL	100%	810.	-	1236.	2046.	2424.	88.27

Functional Subsystem 1.0: Provide For Food

Figure III-30

Examples of Food Type Weights, Water Content, and Volume By Mission For A 60/40 Food Mix Using Wet Percentage B

MISSION: 027 ; Men - 6 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	486.0	4	20.52	506.5	527.3	30.90
FROZEN Frozen Dehydrofrozen	22	178.2	66	346.1	524.3	567.3	33.56
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8	64.80	66	125.8	190.7	242.4	4.38
PERISHABLE Refrigerated	10	81.00	60	121.5	202.5	223.2	13.97
TOTAL	100%	810.0	-	613.9	1424.	1605.	82.81

Functional Subsystem 1.0: Provide For Food

Figure III-31

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 60/40 Food Mix Using Wet Percentage C

MISSION: 028 ; Men -6 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	486	4	20.52	506.5	572.3	30.90
FROZEN Frozen Dehydrofrozen	14	113.4	66	220.3	333.7	361.1	21.36
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	22	178.2	66	346.1	524.3	666.9	12.06
PERISHABLE Refrigerated	4	32.40	60	48.60	81.00	89.26	5.59
TOTAL	100%	810.	-	635.5	1446.	1690.	69.91

Functional Subsystem 1.0: Provide For Food

Figure III-32

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage B

MISSION: 029 ; Men -6 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	688.5	4	28.62	717.1	810.3	43.74
FROZEN Frozen Dehydrofrozen	8.25	66.96	66	130.1	197.1	213.3	12.61
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	3.	24.3	60	46.98	71.28	90.67	1.64
PERISHABLE Refrigerated	3.75	30.24	60	45.36	75.60	83.31	5.22
TOTAL	100%	810.	-	251.1	1061.	1198.	63.21

Functional Subsystem 1.0: Provide For Food

Figure III-33

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage C

MISSION: 030 ; Men - 6 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	688.5	4	28.62	717.1	810.3	43.74
FROZEN Frozen Dehydrofrozen	5.25	42.66	66	82.62	125.2	135.5	8.01
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8.25	66.96	66	130.1	197.1	250.7	4.53
PERISHABLE Refrigerated	1.5	11.88	60	17.82	29.70	32.73	2.05
TOTAL	100%	810.	-	249.2	1069.	1229.	58.33

Functional Subsystem 1.0: Provide For Food

Figure III-34

Examples of Food Type Weights, Water Content, and Volume By Mission For A 20/80 Food Mix Using Wet Percentage B

MISSION:031 ; Men -12 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	3240.	4	14.04	338.0	381.9	20.62
FROZEN Frozen Dehydrofrozen	44	712.8	66	1383.	2096.	2268.	134,1
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	16	259.2	66	503.3	762.4	969.8	17.54
PERISHABLE Refrigerated	20	324.0	60	486.0	810.0	892.6	55.89
TOTAL	100%	1620.0	-	2386.	4006.	4512.	228.2

Functional Subsystem 1.0: Provide For Food

Figure III-35

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage C

MISSION: 032 ; Men -12 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	324.0	4	14.04	338.0	381.9	20.62
FROZEN Frozen Dehydrofrozen	28	453.6	66	880.2	1334.	1443.	85.38
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	44	712.8	66	1384.	2096.	2666.	48.21
PERISHABLE Refrigerated	8	129.6	60	194.4	324.0	357.0	22.36
TOTAL	100%	1620.0	-	2472.12	4092.	4848.	176.6

Functional Subsystem 1.0: Provide For Food

Figure III-36

Examples of Food Type Weights, Water Content, and Volume By Mission
For A *60/40 Food Mix Using Wet Percentage* B

MISSION: 033 ; Men - 12 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	972.0	4	41.04	1013.	1445.	61.79
FROZEN Frozen Dehydrofrozen	22	356.4	66	692.2	1048.	1334.	67.07
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8	129.6	66	251.6	381.2	484.9	8.77
PERISHABLE Refrigerated	10	162.0	60	243.0	405.0	446.3	27.95
TOTAL	100%	1620.	-	1227	2847.	3510.	165.6

Functional Subsystem 1.0: Provide For Food

Figure III-37

Examples of Food Type Weights, Water Content, and Volume By Mission For A 60/40 Food Mix Using Wet Percentage C

MISSION: 034 ; Men - 12 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	972.0	4	41.04	1013	1445.	61.79
FROZEN Frozen Dehydrofrozen	14	226.8	66	440.6	667.4	722.1	42.71
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	22	356.4	66	692.3	1049	1334.	24.13
PERISHABLE Refrigerated	4	64.8	60	97.20	162	178.5	11.18
TOTAL	100%	1620	-	1271	2891	3680.	139.8

Functional Subsystem 1.0: Provide For Food

Figure III-38

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage B

MISSION: 035 ; Men -12 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	1377	4	57.24	1434	1620.	87.47
FROZEN Frozen Dehydrofrozen	8.25	133.92	66	260.3	394.2	426.5	25.23
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	3	48.6	66	93.96	142.5	181.3	3.28
PERISHABLE Refrigerated	3.75	60.48	60	90.72	151.2	166.6	10.43
TOTAL	100%	1620	-	502.2	2122	2394	126.4

Functional Subsystem 1.0: Provide For Food

Figure III-39

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage C

MISSION: 036 ; Men - 12 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	1377.	4	57.24	1434	1620.	87.47
FROZEN Frozen Dehydrofrozen	5.25	85.32	66	165.2	250.6	271.1	16.04
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8.25	133.9	66	260.3	394.2	501.4	9.07
PERISHABLE Refrigerated	1.5	23.76	60	35.64	59.40	65.46	4.10
TOTAL	100%	1620	-	518.4	2138	2458.	116.7

Functional Subsystem 1.0: Provide For Food

Figure III-40

Examples of Food Type Weights, Water Content, and Volume By Mission
For A20/80 Food Mix Using Wet Percentage B

MISSION: 037 ; Men - 25 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	675	4	29.25	704.2	795.7	42.96
FROZEN Frozen Dehydrofrozen	44	1485	66	2882	4367	4725.	279.5
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	16	540	66	1048	1588	2020.	36.52
PERISHABLE Refrigerated	20	675	60	1013	1688	1860	116.5
TOTAL	100%	3375	-	4972	8347	9401.	475.5

Functional Subsystem 1.0: Provide For Food

Figure III-41

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 20/80 Food Mix Using Wet Percentage C

MISSION: 038 ; Men - 25 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	20	675	4	29.25	704	795.7	42.96
FROZEN Frozen Dehydrofrozen	28	945	66	1834	2779	3007.	177.9
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	44	185	66	2882	4367	5555.	100.4
PERISHABLE Refrigerated	8	270	60	405	675	743.9	46.58
TOTAL	100%	3375	-	5150	8525	10102.	361.8

Functional Subsystem 1.0: Provide For Food

Figure III-42

Examples of Food Type Weights, Water Content, and Volume By Mission
For A60/40 Food Mix Using Wet Percentage B

MISSION: 039 ; Men - 25 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	2025	4	85.5	2110	2384	145.4
FROZEN Frozen Dehydrofrozen	22	742.5	66	1442	2185	2364.	139.8
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8	270.	66	524.2	794.2	1010.	18.27
PERISHABLE Refrigerated	10	337.5	60	506.2	843.8	929.9	58.22
TOTAL	100%	3375	-	2558	5933	6688.	361.7

Functional Subsystem 1.0: Provide For Food

Figure III-43

Examples of Food Type Weights, Water Content, and Volume By Mission For A 60/40 Food Mix Using Wet Percentage C

MISSION: 040 ; Men - 25 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	60	2025	4	85.50	2110	2384.	145.4
FROZEN Frozen Dehydrofrozen	14	472.5	66	918	1390	1504.	88.96
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	22	742.5	66	1442	2185	2779.	50.26
PERISHABLE Refrigerated	4	135	60	202.5	337.5	371.9	23.29
TOTAL	100%	3375	-	2648	6022	7039.	307.9

Functional Subsystem 1.0: Provide For Food

Figure III-44

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage B

MISSION: 041 ; Men -25 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	2869	4	119.2	2988	3376.	182.3
FROZEN Frozen Dehydrofrozen	8.25	279	66	542.2	821.2	888.5	52.56
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	3	101.2	66	195.8	297	377.8	6.83
PERISHABLE Refrigerated	3.75	126	60	189	315	347.1	21.74
TOTAL	100%	3.375	-	1046	4421	4989.	263.4

Functional Subsystem 1.0: Provide For Food

Figure III-45

Examples of Food Type Weights, Water Content, and Volume By Mission
For A 85/15 Food Mix Using Wet Percentage C

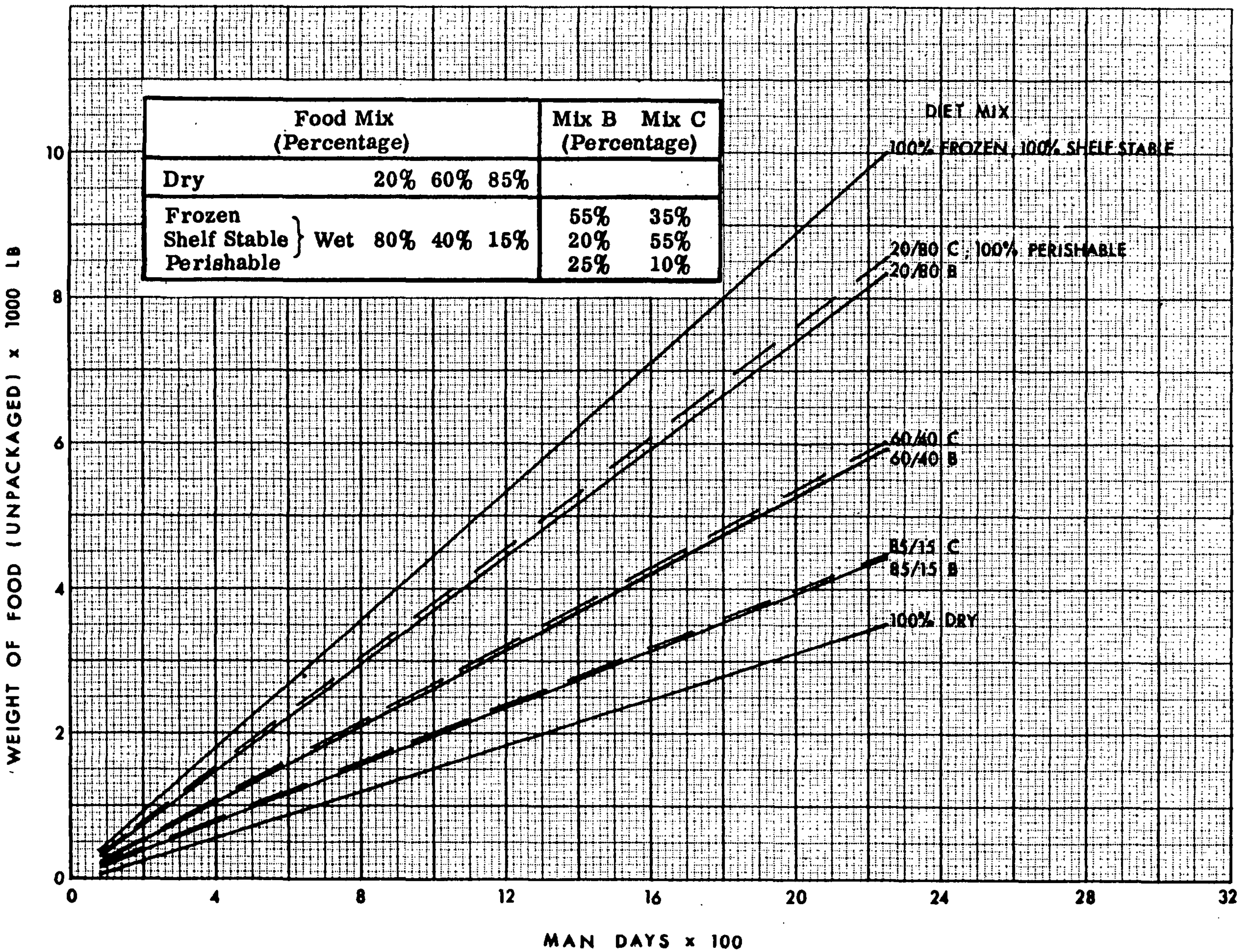
MISSION: 042 ; Men - 25 ; Resupply - 90 Days

Food Type	% Dry Weight of Food	Dry Weight of Food ~ Lb	% Water Content of Wet Food	Water Weight ~ Lb	Wet Weight of Food ~ Lb	Packaged Weight (Lb.)	Packaged Volume (Ft^3)
DRY Freeze Dehydrated Dehydrated Condiments	85	2869	4	119.2	2988	3376.	182.3
FROZEN Frozen Dehydrofrozen	5.25	177.78	66	344.2	522.0	564.8	33.41
SHELF STABLE Irradiated Wet Pack Intermediate Moisture Canned	8.25	279.0	66	542.2	821.2	1045.	18.89
PERISHABLE Refrigerated	1.5	49.5	60	74.25	123.8	136.4	8.54
TOTAL	100%	3.375	-	1080	4455	5122.	243.1

Functional Subsystem 1.0: Provide For Food

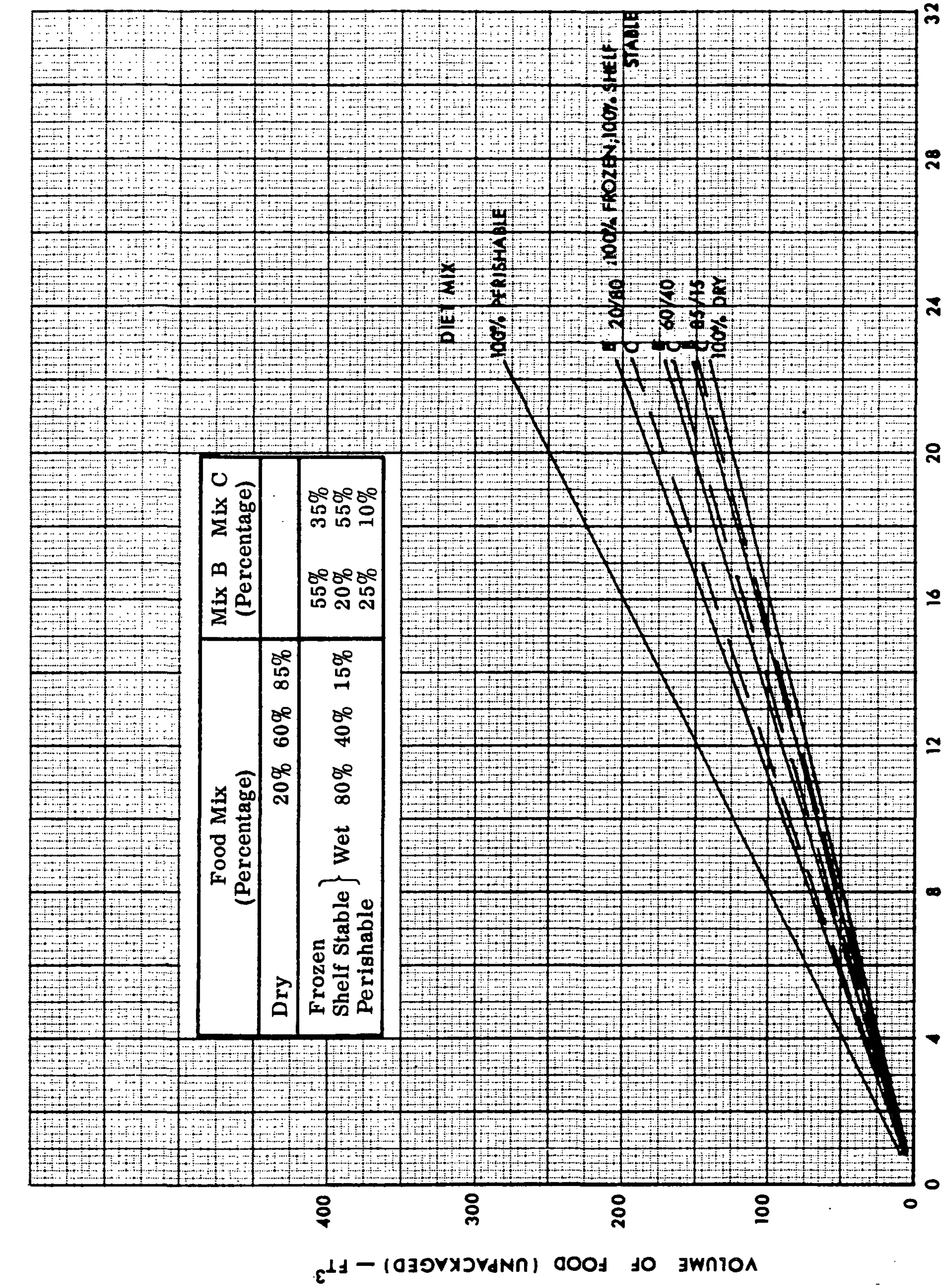
Mission Number	Diet Mix	Packaged Weight (lb)	Packaged Volume (ft^3)	Water Required (lbs/day) 155°F	Water Required (lbs/day) 50°F
001	20/80 B	351.0	17.74	5.178	14.62
002	C	377.0	13.73	4.881	14.39
003	60/40 B	249.7	12.88	8.337	17.84
004	C	262.8	10.88	8.217	17.72
005	85/15 B	186.3	9.84	10.35	19.86
006	C	191.3	9.09	10.31	19.81
007	20/80 B	702.0	35.50	10.36	29.24
008	C	754.3	27.47	9.762	28.77
009	60/40 B	499.5	25.96	16.67	35.68
010	C	525.7	21.74	16.43	35.44
011	85/15 B	372.6	19.66	20.71	39.71
012	C	382.5	18.15	20.62	39.62
013	20/80 B	1463.	73.96	21.58	60.93
014	C	1571.	57.23	20.34	59.94
015	60/40 B	1041.	53.67	34.74	74.34
016	C	1095.	43.31	34.24	73.84
017	85/15 B	776.3	40.97	43.14	82.74
018	C	796.6	37.81	42.95	82.55
025	20/80 B	2256.	114.1	5.178	14.62
026	C	2424.	88.27	4.881	14.39
027	60/40 B	1605.	82.81	8.337	17.84
028	C	1690.	69.91	8.217	17.72
029	85/15 B	1198.	63.21	10.35	19.86
030	C	1229.	58.33	10.31	19.81
031	20/80 B	4512.	228.2	10.36	29.24
032	C	4848.	176.6	9.762	28.77
033	60/40 B	3210.	165.6	16.67	35.68
034	C	3380.	139.8	16.43	35.44
035	85/15 B	2394.	126.4	20.71	39.71
036	C	2458.	116.7	20.62	39.62
037	20/80 B	9401.	475.5	21.58	60.93
038	C	10102.	367.8	20.34	59.94
039	60/40 B	6688.	345.0	34.74	74.34
040	C	7039.	291.2	34.24	73.84
041	85/15 B	4989.	263.4	43.14	82.74
042	C	5122.	243.1	42.95	82.55

Figure III-46. Summary Tabulation of Packaged Food Weight and Volume and Make-Up Water For Each Mission



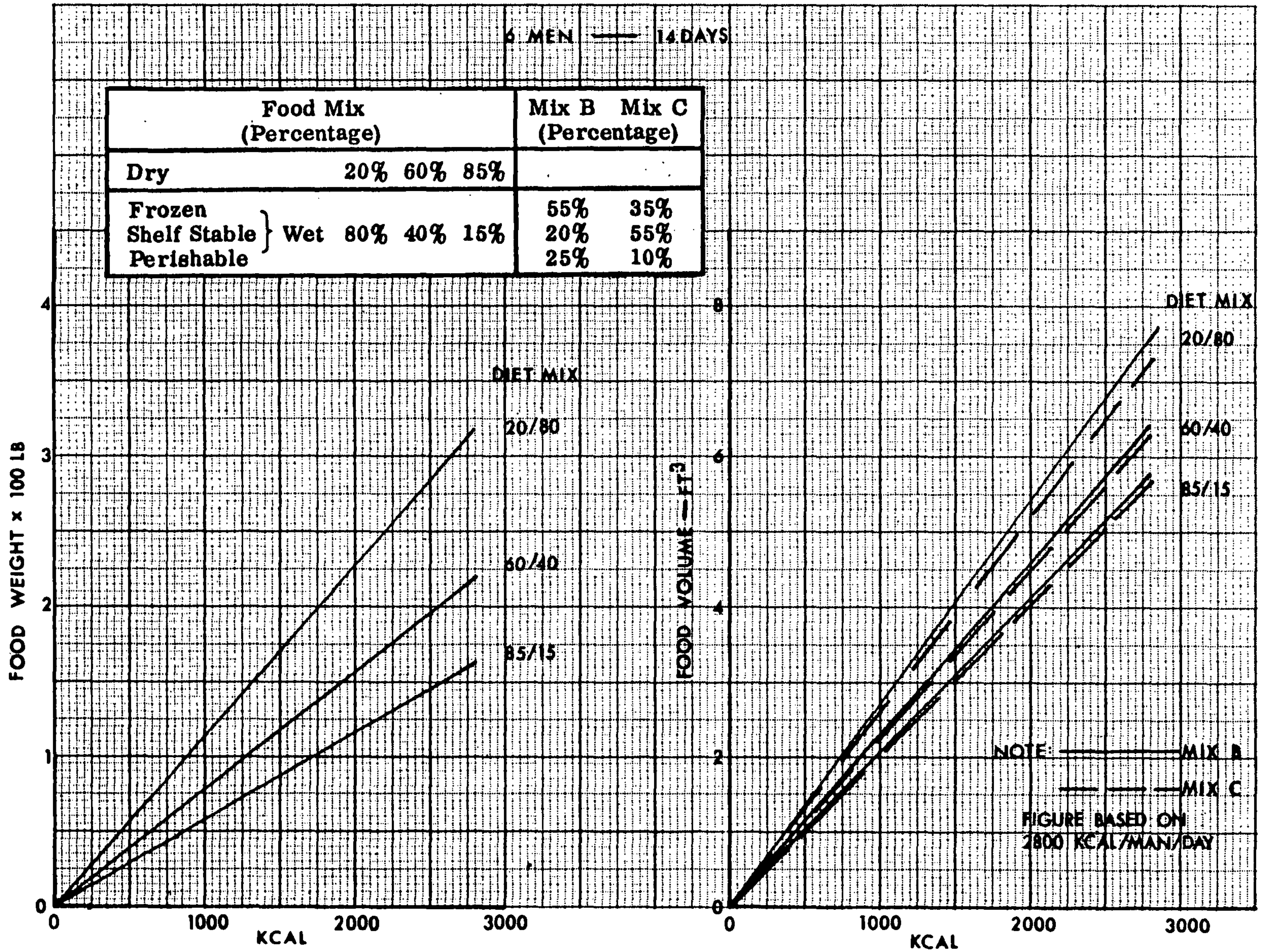
Food Mix (Percentage)					Mix B (Percentage)	Mix C (Percentage)
Dry		20%	60%	85%		
Frozen	Wet	80%	40%	15%	55%	35%
Shelf Stable					20%	55%
Perishable					25%	10%

Figure III-47. Weight of Unpackaged Food for Each Diet Mix as a Function of Man Days



Food Mix (Percentage)					Mix B (Percentage)	Mix C (Percentage)
Dry		20%	60%	85%		
Frozen	Wet	80%	40%	15%	55%	35%
Shelf Stable	Wet				20%	55%
Perishable					25%	10%

Figure III-48. Volume of Unpackaged Food for Each Diet Mix as a Function of Man Days



Food Mix (Percentage)				Mix B (Percentage)	Mix C (Percentage)
Dry	20%	60%	85%		
Frozen } Wet	80%	40%	15%	55%	35%
Shelf Stable } Wet				20%	55%
Perishable } Wet				25%	10%

Figure III-49. Weight and Volume of Unpackaged Food for Each Diet Mix According to Kcal per Man per Day Requirement (6 Men - 14 Days)

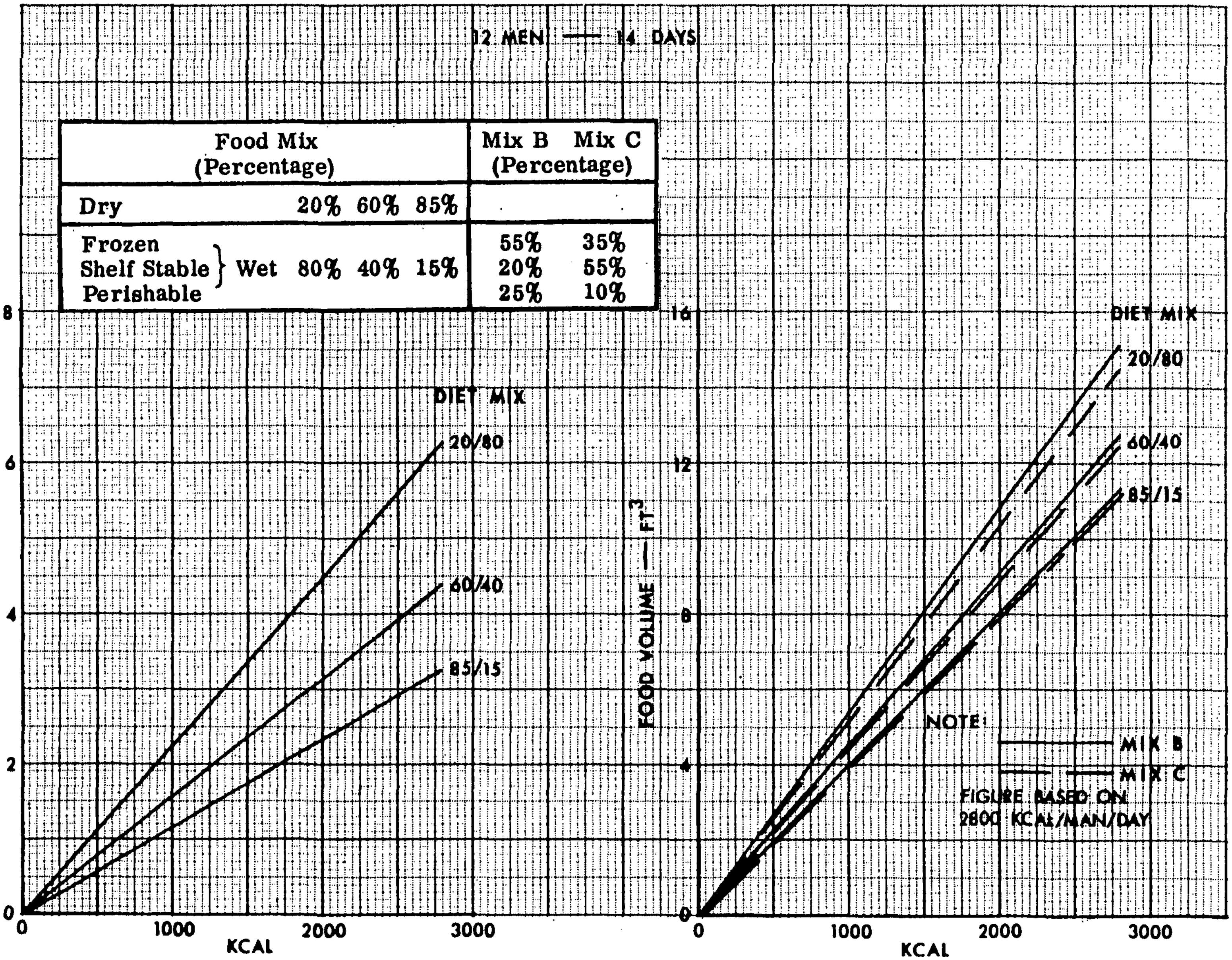
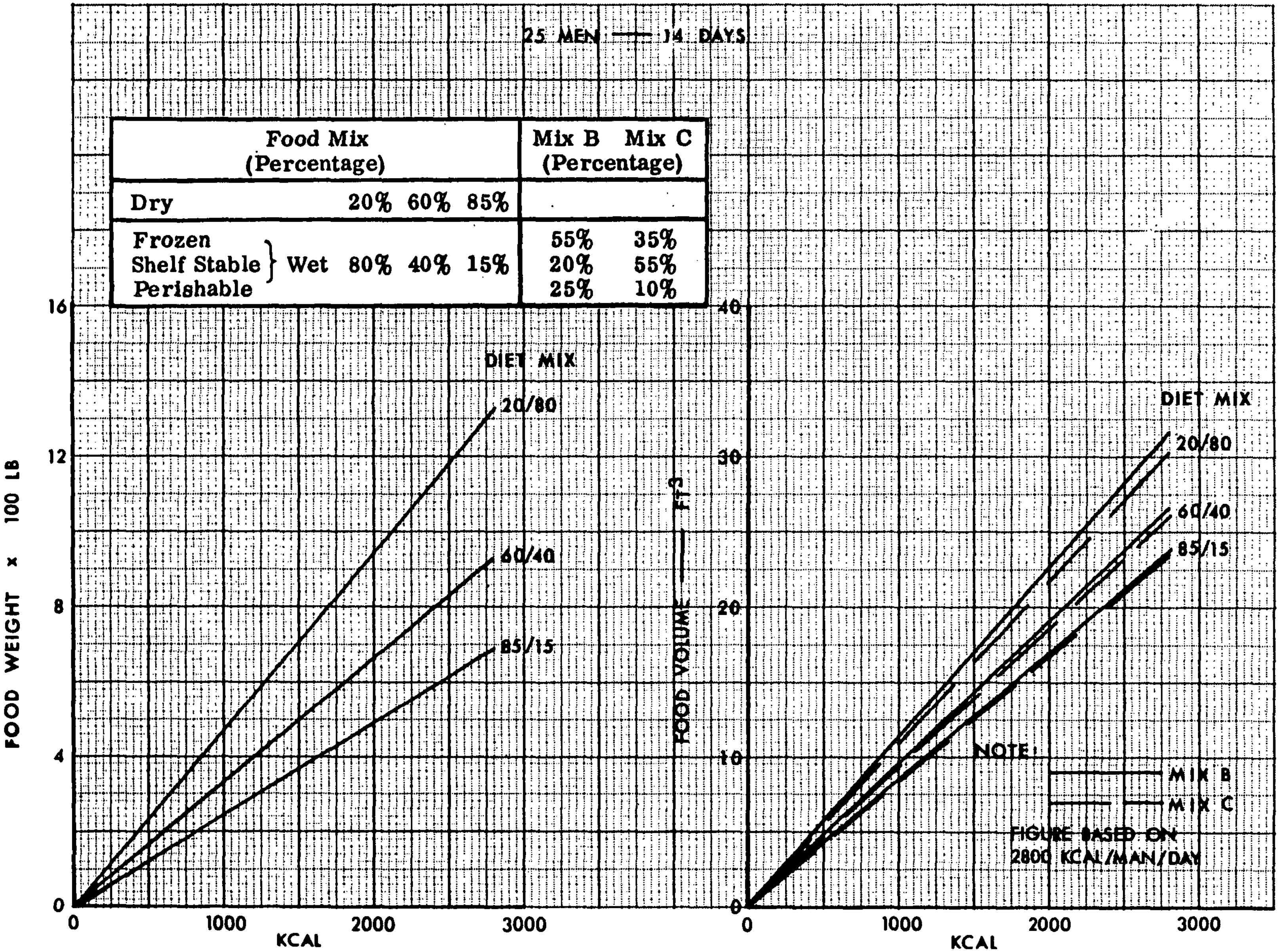


Figure III-50. Weight and Volume of Unpackaged Food for Each Diet Mix According to Kcal per Man per Day Requirement (12 Men - 14 Days)



Food Mix (Percentage)					Mix B	Mix C
					(Percentage)	
Dry		20%	60%	85%		
Frozen	Wet	80%	40%	15%	55%	35%
Shelf Stable					20%	55%
Perishable					25%	10%

Figure III-51. Weight and Volume of Unpackaged Food for Each Diet Mix According to Kcal per Man per Day Requirement (25 Men - 14 Days)

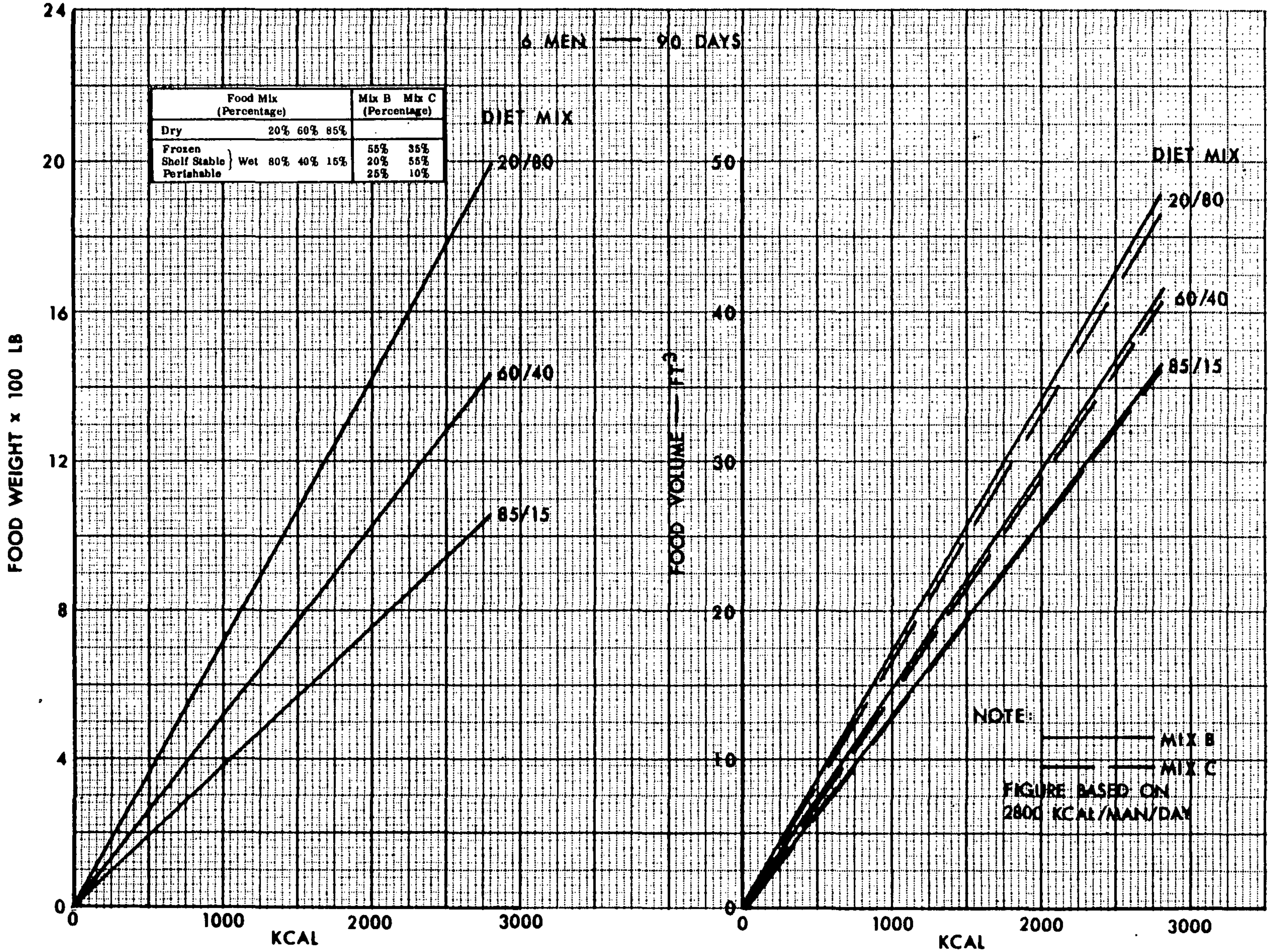


Figure III-52. Weight and Volume of Unpackaged Food for Each Diet Mix According to Kcal per Man per Day Requirement (6 Men - 90 Days)

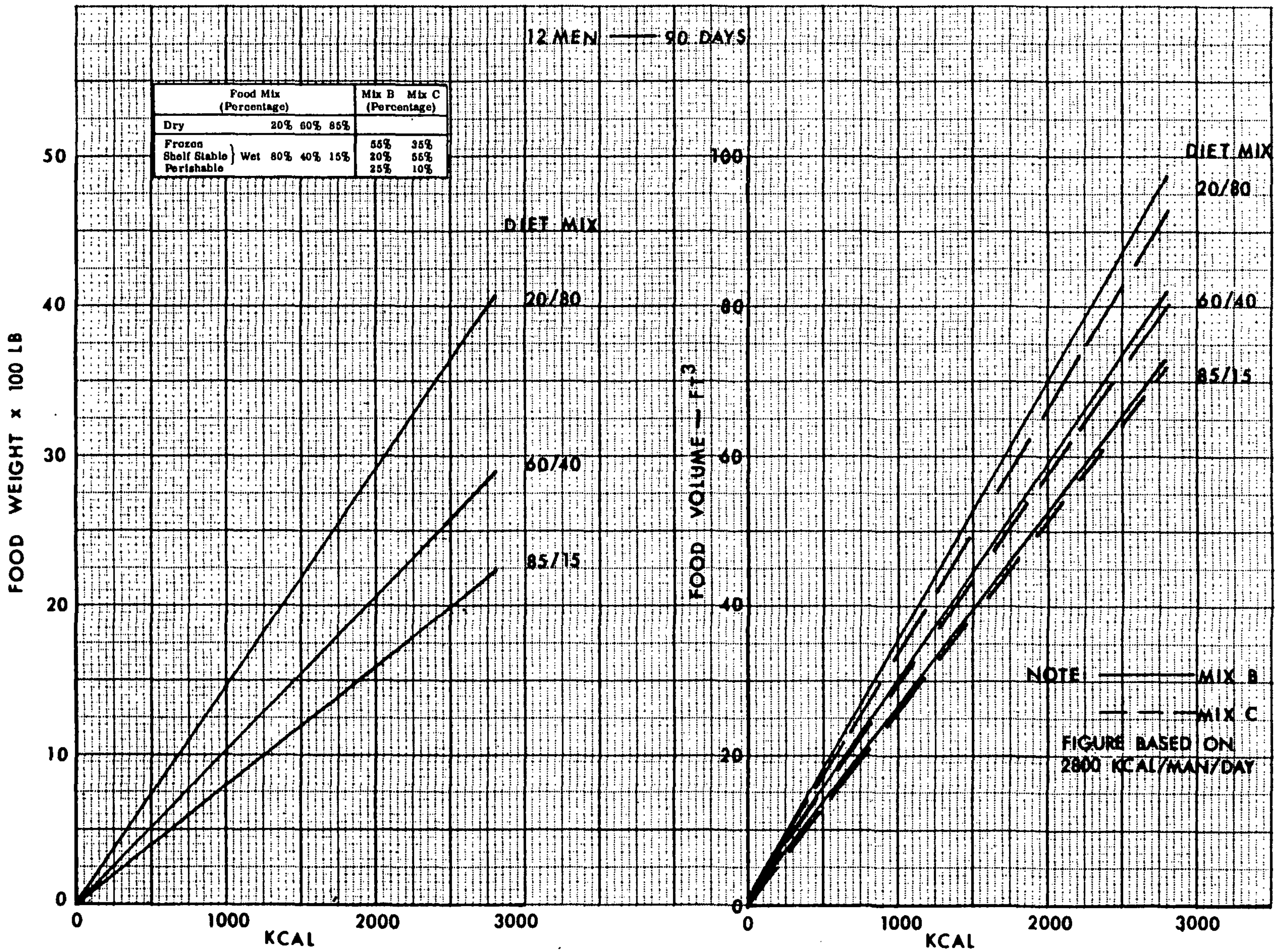


Figure III-53. Weight and Volume of Unpackaged Food for Each Diet Mix According to Kcal per Man per Day Requirement (12 Men - 90 Days)

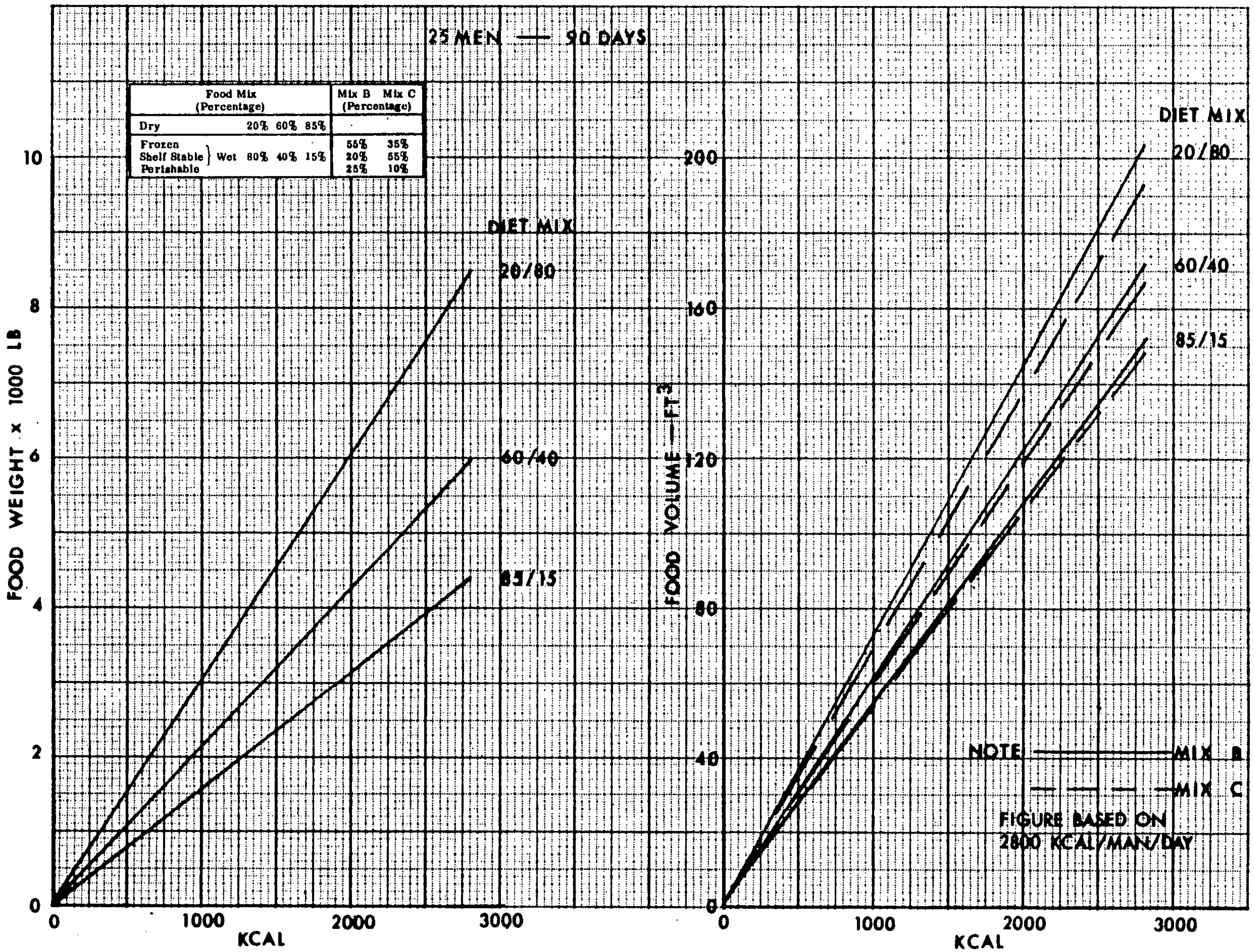
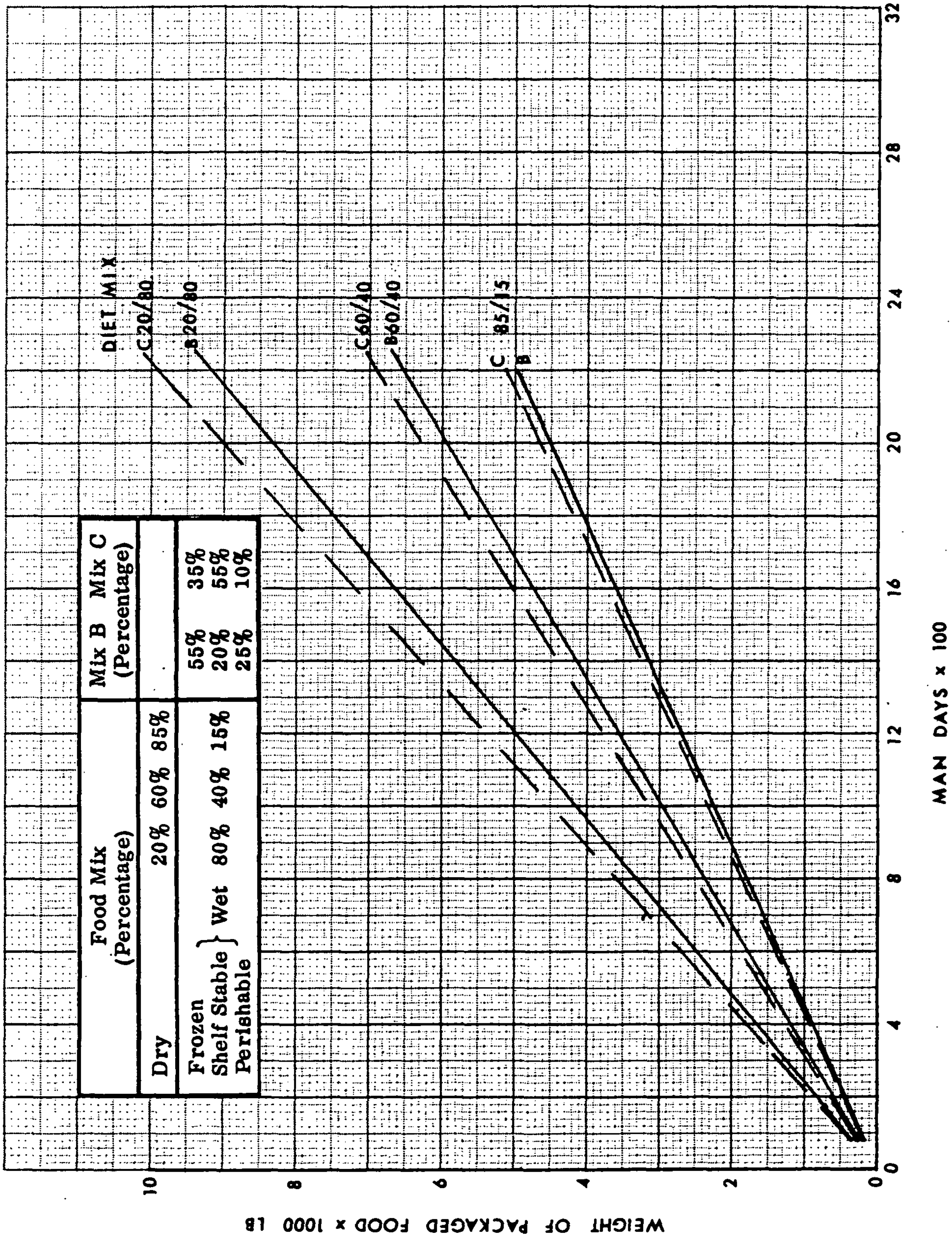


Figure III-54. Weight and Volume of Unpackaged Food for Each Diet Mix According to Kcal per Man per Day Requirement (25 Men - 90 Days)



Food Mix (Percentage)				Mix B (Percentage)	Mix C (Percentage)
Dry	20%	60%	85%		
Frozen				55%	35%
Shelf Stable } Wet	80%	40%	15%	20%	55%
Perishable				25%	10%

Figure III-55. Weight of Packaged Food as a Function of Diet Mix and Man Days

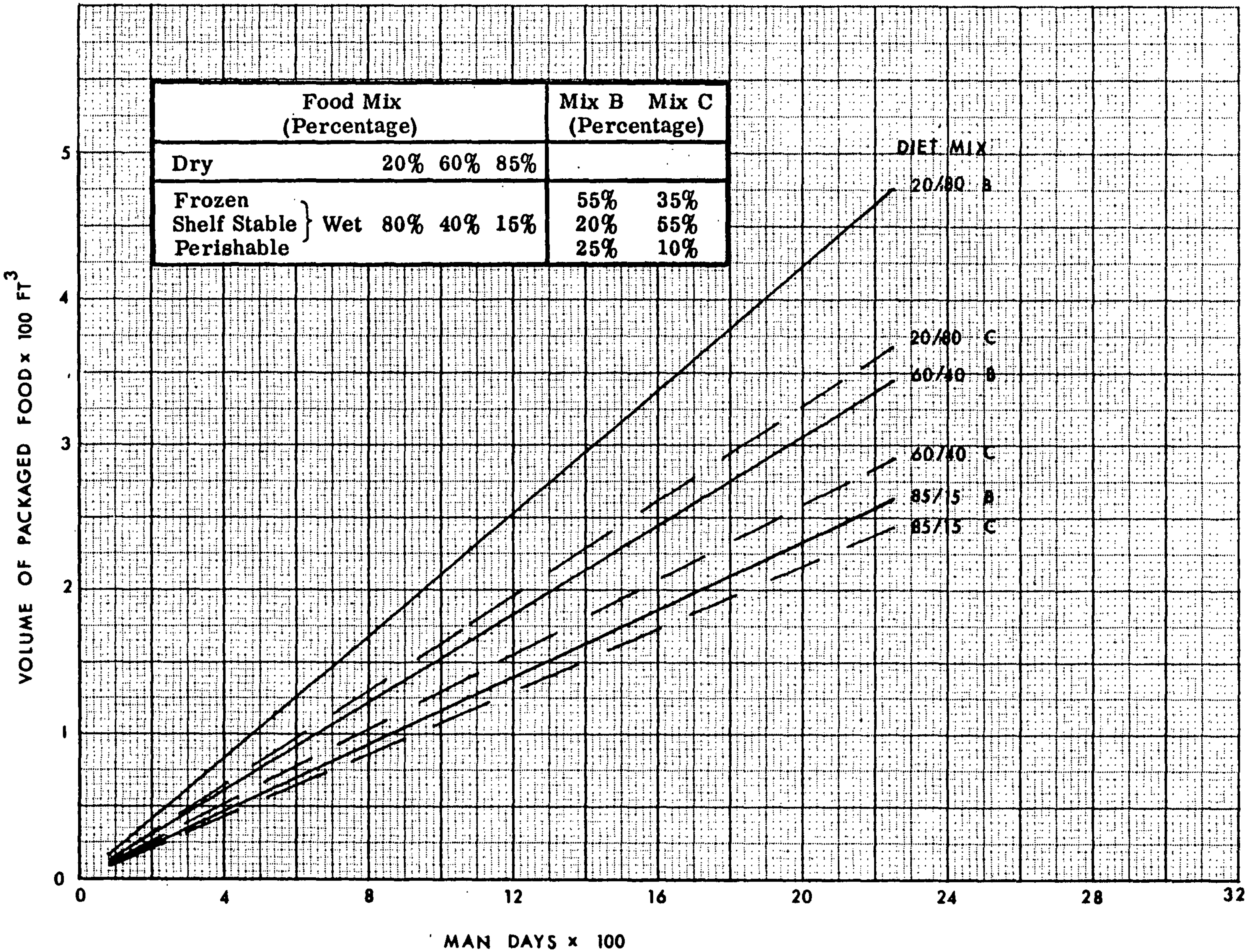


Figure III-56. Volume of Packaged Food for Each Diet Mix as a Function of Man Days

1) Figure III-57 shows the man day water requirement total and the amount of water supplied in the food of each diet mix.

2) The daily recovered or stored water requirement per man depending upon diet mix consumed is tabulated in Figure III-58.

3) Figure III-59 shows the detail allocation of hot and cold water for each diet mix as a function of man days.

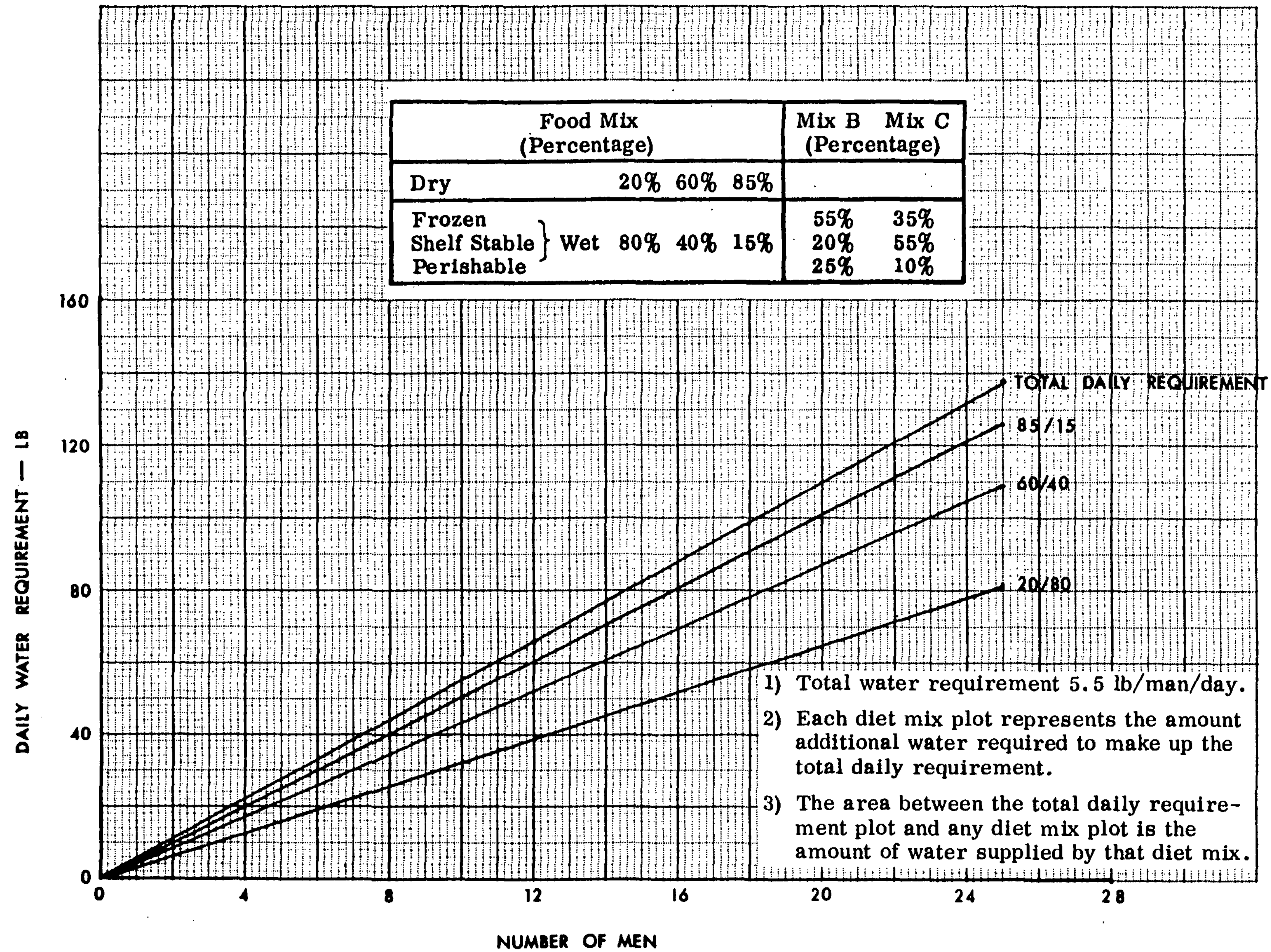


Figure III-57. Daily Make-Up Water Requirement

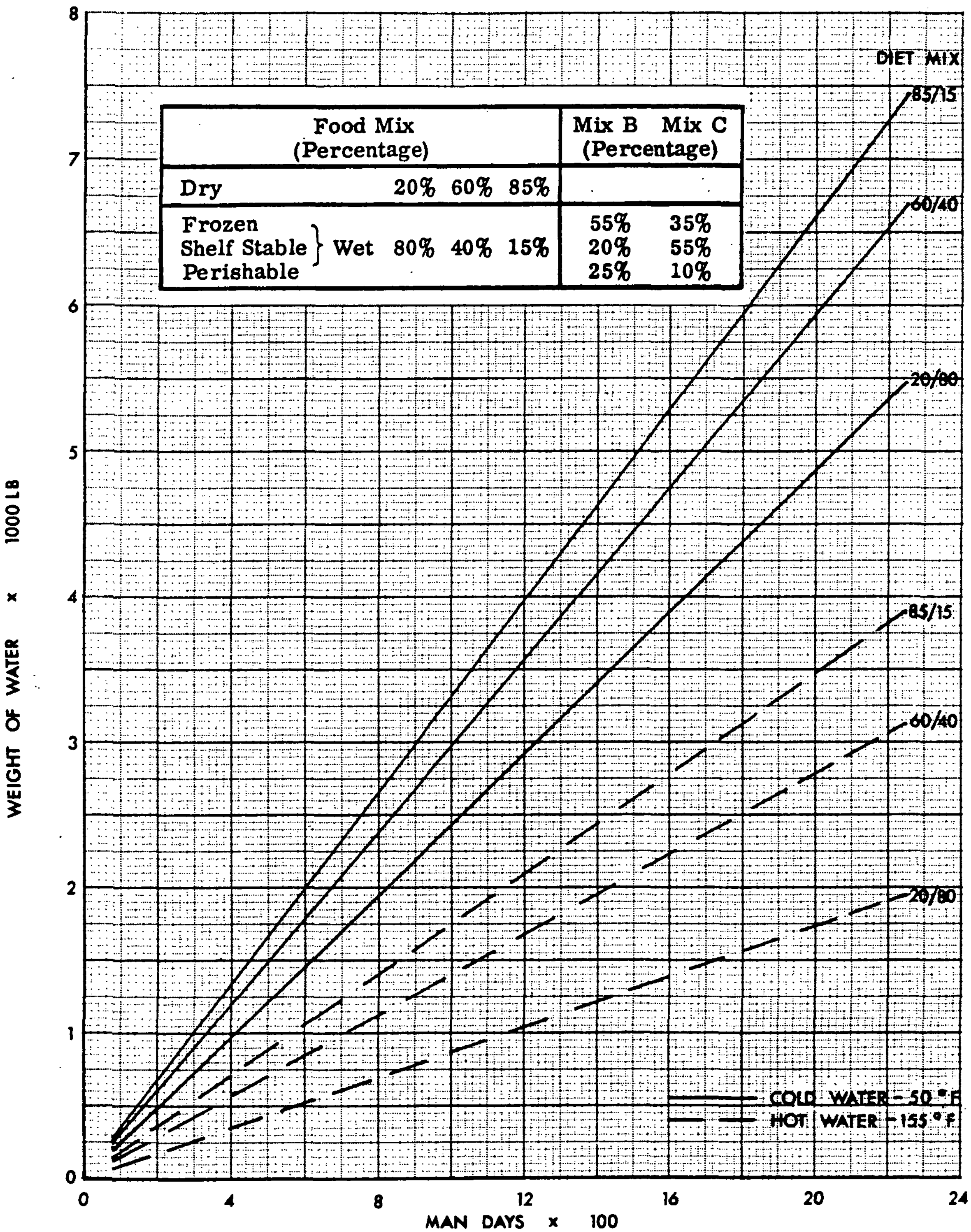
DAILY BIOLOGICAL WATER REQUIREMENTS

Diet Mix*	Daily Water Requirement Per Man	(Minus)	Water In Food	(Equals)	Daily Water Recovery or Supply Requirement
20/80 B	5.500 pounds	-	2.210 pounds	=	3.290 pounds
20/80 C	5.500 pounds	-	2.289 pounds	=	3.211 pounds
60/40 B	5.500 pounds	-	1.137 pounds	=	4.363 pounds
60/40 C	5.500 pounds	-	1.177 pounds	=	4.323 pounds
85/15 B	5.500 pounds	-	0.465 pounds	=	5.035 pounds
85/15 C	5.500 pounds	-	0.480 pounds	=	5.020 pounds

*Diet Mix: % Dry/% Wet Food
B and C designations further define % wet food as follows:

B		C
55%	Frozen	35%
20%	Shelf Stable	55%
25%	Perishable	10%

Figure III-58. Daily Biological Water Requirements



Food Mix (Percentage)					Mix B	Mix C
Dry		20%	60%	85%		
Frozen / Shelf Stable / Perishable	Wet	80%	40%	15%	55% / 20% / 25%	35% / 55% / 10%

Figure III-59. Detail Hot and Cold Water Requirements

1.2 Packaging Data

The two driving factors in this present study of food packaging for the Space Station/Base food systems are the planned earth-like environment and the inclusion of familiar foods in the diet. The environment factor precludes consideration of foil laminates, pressure vessels, and nitrogen atmosphere. The addition of familiar foods to the previously austere diet necessitates use of packages which are compatible with refrigerated, freezer, and pantry storage. Together, these two factors allow for the application of commercially available materials and techniques to the packaging of food for inclusion aboard the Space Station/Base.

a. Candidate Packaging Concepts

1. Concept: Complete Individual Meal Prepared From Primary Meal Components (1.2.1)

Concept Description: Add secondary components, heat, or reconstitute. For crew size/sitting of 6/1; 12/1; (2) 6/1; 25/1; (2) 12/1; 50/2.

Technical Analysis: Meal ingredients would consist of wet consistency food which would generally require heating, or alternatively dehydrated foods which would require hot/cold water rehydration. The individual meal would include the classical menu items associated with three daily meals. Secondary components would include desserts, beverages, and condiments. Food would be packaged in dry to wet ratios of 20/80, 60/40, 85/15 in all cases.

2. Concept: Bulk Meal Packaging Assembled in Space From Primary Components (1.2.2)

Concept Description: Add secondary components, heat or reconstitute for crew size/sittings of 6/1; (2) 6/1; 12/1; 25/1; (2) 12/1; 50/2.

Technical Analysis: Meal ingredients are defined as in Concept 1.2.1 but heated, chilled, or reconstituted in the bulk package, then assembled into an individual meal with the addition of secondary components.

3. Concept: Complete Individual Meal Prepared From Primary and Secondary Components (1.2.3)

Concept Description: Heat or reconstitute for crew size/sittings of 6/1; 12/1; (2) 6/1, 25/1; (2) 12/1; 50/2.

Technical Analysis: Meal ingredients are defined as in Concept 1.2.1, but including secondary items in the same unitized package as well. Preparation would require heating, chilling, thawing, or reconstitution. This concept is discarded from further study since all the meal components would be prepared at one uniform temperature and hot and/or cold appetizers and desserts could not be optional.

4. Concept: Edible Packages (1.2.4)

Concept Description: Films in which food can be packaged have been available by utilizing various materials and combinations of materials to form these films. For example: hot melts of acetoglycerides, mixtures of monoglycerides, and polyglycolesters, proteins, fatty esters of amylose and hard fats.

Technical Analysis: This concept has been discarded from further study since, although the edible films could be applied as inner food wraps, crew acceptability is judged to be very low and bacterial contamination in the process of handling can be very high.

5. Concept: Soluble Packages (1.2.5)

Concept Description: These containers could be formulated from any of the hot melt acetoglycerides or starch products and could aid in moderating the garbage disposal problem. In large stations this material may be processed for reuse in applications other than food protection.

Technical Analysis: This concept will be studied because soluble packages can be fabricated with acceptable rigidity to serve as food storage containers and/or dining trays from which meals may be eaten directly. This concept would assist in minimizing waste disposal problems, but may impose additional design considerations on the water recovery system.

6. Concept: No Package (1.2.6)

Concept Description: The "no package" concept would be applicable only to those foods (frozen or dehydrated) which could be stored as identifiable geometric shapes, bars, cubes, etc. No protective wrapping would be provided. Only the protection afforded by the storage container would be realized.

Technical Analysis: This concept is excluded from further study for the following reasons: (a) low crew acceptability, (b) high microbial contamination potential, (c) possible disorganization of food supply, (d) difficult food identification, and (e) degradation of quality due to freezer burn and/or exposure to oxygen.

7. Concept: Heatable Packages (1.2.7)

Concept Description: These packages may be of two types: (1) current commercially available types in which foods are sealed in flexible plastic films and heated in a fluid medium not in excess of 212°F, and (2) a composite plastic laminate having a metallic conductor as an interlaminate. When connected to an appropriate power supply, the conductor will heat the contents to an acceptable temperature.

Technical Analysis: A wide variety of highly acceptable foods are presently being provided in these types of package. The food industry also forecasts the marketing of many more additional items in the next few years. The packages have a high reliability factor and the food, in many instances, can be eaten directly from the package.

8. Concept: Conventional Packages (1.2.8)

Concept Description: These are the packaging techniques currently in use by the food industry and include varieties of plastic films, coated and impregnated papers and fabrics, composite material cartons and semi-rigid plastic containers.

Technical Analysis: This is an admissible concept for further study since the spacecraft environment has been defined as 10-14 psi with none of the hazards associated with a 100% oxygen atmosphere. The packaging systems and techniques have a long history of development and commercial application with a high degree of reliability.

9. Concept: Storage/Service Package (1.2.9)

Concept Description: These are essentially limited to either frozen meals or dehydrated single food item packages. The current TV-type dinner is representative of this category of packaging.

Technical Analysis: This type of packaging has application especially to smaller sized crews in that the crew time required for food handling and preparation can be reduced to a minimum.

10. Concept: Casseroles (1.2.10)

Concept Description: Major menu items such as stew, gumbo, meat pie packaged in either disposable or reusable containers. These meals may be prepared by heating or rehydrating the major item and adding secondary components.

Technical Analysis: Single dish menus are frequently encountered in the normal earth dining patterns and would, therefore, be acceptable to the crew. Handling and preparation would not be time consuming and the addition of secondary food items would provide the necessary variety to prevent monotony in the diet.

11. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-2 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-2

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 1.2	TITLE: Packaging	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
1.2.1	Complete Individual Meal Prepared From Primary Meal Components	11.5		X	-		X
1.2.2	Bulk Meal Packaging Assembled In Space From Primary Components	12.8		X	-		X
1.2.3	Complete Individual Meal Prepared From Primary and Secondary Components	(11.7)	X		-		
1.2.4	Edible Packages	(9.2)	X		-		
1.2.5	Soluble Packages	14.5		X	-		X
1.2.6	No Package	(10.0)	X		-		
1.2.7	Heatable Packages	12.7		X	-		X
1.2.8	Conventional Packages	13.5		X	-		X
1.2.9	Storage/Service Package	10.3		X	-		X
1.2.10	Casseroles	10.3		X	-		X

b. Packaging Weight and Volume

In the absence of packaging data specifically tailored to 6-man meal portions applicable to the Space Station/Base, packaging weight criteria were recommended by the Team Study Panel for the various food types. In addition, limited laboratory measurements and subsequent analyses were performed on purchased food products. These products were selected from dry, frozen, shelf stable, and perishable food types in net weight quantities sufficient for six servings. Represented packaging types were as follows:

- Canned: Steel and tin can.
- Box and Bag: Coated paperboard box and polyethylene bag.
- Bag: Polyethylene bag.
- Cylindrical: Rigid polyethylene container and pull-ring aluminum can.

The products were measured for net weight of food, net weight of accompanying package, and dimensional volume of the package. From these measurements, analyses were made to determine average values for the following ratios:

- $\frac{\text{Package Weight}}{\text{Food Net Weight}}$
- $\frac{\text{Package Volume}}{\text{Food Net Weight}}$

The weight and volume ratios for each packaging type and the storage mode to which the packaging could apply are presented in Figure III-60.

The effect of packaging food for each diet mix in any possible package type is illustrated in Figures III-61 through III-66. The worst and best case package weights (less food) are plotted for each storage mode.

The most likely packaging type was chosen for each food type and packaged weight and packaged volume data were generated for each mission. These data are presented in Figure III-67.

	*Package Type			
Food Type	A	B	C	D
Storage Mode	Canned	Box and Bag	Bag	Cylindrical
DRY (Ambient)	W = .272 V = .023	W = .130 V = .061	N/A	W = .114 V = .018
FROZEN (Freezer)	N/A	W = .082 V = .064	W = .015 V = .032	W = .014 V = .057
SHELF STABLE (Ambient)	W = .272 V = .023	W = .130 V = .061	N/A	W = .114 V = .018
PERISHABLE (Refrigerated)	N/A	W = .102 V = .069	W = .035 V = .037	W = .095 V = .022

Ratios are expressed as $\frac{\text{lb pkg}}{\text{lb food}}$ and $\frac{\text{pkg (ft}^3\text{)}}{\text{lb food}}$ therefore...

$$W = \frac{\text{lb pkg}}{\text{lb food}} \times \text{lb food} \qquad V = \frac{\text{pkg (ft}^3\text{)}}{\text{lb food}} \times \text{lb food}$$

*Package Type

- A Steel and tin can (canned)
- B Paperboard box and polyethylene bag (box and bag)
- C Polyethylene bag with rehydration valve (bag)
- D Rigid polyethylene or aluminum pull-ring can (cylindrical)

Figure III-60. Package Type
Weight (W) and Volume (V) Ratios

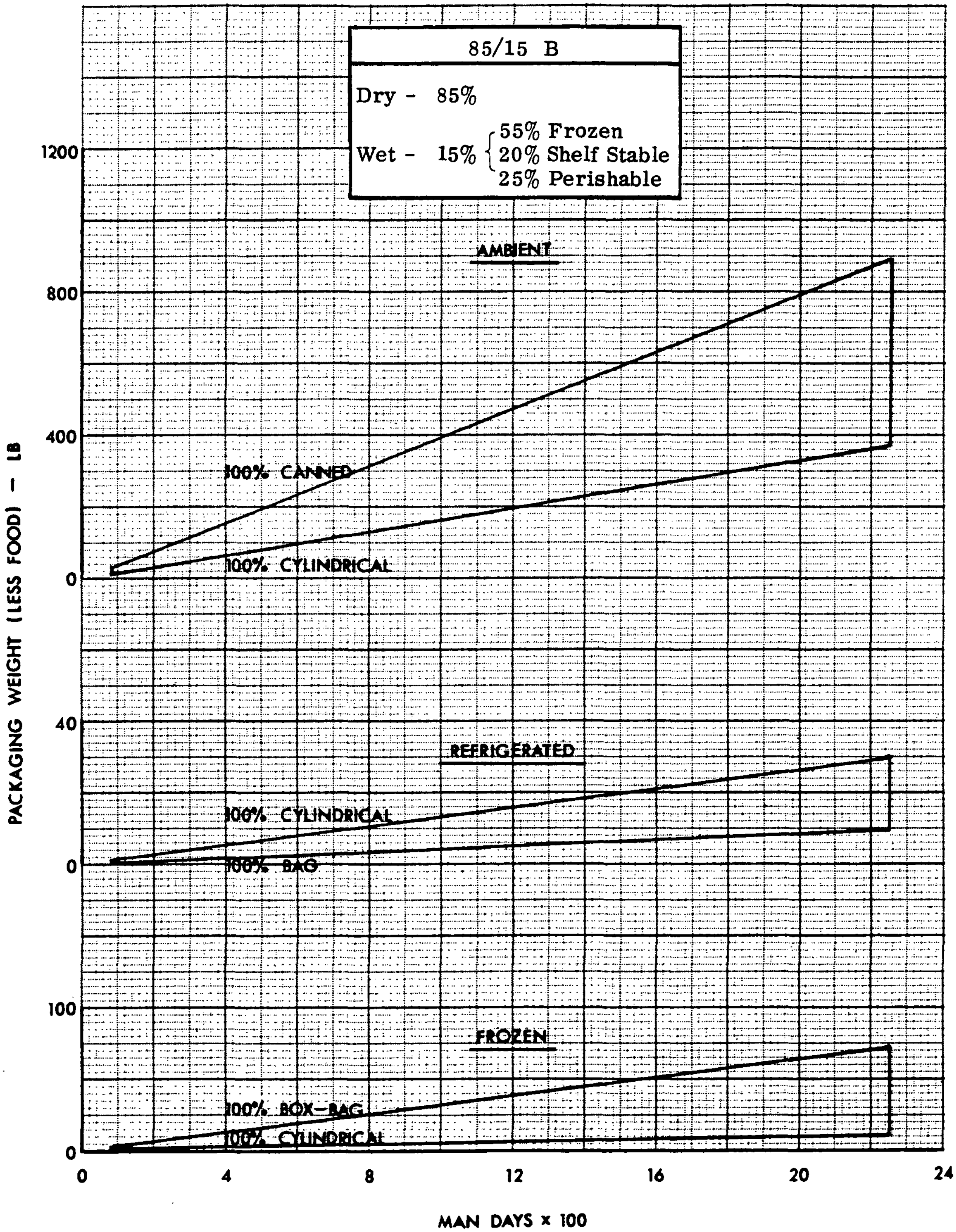


Figure III-61. Effect of Packaging Type Upon Mission Packaging Weight For A 85/15B Diet Mix

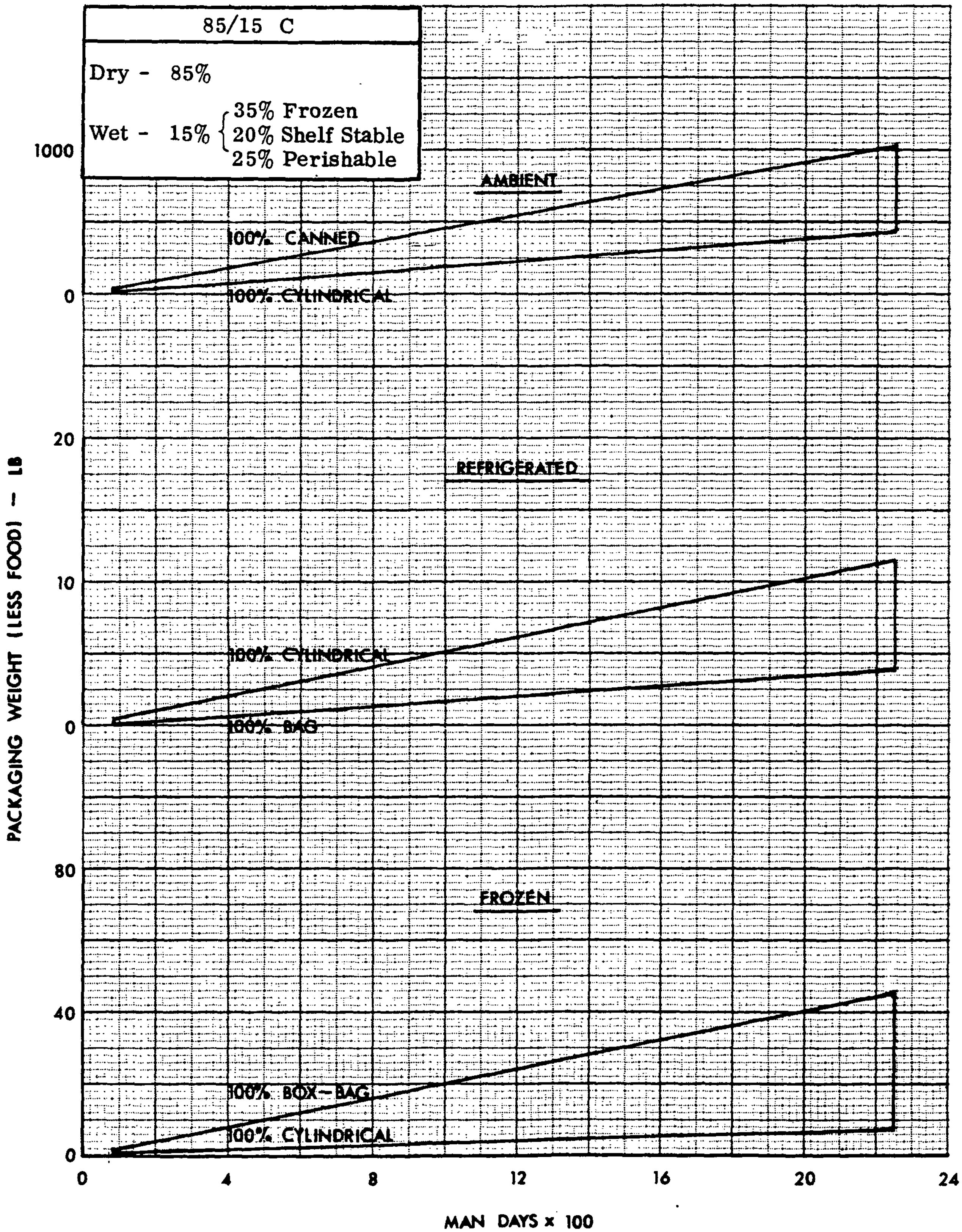


Figure III-62. Effect of Packaging Type Upon Mission Packaging Weight For A 85/15C Diet Mix

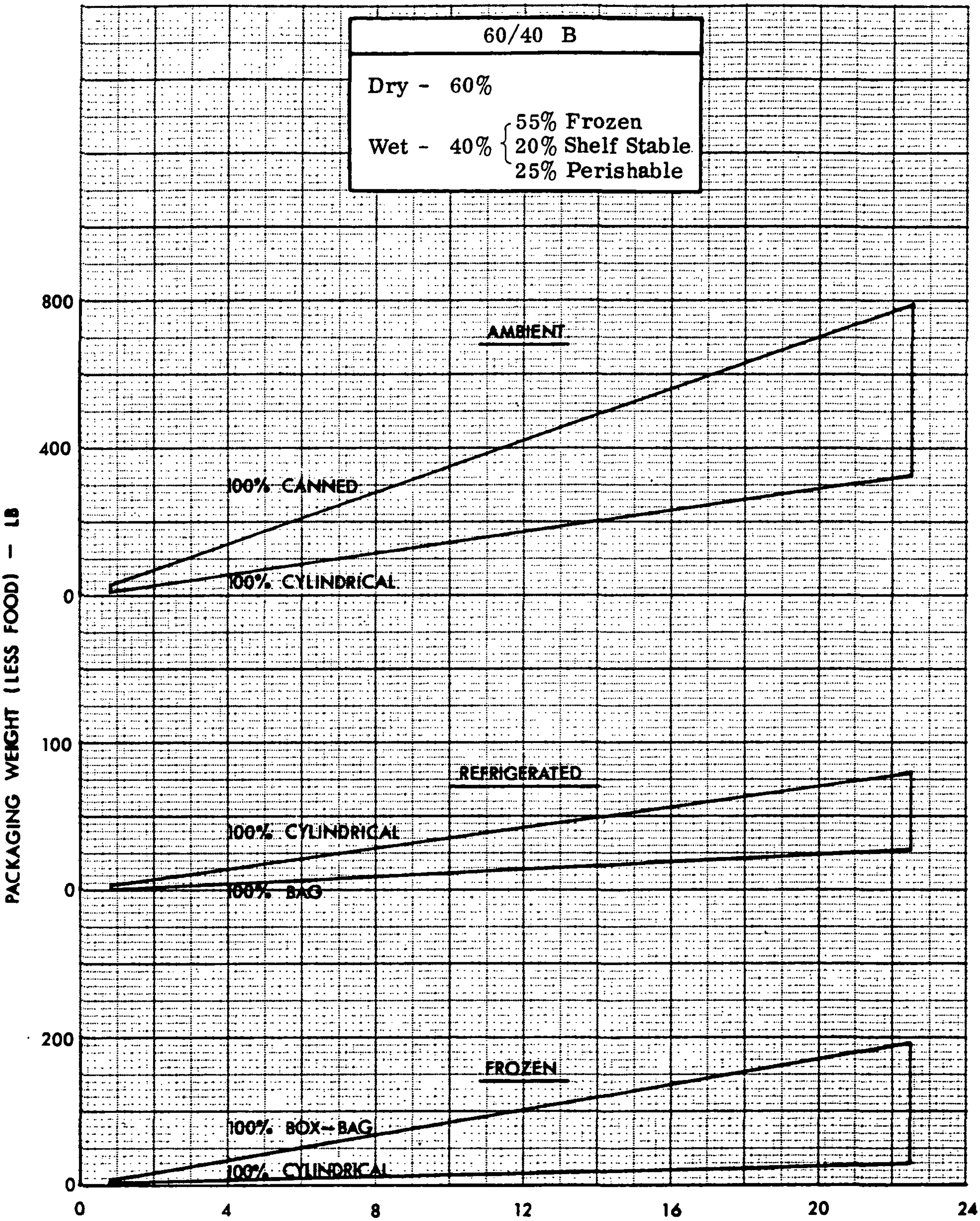


Figure III-63. Effect of Packaging Type Upon Mission Packaging Weight For A 60/40B Diet Mix

3⊕

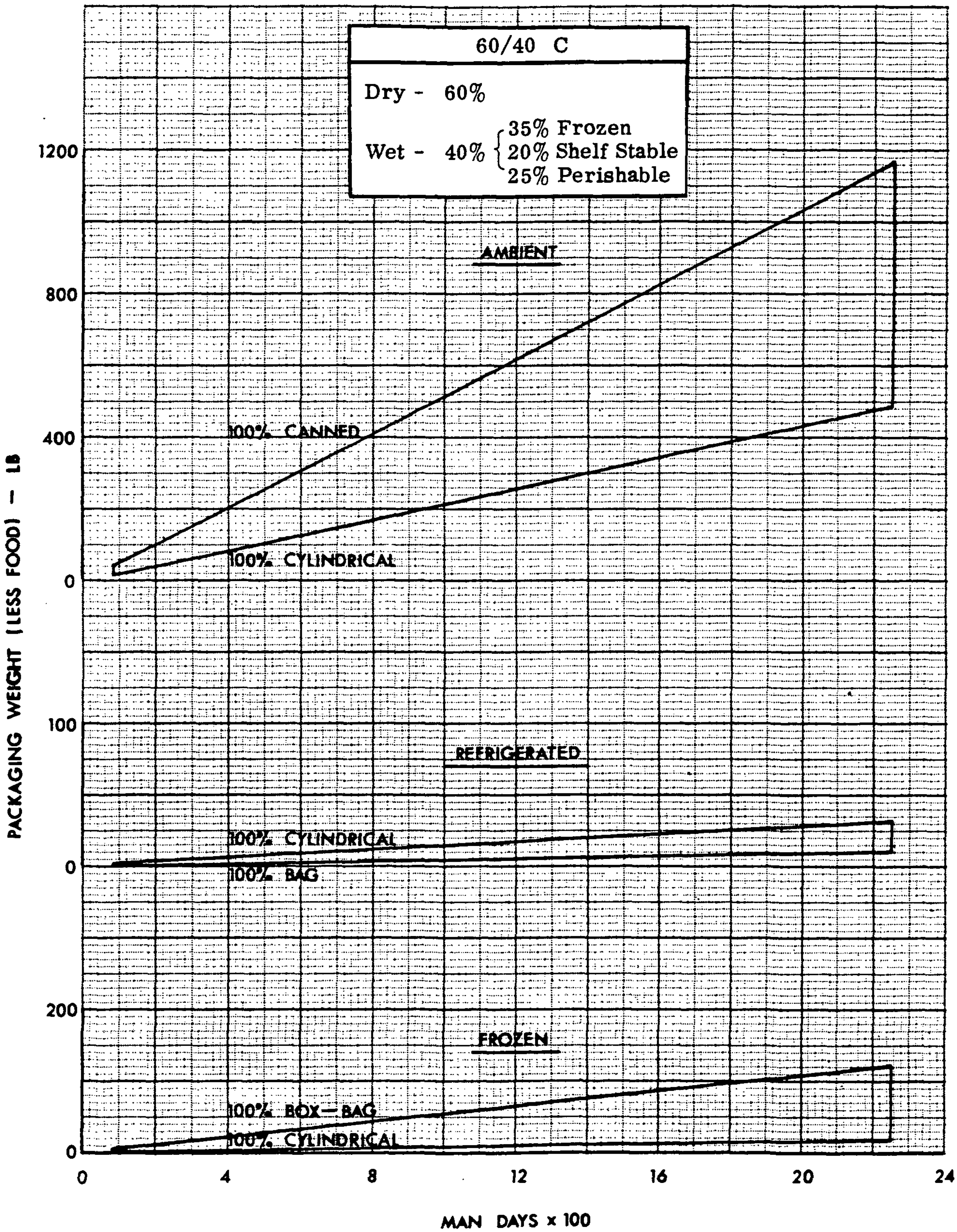


Figure III-64. Effect of Packaging Type Upon Mission Packaging Weight For A 60/40C Diet Mix

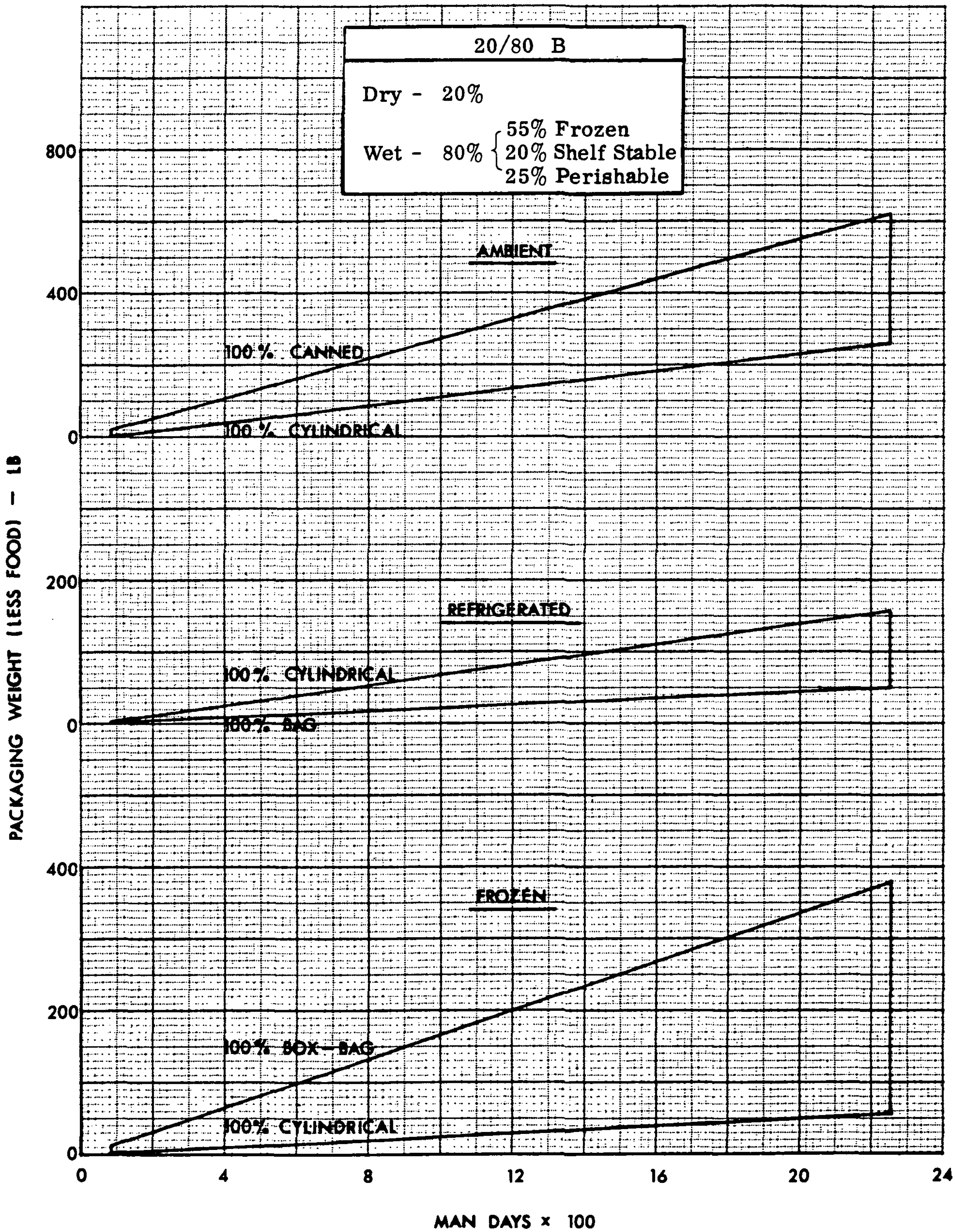


Figure III-65. Effect of Packaging Type Upon Mission Packaging Weight For A 20/80B Diet Mix

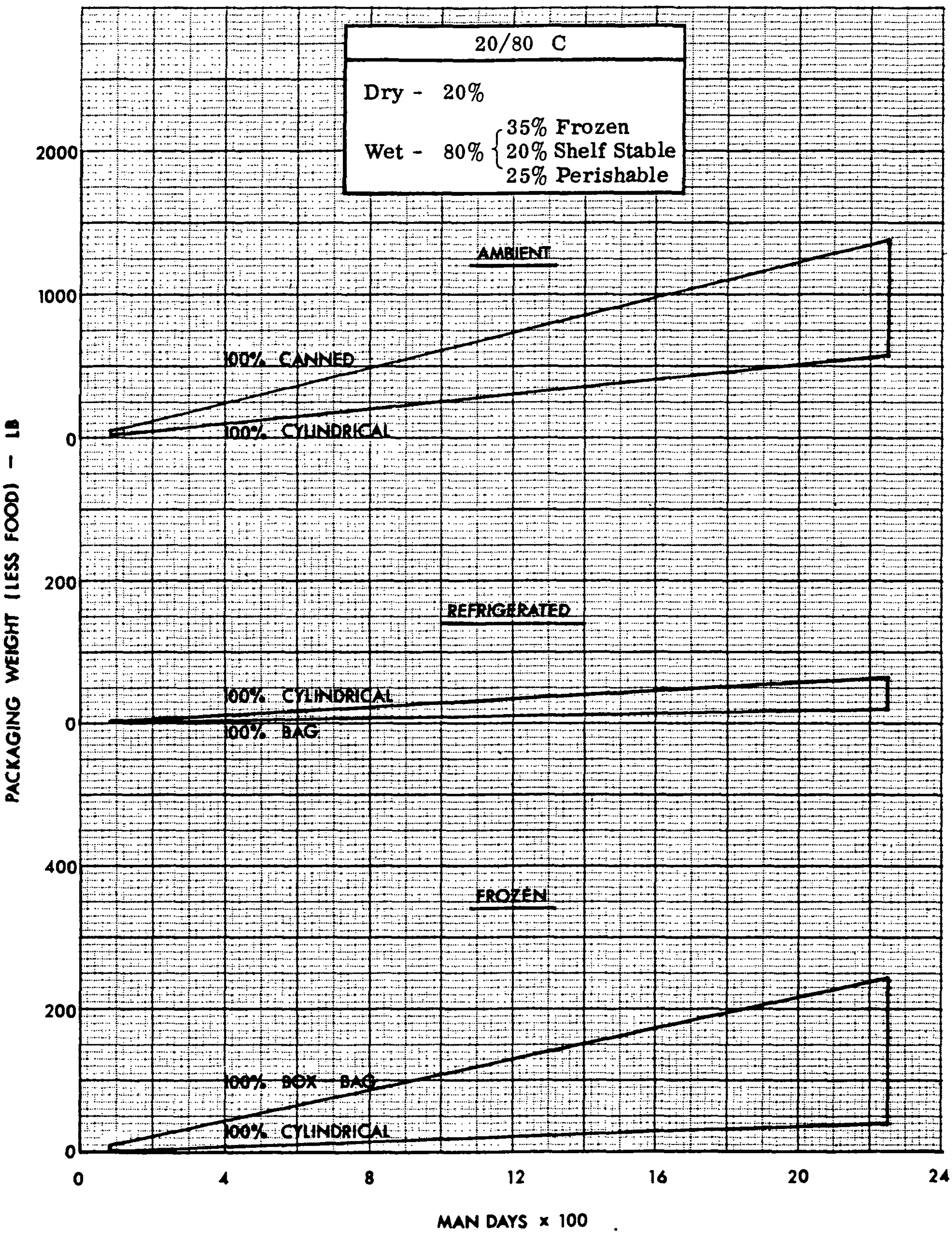


Figure III-66. Effect of Packaging Type Upon Mission Packaging Weight For A 20/80C Diet Mix

Mission	DRY (Box and Bag)			FROZEN (Box and Bag)			SHELF STABLE (Canned)			PERISHABLE (Box and Bag)			TOTALS		
	Food (lb)	Pkgd Wt (lb)	Pkgd Vol (ft^3)	Food (lb)	Pkgd Wt (lb)	Pkgd Vol (ft^3)	Food (lb)	Pkgd Wt (lb)	Pkgd Vol (ft^3)	Food (lb)	Pkgd Wt (lb)	Pkgd Vol (ft^3)	Food (lb)	Pkgd Wt (lb)	Pkgd Vol (ft^3)
001	26.29	29.71	1.60	163.00	176.40	10.43	59.30	75.43	1.36	63.00	69.43	4.35	311.6	351.0	17.74
002	26.29	29.71	1.60	103.70	112.20	6.64	163.00	207.30	3.75	25.20	27.77	1.74	318.3	377.0	13.73
003	78.79	89.03	4.81	81.56	88.25	5.22	29.65	37.71	0.68	31.50	34.71	2.17	221.5	249.7	12.88
004	78.79	89.03	4.81	51.91	56.17	3.32	81.56	103.70	1.88	12.60	13.89	0.87	224.9	262.8	10.88
005	111.60	126.10	6.81	30.66	33.17	1.96	11.09	14.11	0.26	11.76	12.96	0.81	165.1	186.3	9.84
006	111.60	126.10	6.81	19.49	21.09	1.25	30.66	39.00	0.71	4.62	5.09	0.32	166.3	191.3	9.09
007	52.58	59.42	3.21	326.10	352.80	20.87	118.60	150.90	2.73	126.00	138.90	8.69	623.3	702.0	35.50
008	52.58	59.42	3.21	207.50	224.50	13.28	326.10	414.80	7.50	50.40	55.54	3.48	636.6	754.3	27.47
009	157.60	178.10	9.61	163.10	176.50	10.44	59.30	75.43	1.36	63.00	69.43	4.35	443.0	499.5	25.76
010	157.60	178.10	9.61	103.80	112.30	6.64	163.10	207.50	3.75	25.20	27.77	1.74	449.7	525.7	21.74
011	223.10	252.10	13.61	61.32	66.35	3.92	22.18	28.21	0.51	23.52	25.92	1.62	330.1	372.6	19.66
012	223.10	252.10	13.61	38.98	42.18	2.49	61.32	78.00	1.41	9.24	10.18	0.64	332.6	382.5	18.15
013	109.60	123.80	6.69	679.40	735.10	43.48	247.10	314.30	5.68	262.50	289.30	18.11	1298.0	1463.0	73.96
014	109.60	123.80	6.69	432.20	467.60	27.66	679.40	864.20	15.63	105.00	115.70	7.25	1326.0	1571.0	57.23
015	328.30	371.00	20.03	339.90	367.80	21.75	123.60	157.20	2.84	131.20	144.60	9.05	923.0	1041.0	53.67
016	328.30	371.00	20.03	216.30	234.00	13.84	339.80	432.20	7.82	52.50	57.86	3.62	937.0	1095.0	45.31
017	464.80	525.20	28.35	127.80	138.30	8.18	46.20	58.77	1.06	49.00	54.00	3.38	687.8	776.3	40.97
018	464.80	525.20	28.35	81.20	87.86	5.20	127.60	162.30	2.93	19.25	21.21	1.33	693.0	796.6	37.81
025	169.00	191.00	10.31	1048.00	1134.00	67.07	381.20	484.90	8.77	405.00	446.30	27.95	2003.0	2256.0	114.10
026	169.00	191.00	10.31	666.90	721.60	42.68	1048.00	1333.00	24.10	162.00	178.50	11.18	2046.0	2424.0	88.27
027	506.50	572.30	30.90	524.30	567.30	33.56	190.60	242.40	4.38	202.50	223.20	13.97	1424.0	1605.0	82.81
028	506.50	572.30	30.90	333.70	361.10	21.36	524.30	666.90	12.06	81.00	89.26	5.59	1446.0	1690.0	69.91
029	717.10	810.30	43.74	197.10	213.30	12.61	71.28	90.67	1.64	75.60	83.31	5.22	1061.0	1198.0	63.21
030	717.10	810.30	43.74	125.20	135.50	8.01	197.10	250.70	4.53	29.70	32.73	2.05	1069.0	1229.0	58.33
031	338.00	381.90	20.62	2096.00	2268.00	134.10	76.24	969.80	17.54	810.00	892.60	55.89	4006.0	4512.0	228.20
032	338.00	381.90	20.62	1334.00	1443.00	85.38	2096.00	2666.00	48.21	324.00	357.00	22.36	4092.0	4848.0	176.60
033	1013.00	1145.00	61.79	1048.00	1134.00	67.07	381.20	484.90	8.77	405.00	446.30	27.95	2847.0	3210.0	165.60
034	1013.00	1145.00	61.79	667.40	722.10	42.71	1049.00	1334.00	24.13	162.00	178.50	11.18	2891.0	3380.0	139.80
035	1434.00	1620.00	87.47	394.20	426.50	25.23	142.50	181.30	3.28	151.20	166.60	10.43	2122.0	2394.0	126.40
036	1434.00	1620.00	87.47	250.60	271.10	16.04	394.20	501.40	9.07	59.40	65.46	4.10	2138.0	2458.0	116.70
037	704.20	795.70	42.96	436.70	4725.00	279.50	1588.00	2020.00	36.52	1688.00	1860.00	116.50	8347.0	9401.0	475.50
038	704.20	795.70	42.96	2779.00	3007.00	177.90	4367.00	5555.00	100.40	675.00	743.90	46.58	8525.0	10102.0	367.80
039	2110.00	2384.00	128.70	2185.00	2364.00	139.80	794.20	1010.00	18.27	843.80	929.90	58.22	5933.0	6688.0	345.00
040	2110.00	2384.00	128.70	1390.00	1504.00	88.96	2185.00	2779.00	50.26	337.50	371.90	23.29	6022.0	7039.0	291.20
041	2988.00	3376.00	182.30	821.20	888.50	52.56	297.00	377.80	6.83	315.00	347.10	21.74	4421.0	4989.0	263.40
042	2988.00	3376.00	182.30	522.00	564.80	33.41	821.20	1045.00	18.89	123.80	136.40	8.54	4455.0	5122.00	243.10

Figure III-67. Packaged Weight and Volume of Each Food Type For Each Mission

Mission	DRY (Box and Bag) Food (lb)	DRY Pkgd Wt (lb)	DRY Pkgd Vol (ft³)	FROZEN (Box and Bag) Food (lb)	FROZEN Pkgd Wt (lb)	FROZEN Pkgd Vol (ft³)	SHELF STABLE (Canned) Food (lb)	SHELF STABLE Pkgd Wt (lb)	SHELF STABLE Pkgd Vol (ft³)	PERISHABLE (Box and Bag) Food (lb)	PERISHABLE Pkgd Wt (lb)	PERISHABLE Pkgd Vol (ft³)	TOTALS Food (lb)	TOTALS Pkgd Wt (lb)	TOTALS Pkgd Vol (ft³)
001	26.29	29.71	1.60	163.00	176.40	10.43	59.30	75.43	1.36	63.00	69.43	4.35	311.6	351.0	17.74
002	26.29	29.71	1.60	103.70	112.20	6.64	163.00	207.30	3.75	25.20	27.77	1.74	318.3	377.0	13.73
003	78.79	89.03	4.81	81.56	88.25	5.22	29.65	37.71	0.68	31.50	34.71	2.17	221.5	249.7	12.88
004	78.79	89.03	4.81	51.91	56.17	3.32	81.56	103.70	1.88	12.60	13.89	0.87	224.9	262.8	10.88
005	111.60	126.10	6.81	30.66	33.17	1.96	11.09	14.11	0.26	11.76	12.96	0.81	165.1	186.3	9.84
006	111.60	126.10	6.81	19.49	21.09	1.25	30.66	39.00	0.71	4.62	5.09	0.32	166.3	191.3	9.09
007	52.58	59.42	3.21	326.10	352.80	20.87	118.60	150.90	2.73	126.00	138.90	8.69	623.3	702.0	35.50
008	52.58	59.42	3.21	207.50	224.50	13.28	326.10	414.80	7.50	50.40	55.54	3.48	636.6	754.3	27.47
009	157.60	178.10	9.61	163.10	176.50	10.44	59.30	75.43	1.36	63.00	69.43	4.35	443.0	499.5	25.76
010	157.60	178.10	9.61	103.80	112.30	6.64	163.10	207.50	3.75	25.20	27.77	1.74	449.7	525.7	21.74
011	223.10	252.10	13.61	61.32	66.35	3.92	22.18	28.21	0.51	23.52	25.92	1.62	330.1	372.6	19.66
012	223.10	252.10	13.61	38.98	42.18	2.49	61.32	78.00	1.41	9.24	10.18	0.64	332.6	382.5	18.15
013	109.60	123.80	6.69	679.40	735.10	43.48	247.10	314.30	5.68	262.50	289.30	18.11	1298.0	1463.0	73.96
014	109.60	123.80	6.69	432.20	467.60	27.66	679.40	864.20	15.63	105.00	115.70	7.25	1326.0	1571.0	57.23
015	328.30	371.00	20.03	339.90	367.80	21.75	123.60	157.20	2.84	131.20	144.60	9.05	923.0	1041.0	53.67
016	328.30	371.00	20.03	216.30	234.00	13.84	339.80	432.20	7.82	52.50	57.86	3.62	937.0	1095.0	45.31
017	464.80	525.20	28.35	127.80	138.30	8.18	46.20	58.77	1.06	49.00	54.00	3.38	687.8	776.3	40.97
018	464.80	525.20	28.35	81.20	87.86	5.20	127.60	162.30	2.93	19.25	21.21	1.33	693.0	796.6	37.81
025	169.00	191.00	10.31	1048.00	1134.00	67.07	381.20	484.90	8.77	405.00	446.30	27.95	2003.0	2256.0	114.10
026	169.00	191.00	10.31	666.90	721.60	42.68	1048.00	1333.00	24.10	162.00	178.50	11.18	2046.0	2424.0	88.27
027	506.50	572.30	30.90	524.30	567.30	33.56	190.60	242.40	4.38	202.50	223.20	13.97	1424.0	1605.0	82.81
028	506.50	572.30	30.90	333.70	361.10	21.36	524.30	666.90	12.06	81.00	89.26	5.59	1446.0	1690.0	69.91
029	717.10	810.30	43.74	197.10	213.30	12.61	71.28	90.67	1.64	75.60	83.31	5.22	1061.0	1198.0	63.21
030	717.10	810.30	43.74	125.20	135.50	8.01	197.10	250.70	4.53	29.70	32.73	2.05	1069.0	1229.0	58.33
031	338.00	381.90	20.62	2096.00	2268.00	134.10	76.24	969.80	17.54	810.00	892.60	55.89	4006.0	4512.0	228.20
032	338.00	381.90	20.62	1334.00	1443.00	85.38	2096.00	2666.00	48.21	324.00	357.00	22.36	4092.0	4848.0	176.60
033	1013.00	1145.00	61.79	1048.00	1134.00	67.07	381.20	484.90	8.77	405.00	446.30	27.95	2847.0	3210.0	165.60
034	1013.00	1145.00	61.79	667.40	722.10	42.71	1049.00	1334.00	24.13	162.00	178.50	11.18	2891.0	3380.0	139.80
035	1434.00	1620.00	87.47	394.20	426.50	25.23	142.50	181.30	3.28	151.20	166.60	10.43	2122.0	2394.0	126.40
036	1434.00	1620.00	87.47	250.60	271.10	16.04	394.20	501.40	9.07	59.40	65.46	4.10	2138.0	2458.0	116.70
037	704.20	795.70	42.96	436.70	4725.00	279.50	1588.00	2020.00	36.52	1688.00	1860.00	116.50	8347.0	9401.0	475.50
038	704.20	795.70	42.96	2779.00	3007.00	177.90	4367.00	5555.00	100.40	675.00	743.90	46.58	8525.0	10102.0	367.80
039	2110.00	2384.00	128.70	2185.00	2364.00	139.80	794.20	1010.00	18.27	843.80	929.90	58.22	5933.0	6688.0	345.00
040	2110.00	2384.00	128.70	1390.00	1504.00	88.96	2185.00	2779.00	50.26	337.50	371.90	23.29	6022.0	7039.0	291.20
041	2988.00	3376.00	182.30	821.20	888.50	52.56	297.00	377.80	6.83	315.00	347.10	21.74	4421.0	4989.0	263.40
042	2988.00	3376.00	182.30	522.00	564.80	33.41	821.20	1045.00	18.89	123.80	136.40	8.54	4455.0	5122.00	243.10

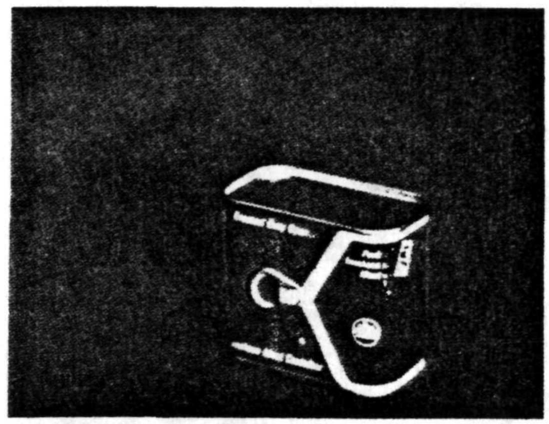
Figure III-67. Packaged Weight and Volume of Each Food Type For Each Mission

c. Packaging Concepts

Packaging concepts recently devised by the American Can Company (Greenwich, Connecticut) are illustrated below. The American Can Company served in a consulting capacity to the Fairchild Hiller Corporation as a member of the Food Systems Team Study Panel.

LUNCHEON-MEAT CAN

A new luncheon meat package that has been developed due to the incidence of sulfide staining in a tinplate container and the inherent disadvantage of the key opening. This all-aluminum can retains the present geometry but uses a thermoplastically bonded side seam and a ring-tab side opening device.



DRAWN ALUMINUM CANS

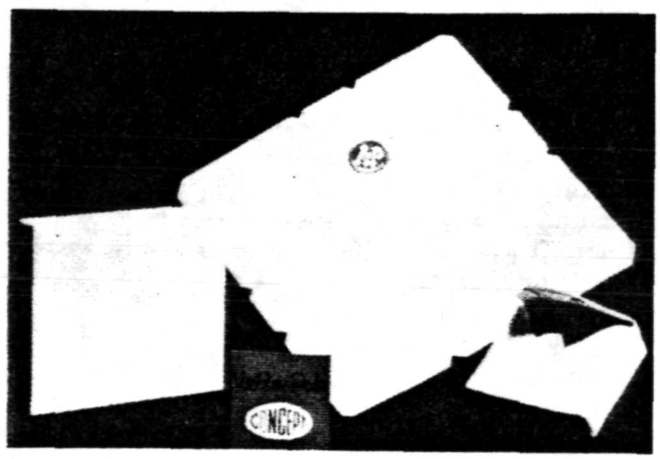
Use of drawn aluminum cans for sausages and potted meats has increased tremendously in the past three years. Two sizes are commonly produced, both fitted with a full opening, aluminum easy open end.

PRESSURE CANS

This pressurized can utilizes a piston to separate the propellent from the product so that a cheese spread or other item is dispensed with an appetizing consistency.

PAPERBOARD

This new carton blank appears like any other rectangular carton, but by closing the back panel similar to an envelope, maximum use is made of the paperboard, by providing an opening feature and a reclosure. It results in a top loading carton which is important for multiple pack items such as dry dinners which include components such as a sauce can, noodles or macaroni and perhaps a garnish. It is also extremely effective when pouches utilizing very limp film material, such as polyethylene with their low cost and good barrier properties, are used for dry components but are extremely difficult to end or side load into a carton either by hand or automatically.

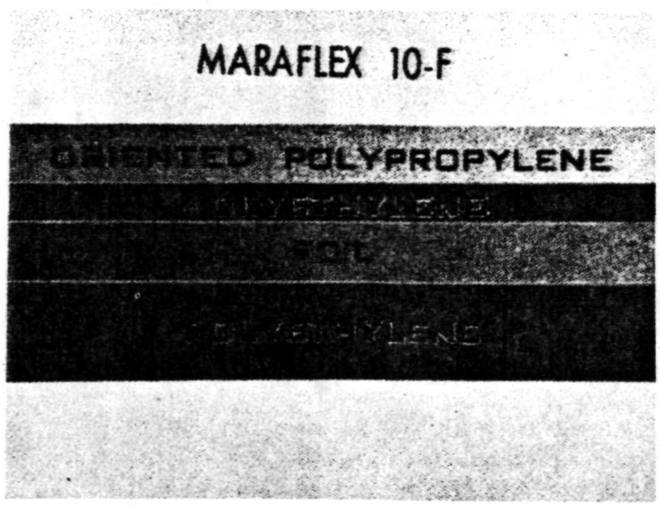


TUBE

Fabrication consists of a variety of layers of barrier materials, each one contributing its individual function to the finished laminated container. This system allows incorporation of rotogravure printing with its excellent register and graphics potential. The initial applications have been found with a number of food manufacturers for products such as syrups, toppings, mustard, catsup, and honey.

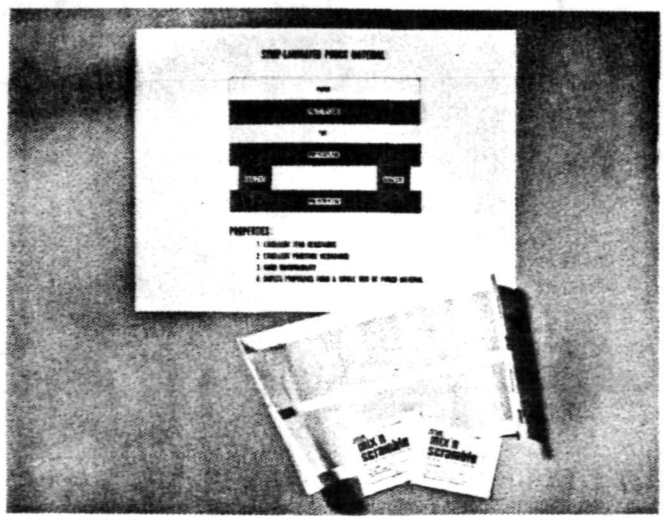
LAMINATED POUCH MATERIAL

A laminated pouch structure-polypropylene-foil-polyethylene sealant is used on various types of form-fill-seal equipment. Initial applications have been snack food packaging. The excellent protection and machinability offered by the sheet will expand its use to other areas. This construction has low WVP and O_2 rates, toughness and excellent shipping durability.



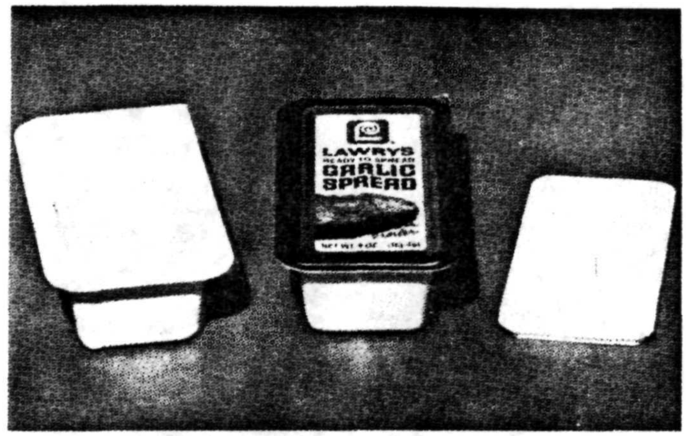
HIGH STRENGTH PACKAGE

This is a technique which was developed for producing laminated pouch materials which exhibited high burst strength. In addition, this construction is adaptable to packaging products which contain sharp pointed particles.



LAMINATED FORM SEAL STRUCTURE

The use of laminated flexible pouch materials is common-place and wide-spread. The reason for this is that laminated structures are used to fill property gaps. No plastic material has all the necessary properties for all packaging applications. The same laminating technology is being applied to rigid plastics in an effort to tailor the sheet stock for specific end use applications.

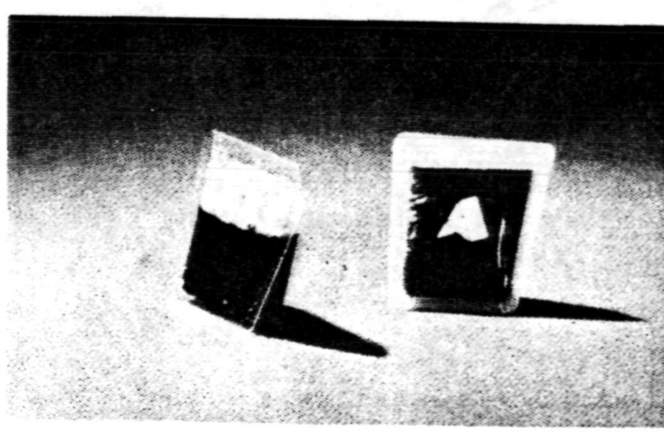


SINGLE-SERVICE POUCHES

Depicted here are flexible pouch materials which may be adapted for single-service condiment packaging. The mechanics of determining "which web to use" depends on the specific end use requirements for the product, physical and chemical properties of the product, shelf life and handling requirements, etc.

STAND PACK

This concept is a pitcher shape obtained from thermoforming to provide unit portion of product and shaped to stand on end. A variety of material possibilities are available to fit product requirements.



SINGLE STRENGTH JUICE CUP

This concept utilizes a pre-form plastic cup which would be factory filled with a single strength juice product. A peelable cover material is heat sealed to the brim of the cup.

GAS PACKED COFFEE POUCHES

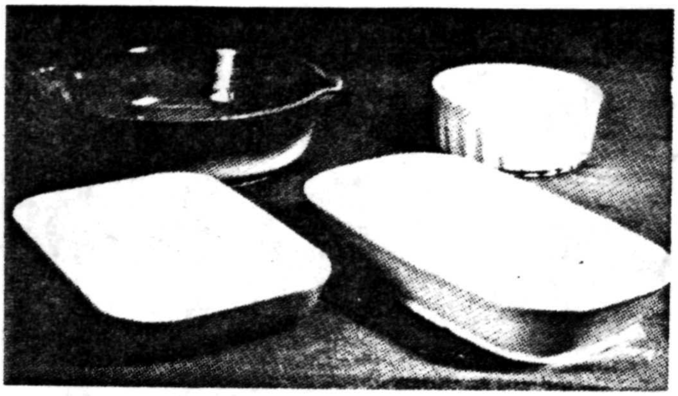
This technique is for the inert gas packaging of ground nonsoluble coffee which assures 60-120 days shelf life. Various size pouches can be packed from fractional packs (three-ounces or less) to two pounds.

PLASTIC HAM CAN

The plastic ham can incorporates a laminated thermoformed plastic base, with an O_2 barrier, and a full panel easy-open roll top aluminum end. If desired, a plastic overcap may be used for reclosure. This container is also designed for a pasteurization process--maximum temperature of 170°F water for five hours. The laminated plastic base used for the ham can give sufficient O_2 barrier and light screening properties to give ham a 12-16 month shelf life under normal refrigerated conditions.

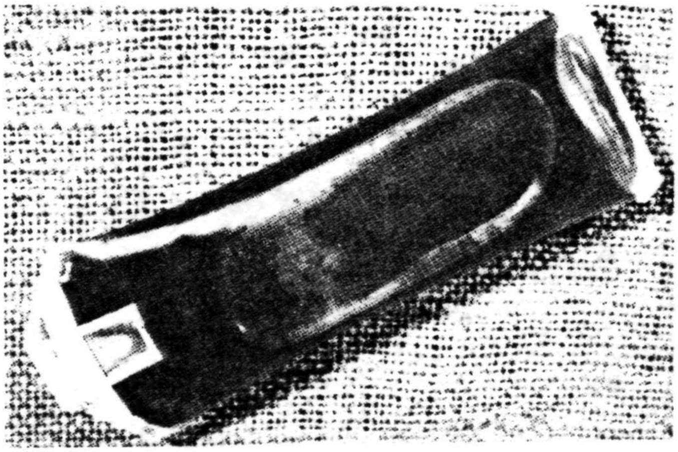
CERAMIC PACKAGE

A new development is an economic ceramic food package having the appearance and quality of "china". The container will withstand temperatures from -20°F to 700°F and can be used in any heating medium. The package can be tinted various colors. Concept is still experimental.



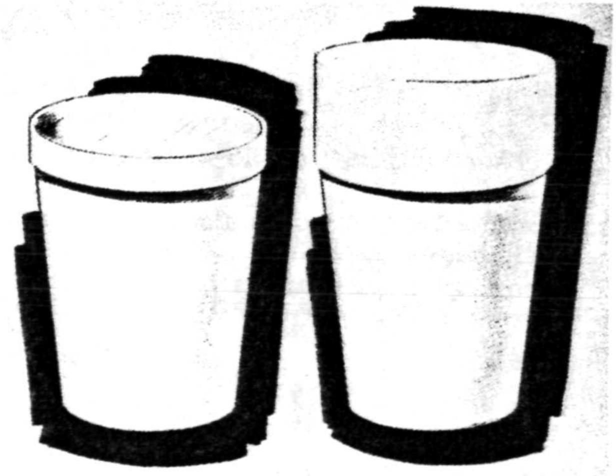
TUCK TUBE

This is a concept which utilizes polyethylene tubing to form a simple tube container. The user removes the spout, cuts the end off, inverts the tube, squeezes to dispense the required amount, re-inverts the tube, and then tucks the spout under the film strip for closure.



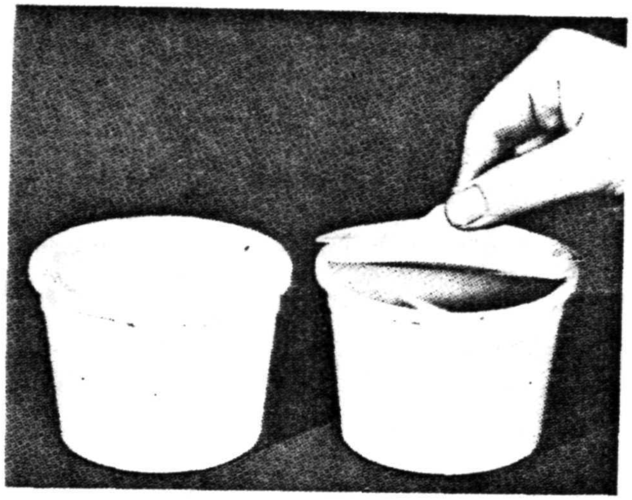
BREAK PACK

With this concept it is possible to provide a snack in conjunction with a beverage.



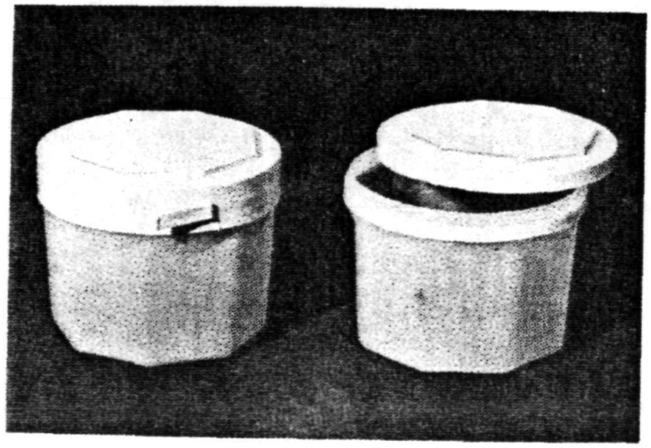
PLASTIC CONTAINER

A newly designed, sealed and tamperproof, full panel, easy open container. The reinforced brim, after opening, insures a positive reclosure. The "pouring lip" is sufficiently protected to meet various health regulations.



PLASTIC CONTAINER

This concept utilizes a spin welding technique to weld a thermoformed bottom to a combination injection-molded cover and reclosure cap. This combination closure also incorporates a tear strip easy opening device.



PLASTIC CONTAINER

Molded plastic package with a peel top aluminum cover bonded to the container. Several choices of plastic can be made available depending on product requirements.

BONDED FIBRE BOARD CARTON

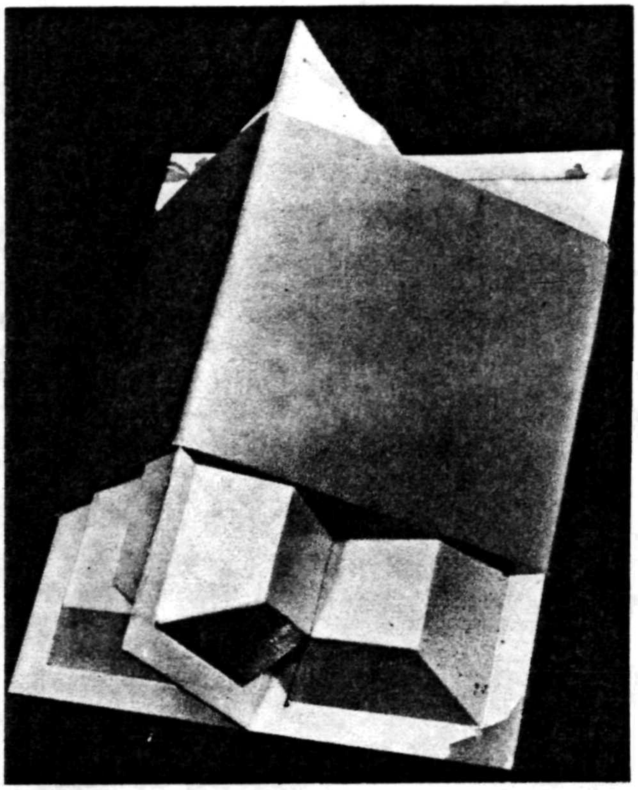
A leakproof, rectangular container suitable for storing liquids or semi-liquids in the frozen state. The adhesive is chemically inert with respect to the food products in contact at the seal interface.

BONDED FIBRE BOARD CARTON

Incorporates a square to round transition in geometry for more effective stacking. The integrally sealed aluminum cover can be easily removed by means of the peel strip.

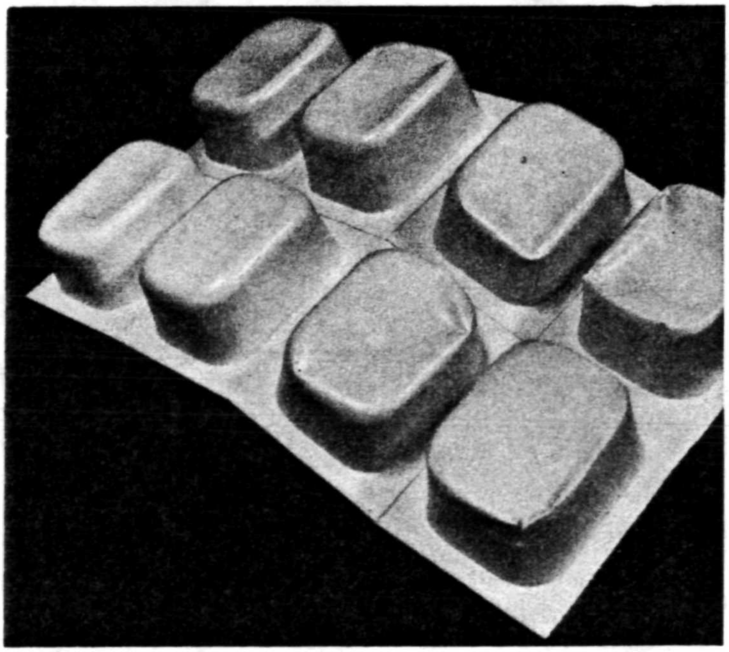
FIBRE BOARD CONTAINER

Plastic end caps and a peel strip at the centerline provide excellent product containment with easy opening features. Originally developed to package frozen sandwiches for use with an automated microwave heating device.



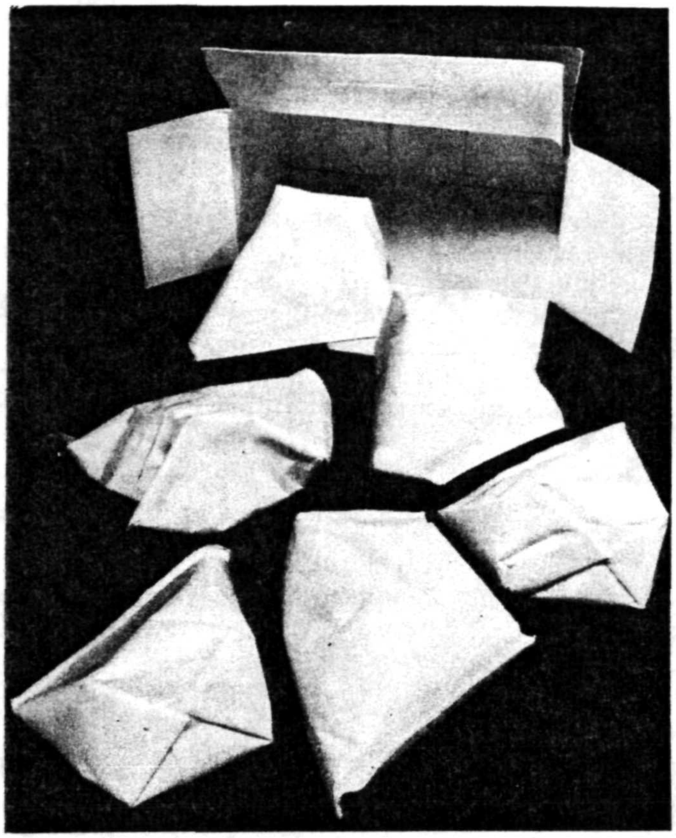
MOLDED PLASTIC CONTAINER

May be designed to any suitable configuration or dimension for packaging single service foods in any desired quantity. The peel top is a single sheet of plastic film which can cover any number of packages providing a quick means of organizing a meal consisting of several food items.



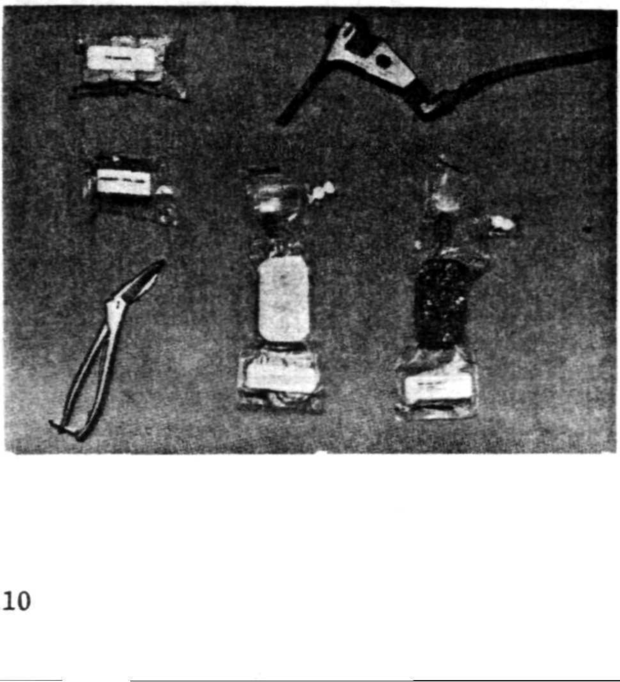
MOLDED PLASTIC CONTAINER

A variation of the previous concept in shape only. This configuration is presently used to package shelf stable items, but is not limited to either that size, shape, or product utilization.



TETRAHEDRON PACKAGING

By utilizing this geometry, the maximum volume of the storage container is utilized as there are no empty spaces produced. The configuration lends itself to a wide variety packaging materials and food items.



GEMINI PROGRAM FOOD PACKAGING

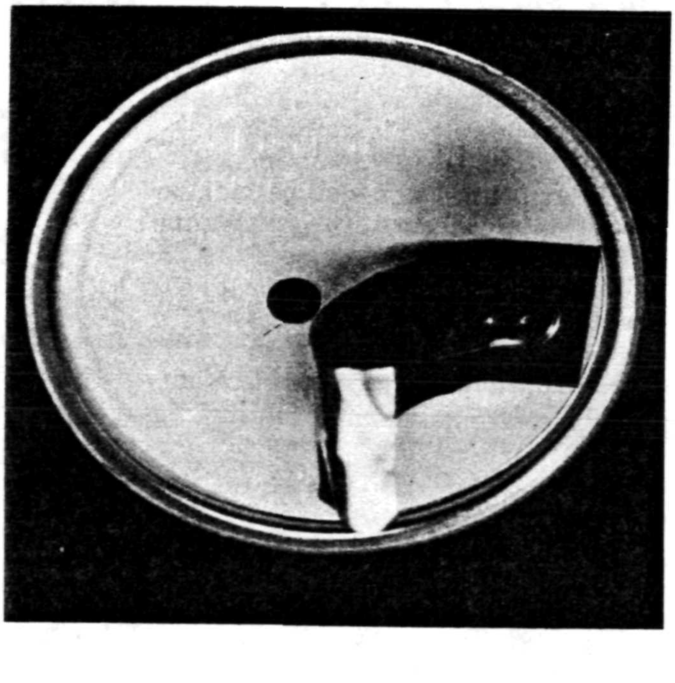
Freeze dried foods were vacuum packaged in 4-ply laminated plastic containers similar to those used to package cubes of dehydrated food. However, the container was fabricated with a one-way, spring-activated water injection valve at one end and a folded eating tube at the other end.

APOLLO PROGRAM
FOOD PACKAGING

Apollo foods are similar to the bite-sized and rehydratable products used in the Gemini missions, but with a wider variety of selection and the inclusion of both hot and cold water rehydration devices. All food and beverage packets for each one man/meal are placed in aluminum overwrap packages which are color coded to designate the meals selected by each astronaut.

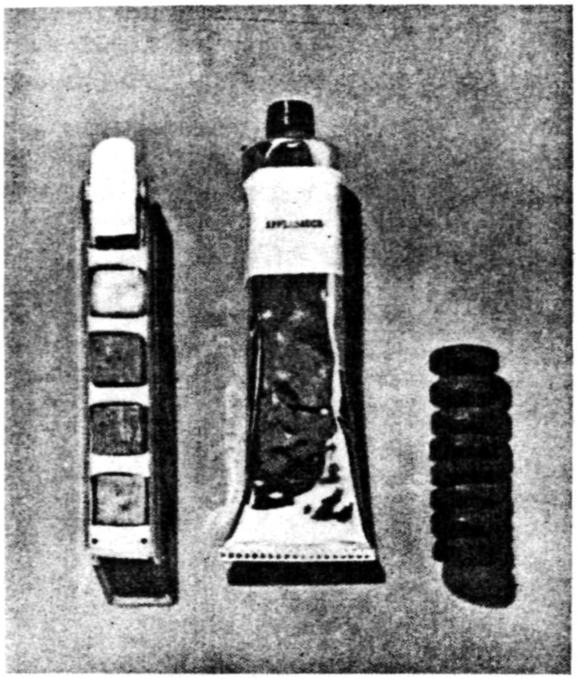
BONDED FOIL CLOSURE

This design utilizes an adhesive coated tab bonded to a substrate material to effect closure of one or more openings in the container top. A variety of adhesive systems are available which are inert regarding contact with food products and which can be bonded to several substrate materials.



MERCURY PROGRAM
FOOD PACKAGING

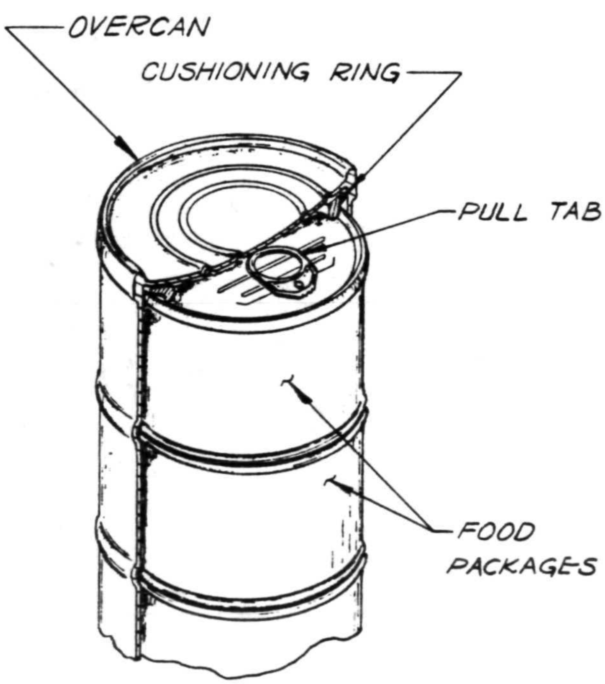
The tubed foods were contained in aluminum tubes (later plastic to reduce weight) coated on the inside to prevent hydrogen gas formation. The average tube weighed 5.5 ounces with the tube accounting for most of the weight. The 3/4-inch cubes of dehydrated food were coated with edible gelatin to prevent crumbling and vacuum packed in a 4-ply laminated plastic film.



SKYLAB PROGRAM
FOOD PACKAGING

Food items for these missions will be packaged in hermetically sealed, drawn aluminum cans with pull-top lids or in flexible plastic with one-way valves for water insertion. A secondary film liner may be included to prevent spills in zero-g operation. Each can will be pressurized to 4.7 - 5.0 psia to be compatible with the spacecraft nominal pressure.

Food packages will be stored in the aluminum overcans shown in the accompanying illustration.



2.0 Provide For Storage - Functional Subsystem Area 2.0

This function is primarily concerned with providing concepts of storing food and supplies onboard the space station. The storage concepts must be capable of holding shelf stable, refrigerated, and frozen food for predetermined mission lengths and crew sizes. The basic concepts considered for the refrigerator and freezer concepts were space radiator cooling, water sublimation, and thermoelectric cooling. A passive cooling concept (the heat sink) was also evaluated.

Primary requirements considered in the evaluation of the refrigerator/freezers included application to zero-gravity, operability, and safety. The temperature of the food locker interiors will be -10°F and 40°F for the freezer and refrigerator, respectively.

The storage concepts considered for the shelf stable foods are the rigid locker and the elastic netting concepts. Requirements for this evaluation included convenience and application to zero-g.

2.1 Candidate Freezer Techniques

a. Concept: Solid CO_2 Freezer (2.1.1)

Concept Description: This concept would rely on the heat of sublimation associated with solid CO_2 to maintain storage temperatures of -10°F in the freezer devices.

Technical Analysis: The concept has a high crew time rating because it inherently requires continuous attention. In addition, accumulations of gaseous carbon dioxide in the vehicle will have a serious impact on the crew safety rating; consequently, this concept was discarded.

b. Concept: Heat Sink Freezer (2.1.2)

Concept Description: The frozen food is maintained inside an insulated locker at temperatures that vary from an initial value of -10°F to a final temperature of +5°F. The frozen food is loaded into the locker on "Day 1" of the mission with an initial temperature. The refrigeration effect is directly related to the thermal capacity of the food mass within the locker. That is, as heat leaks through the insulated walls of the locker, the internal energy of the food (temperature) increases very slightly. The thickness and quality of the insulation is sized so that the upper temperature range experienced in the locker occurs on the final day of the mission or coincident with the arrival of the resupply ship. Thus, the shorter the resupply period, the more effective is the concept.

Technical Analysis: The mathematical analysis of this concept will predict the required thickness of insulation needed to limit the temperature within the locker to a maximum of +5°F. The analysis is based on an initial installed food temperature of -10°F and a thermal conductivity for the foam insulation of .025 Btu/hr ft °F. Foam insulation was chosen over superinsulation since the superinsulation, although far superior in insulative properties, requires an evacuated environment to maintain its effectiveness. Should the double-wall superinsulation chamber develop a leak, the performance of the freezer or refrigerator concept would be severely degraded; that is, excessive heat flows penetrating the locker interior would prematurely drive the temperature of the frozen food beyond the maximum acceptable level for safe storage.

The results of the analysis indicated that the heat sink freezer concept is not feasible because the required insulation thicknesses were in excess of 9 feet. Based on this analysis, the concept was discarded during the Interim Study phase.

c. Concept: Cryogenic Expansion Freezer (2.1.3)

Concept Description: A suitable liquid cryogen is allowed to expand and vaporize in a heat exchanger device located within the freezer compartment. The resulting volume of gas can be collected for further utilization or it can be vented to space. Liquid nitrogen, hydrogen, ammonia or a suitable commercial refrigerant can be used.

Technical Analysis: The total enthalpy required to bring liquid nitrogen to the boiling point and vaporize it amounts to about 90 Btu per pound of nitrogen. (Compare this to 1430 Btu/lb for LH_2 or 1076 Btu/lb for water.) Consequently, the weight penalty associated with storing liquid nitrogen is very large. The use of liquid hydrogen would reduce the weight of the cryogenic storage tanks, but would inherently acquire operability penalties associated with complex valves, ducts, and heat exchangers. Also, hydrogen leakage constitutes a serious fire or explosion hazard onboard the spacecraft. Other refrigerants such as liquid ammonia and commercial refrigerants are rejected for weight and safety penalties.

d. Concept: Water Sublimation Freezer (2.1.4)

Concept Description: The frozen food is maintained at -10°F inside an insulated locker. The locker walls contain four inches of foam insulation. The cooling configuration within the locker consists of an aluminum sheet structure and a circuit of continuous coolant tubes. The aluminum sheets isolate the frozen food from the inner surface of the foam-insulation walls of the locker. The coolant tubes are integral with these sheets. Heat leaking through the foam walls is intercepted by the aluminum sheets while the coolant flowing through the tubes collects the heat and directs it away from the freezer locker.

The water sublimation equipment receives the warm coolant fluid as it leaves the freezer locker and extracts heat from it. The coolant is then redirected back to the cooling circuit within the locker. The sublimation unit consists of an ice chamber wherein the ice continuously flows from an area where new ice crystals are being formed to an area where sublimation continuously degrades the surface of the ice mass. Circulating water in contact with the ice surface sustains the recrystallization portion of the process. A vacuum line or overboard vent connected to the sublimation chamber sustains the vaporization portion of the process. The coolant tubes leading from the locker are in direct contact with the sublimating ice surface; the coolant temperature is effectively lowered as the heat (of sublimation) is transferred to the sublimating ice layers.

Technical Analysis: The concept yields freezer configurations that have comparatively compact volumes, but weight is high. Crew acceptance and safety factors are considered good, although the development risk and time to perfect a workable sublimating unit will be considerable. Operability problems are inherent only in the initial start-up of the sublimation processes. Once the ice layer is established, the sublimation/recrystallization processes require little attention. The power required for this concept is primarily used to drive the pump in the sublimator water loop. Due to the excessively large heat transfer area to maintain the required sublimation rate, this concept was discarded in the Interim Study.

e. Concept: Vapor Compression Freezer (2.1.5)

Concept Description: This concept requires a vapor compressor, an evaporative heat exchanger, a condensing heat exchanger, and an expansion valve. This refrigeration principle is very nearly identical to a commercial household unit. However, it would be necessary to create and develop an artificial gravity field within which the condensing heat exchanger and perhaps the evaporative heat exchanger would operate. That is, a centrifugal heat exchanger device would be needed to overcome the problems associated with zero-g phase separation. Since the centrifugal heat exchangers would necessarily interface with stationary coolant lines, complex rotating seals will be required. For all but the smallest storage concepts, a space radiator line would also interface with the vapor compression machinery.

Technical Analysis: The operability and safety factors are considered fair. Some development risk is associated with the heat exchanger designs. This concept was discarded for its inherent complexity, development time, weight, and power penalties.

f. Concept: Space Radiator Freezer (2.1.6)

Concept Description: The frozen food is maintained at -10°F inside an insulated locker. The locker walls contain four inches of foam insulation. The cooling configuration within the locker consists of an aluminum sheet structure and a circuit of continuous coolant tubes. The aluminum sheets isolate the frozen food from the inner surface of the foam-insulation walls of the locker. The coolant tubes are integral with these sheets. Heat leaking through the foam walls is intercepted by the aluminum sheets while the coolant flowing through the tubes collects the heat and directs it away from the freezer locker.

The space radiator located on the outer surface of the vehicle receives the warm coolant fluid and extracts heat from it. The fluid is then recirculated back into the cooling circuit within the locker. One or more space radiators may be required if the vehicle lacks attitude control with respect to the sun; the coolant would automatically be routed to the proper radiator using diverter valves to accomplish the switching. Because the coolant flow rates are so small, the coolant pump charges a pressurized accumulator once every 4-hour cycle.

Technical Analysis: Development risk for this concept is considered low. The weight and volume penalties are comparable to the thermoelectric and sublimation concepts. A power requirement of 50 watts for all freezer sizes is considered sufficient to operate the diverter valves and other momentary functions. Because coolant flow rates are minuscle, very little power is required to transport the coolant; the power requirements for this concept are the smallest of all the active freezer concepts.

g. Concept: Thermoelectric Freezer (2.1.7)

Concept Description: The frozen food is maintained at -10°F within an insulated locker. The locker walls contain four inches of foam insulation. Any heat leaking into the locker will be transferred to the air circulating within the freezer locker. The circulating air will be cooled using commercially available thermoelectric modules operating as heat pumps. The module is a solid state device that transfers heat from its colder junction (a plate that absorbs heat from the load) to a hot junction (a heat sink where heat is rejected) using electrical energy to sustain the phenomenon. Forced convection air-cooled fins or a liquid cooled sink must be used to remove heat energy from the hot junction allowing it to operate at predesigned temperature levels. Two fans are required to effectively remove heat from the freezer locker interior. The interior fan circulates air across the cold junction exposed at the rear of the locker interior. The exterior fan is used to cool the hot junction fins protruding from the rear of the freezer locker. A special power supply is required to operate the modules.

Technical Analysis: The development risk for this concept is the lowest of the active freezers; commercially available freezer units are a common reality. However, because the heat pumping capability of the thermoelectric module is severely degraded with increasing temperature differences, a great number of individual modules are required to sufficiently cool the circulating air within the freezer locker. Since the temperature differences (ambient minus freezer load temperature) are greatest for the freezers, an inordinate amount of power is required to operate the thermoelectric modules. The weight and volume penalties are comparable with other freezer concepts, although the mass of the power supply offsets the benefits of not requiring a liquid coolant transport loop and attendant equipment.

h. Concept: Turbo-Compressor/Air Cycle Freezer (2.1.8)

Concept Description: This concept utilizes air as the refrigerant. Air is compressed in a suitable compressor; the compressed air is cooled in a heat exchanger and then allowed to expand down to ambient cabin pressure. The cooler air leaving the expansion process is ducted to the freezer interior providing cooling and circulation simultaneously.

Technical Analysis: Development risk for this concept is low, but volume and power penalties are very high; although this method of achieving a refrigeration effect is primarily used onboard aircraft to cool cabins and electronic equipment, the air cycle freezer cannot be simply transposed into the spacecraft environment without major consequences. It is the interaction with the ambient environment that makes the air cycle attractive onboard high velocity aircraft. That is, the typical heat exchanger in an aircraft is cooled with high velocity air collected by an expedient ram-air intake. The cooling is achieved with virtually no power penalty. Alternatively, the space oriented option is to provide for a separate motor and blower or employ a separate liquid coolant transport line connected to a space radiator, a water sublimator or similar sink.

In Data Book II, the Concept Back-Up Information Sheet for Concept 2.2.8, it was shown in a sample analysis that 18 hp was typically required to operate the air compressor in an air-cycle refrigeration unit. Again, the space environment implementation of the compression process would be accomplished with a separate motor and compressor rated for the 18 hp assignment. However, onboard an aircraft the compression process inherently exists within the many stages of the gas turbine power plant (engine); it is common practice to simply tap an available compressor stage for the desired flow. In addition, 18 hp is a relatively small percentage to demand from the total output of the aircraft power plant.

i. Concept Evaluation Summary and Technical Data

The concepts are summarized in Table III-3 below with the rating factors and study/discard decision as derived in the Selection Rationale Sheets of Data Book - Book III.

TABLE III-3

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 2.1	SUB-FUNCTION TITLE: Freezer Concepts	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
2.1.1	Solid CO_2 Freezer	6.9	X		-		
2.1.2	Heat Sink Freezer	10.7		X	-	X	
2.1.3	Cryogenic Expansion Freezer	7.45	X		-		
2.1.4	Water Sublimation Freezer	11.8		X	-	X	
2.1.5	Vapor Compression Freezer	8.4	X		-		
2.1.6	Space Radiator Freezer	10.8		X	-		X
2.1.7	Thermoelectric Freezer	10.6		X	-		X
2.1.8	Turbo-Compressor/Air Cycle Freezer	11.4		X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Space Radiator Freezer (Concept 2.1.6). Detailed data for this concept are presented on Element Concept Data Sheets 2.1.6.1 through 2.1.6.15 and 2.1.6.18 through 2.1.6.27 in Data Book - Book I.

   Additional analysis is presented under Concept 2.1.6 in Back-Up Information Sheets, Data Book - Book II. Curves of Weight and Volume Versus Crew Size are presented in Figures III-68 and III-69 following.

2) Technical Data - Thermoelectric Freezer (Concept 2.1.7). Detailed data for this concept are presented on Element Concept Data Sheets 2.1.7.1 through 2.1.7.20 and 2.1.7.23 through 2.1.7.28 in Data Book - Book I.

   Additional analysis is presented under Concept 2.1.7 in Back-Up Information Sheets, Data Book - Book II. Curves of Power, Weight and Volume Versus Crew Size are presented in Figures III-70, III-71, and III-72 following.

3) Technical Data - Turbo-Compressor/Air Cycle Freezer (Concept 2.1.8). Detailed data for this concept are presented on Element Concept Data Sheets 2.1.8.1 through 2.1.8.14 in Data Book - Book I.

   Additional analysis for this concept is presented in Back-Up Information Sheets, Concept 2.1.8, Data Book - Book II. Curves of Power, Weight, and Volume For The

Turbo-Compressor/Air Cycle Freezer are presented in Figure III-73 following.

j. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above.

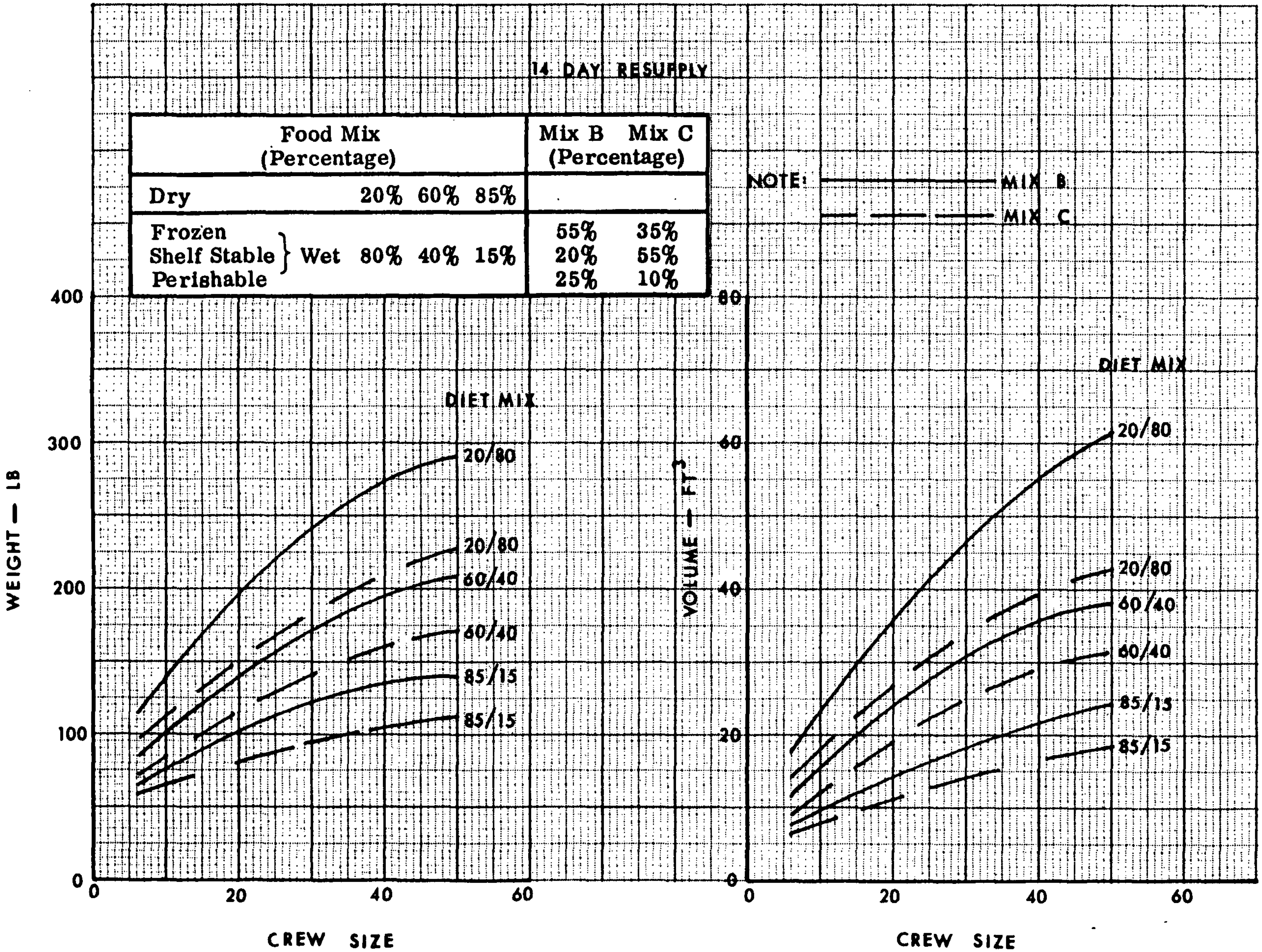
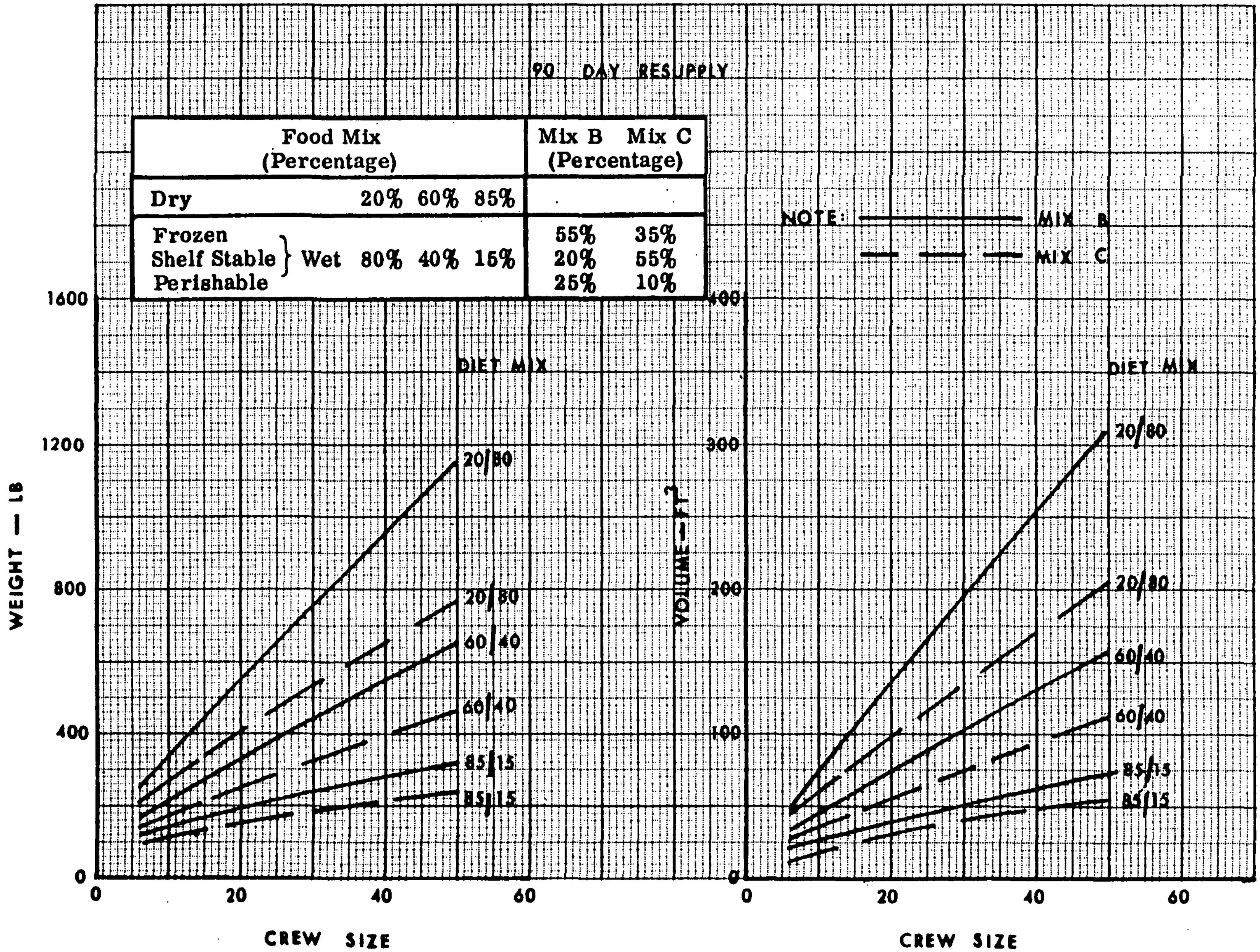


Figure III-68 Total Installed Weight and Volume Versus Crew Size and Diet Mix - 14 Day Resupply
Space Radiator Concept - Freezer Only



Food Mix (Percentage)				Mix B (Percentage)	Mix C (Percentage)
Dry	20%	60%	85%		
Frozen } Wet	80%	40%	15%	55%	35%
Shelf Stable } Wet				20%	55%
Perishable } Wet				25%	10%

Figure III-69. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 90 Day Resupply Space Radiator Concept - Freezer Only

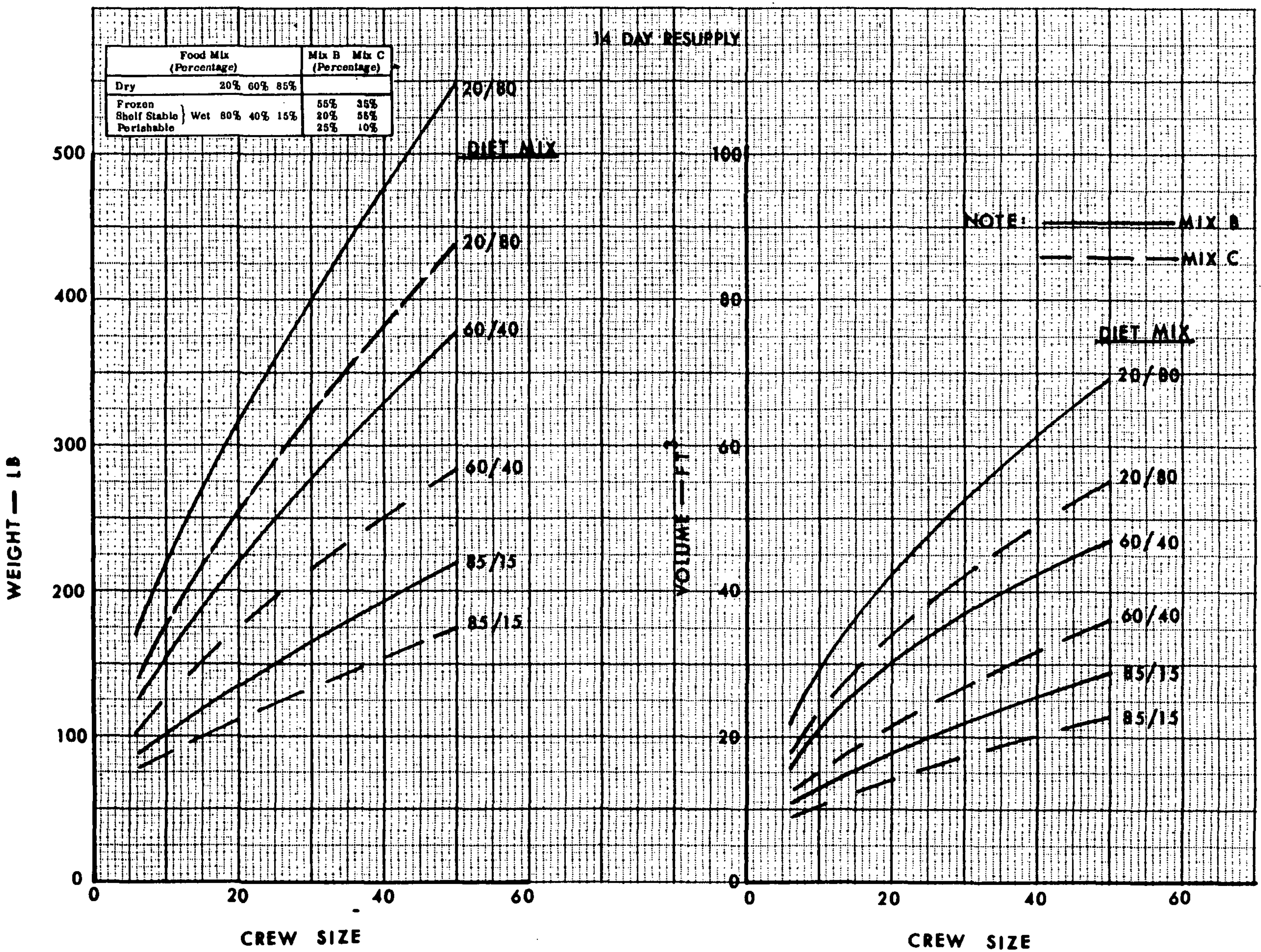


Figure III-70. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 14 Day Resupply Thermoelectric Concept - Freezer Only

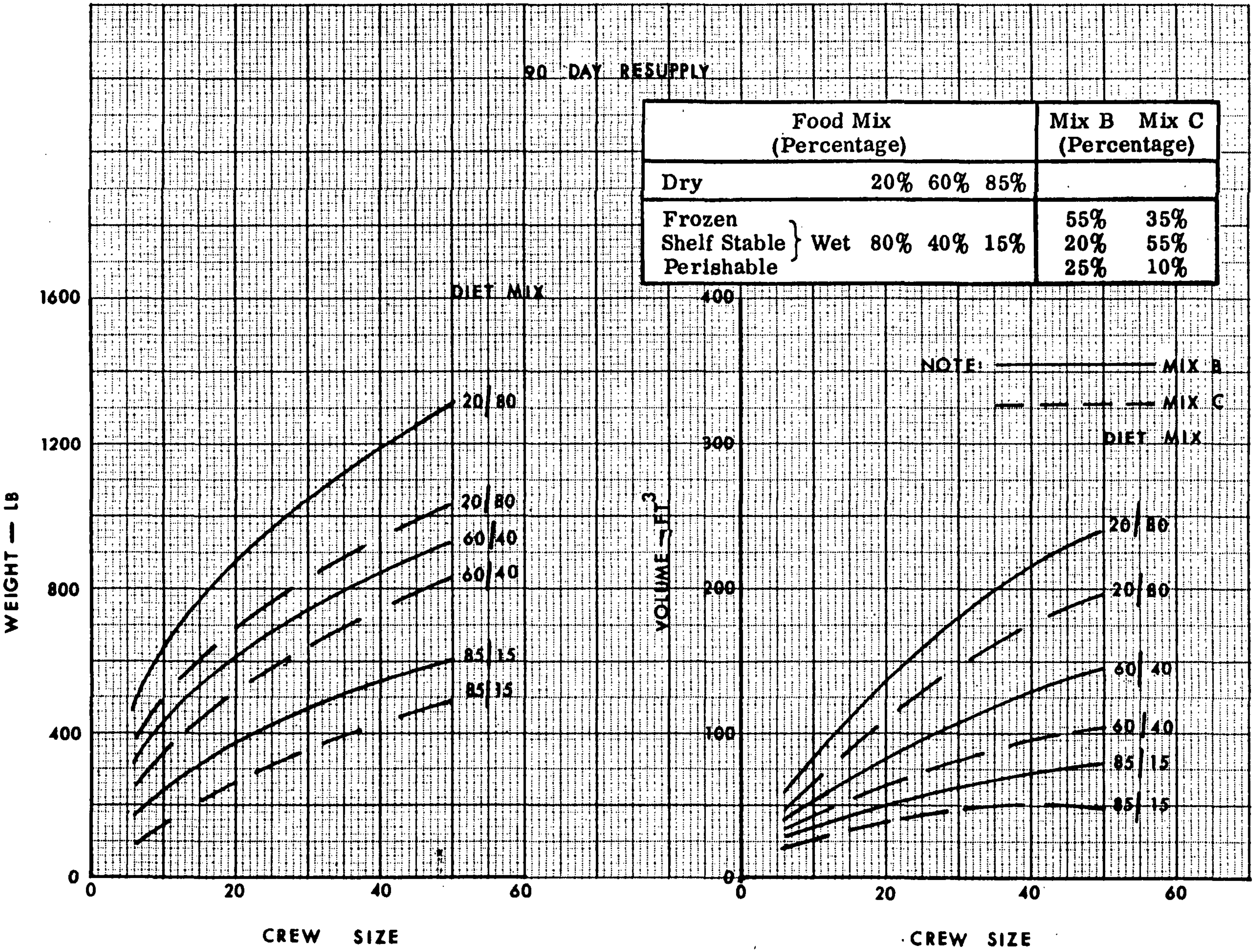


Figure III-71. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 90 Day Resupply Thermoelectric Concept - Freezer Only

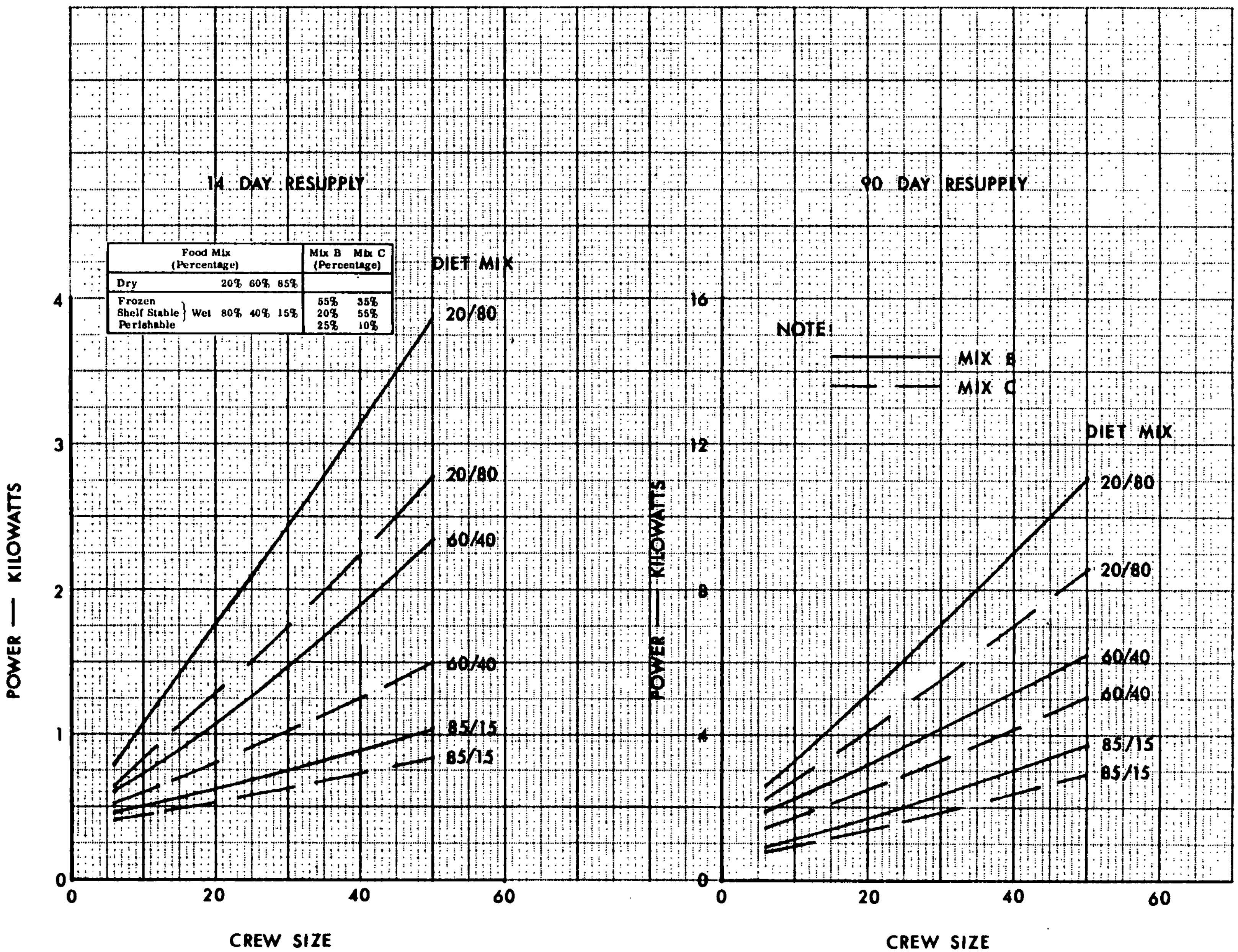


Figure III-72. Total Operating Power Versus Crew Size and Diet Mix - 14 and 90 Day Resupply Thermoelectric Concept - Freezer Only

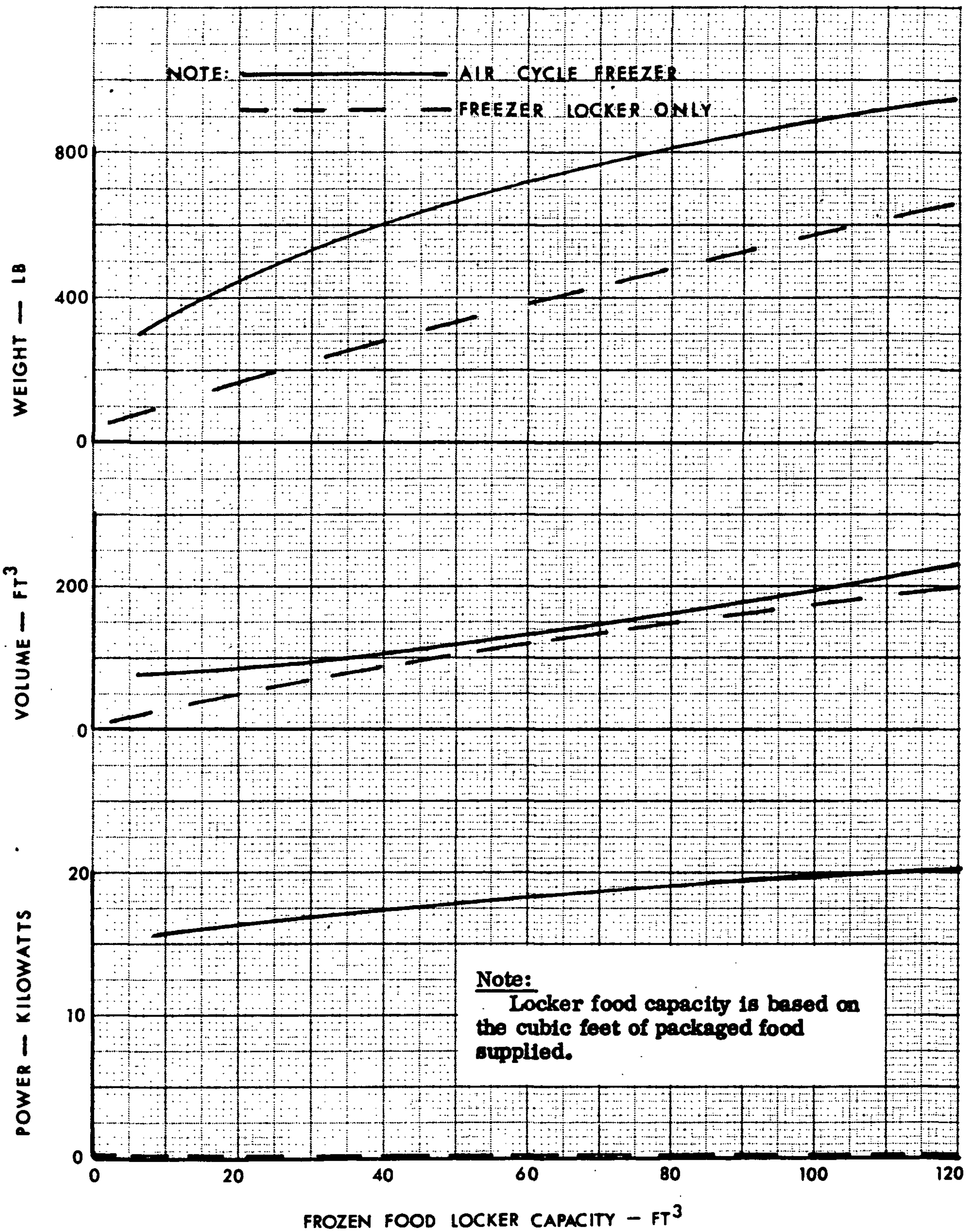
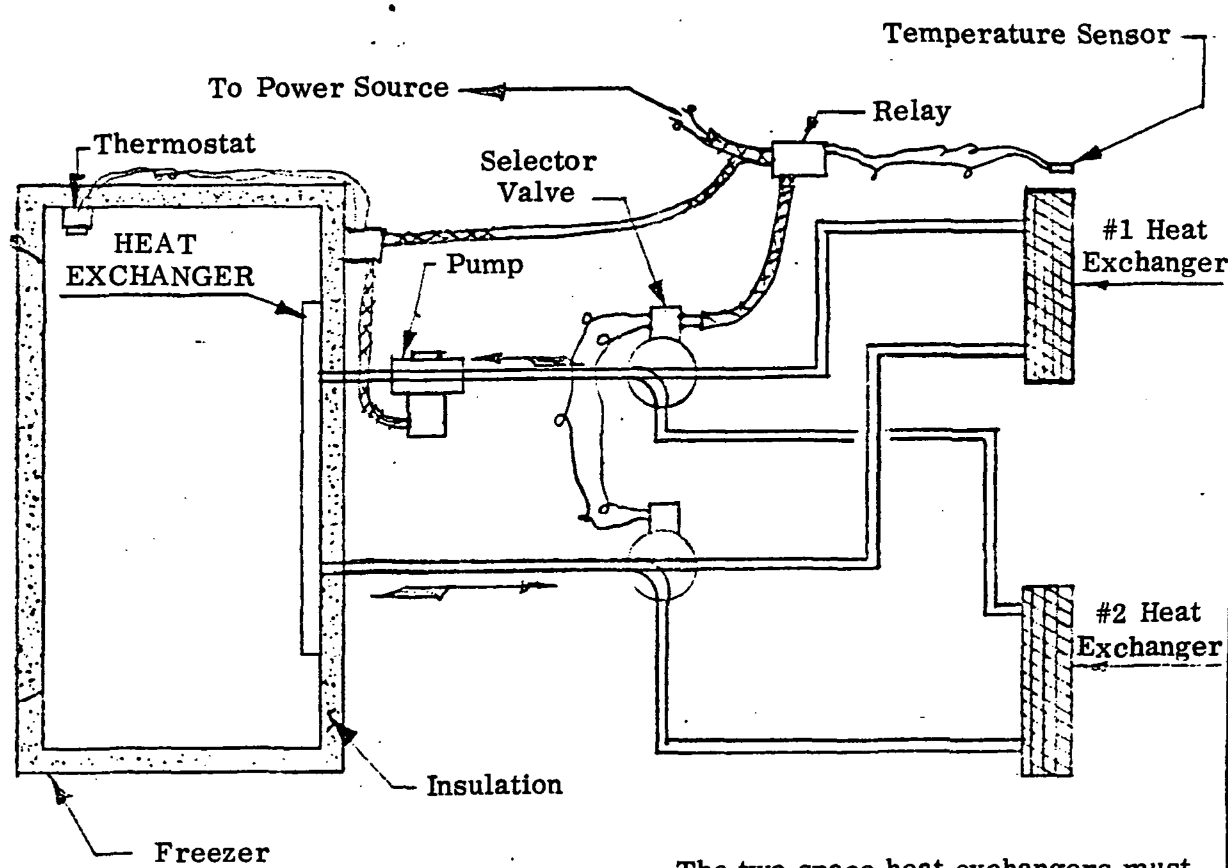


Figure III-73. Total Estimated Power, Weight, and Volume Versus Locker Food Capacity Air Cycle Concept - Freezer Only

FOOD SYSTEM STUDY SKETCH

Title: Space Radiator Freezer



The two space heat exchangers must be located 180 degrees apart on the outside of the Space Station.

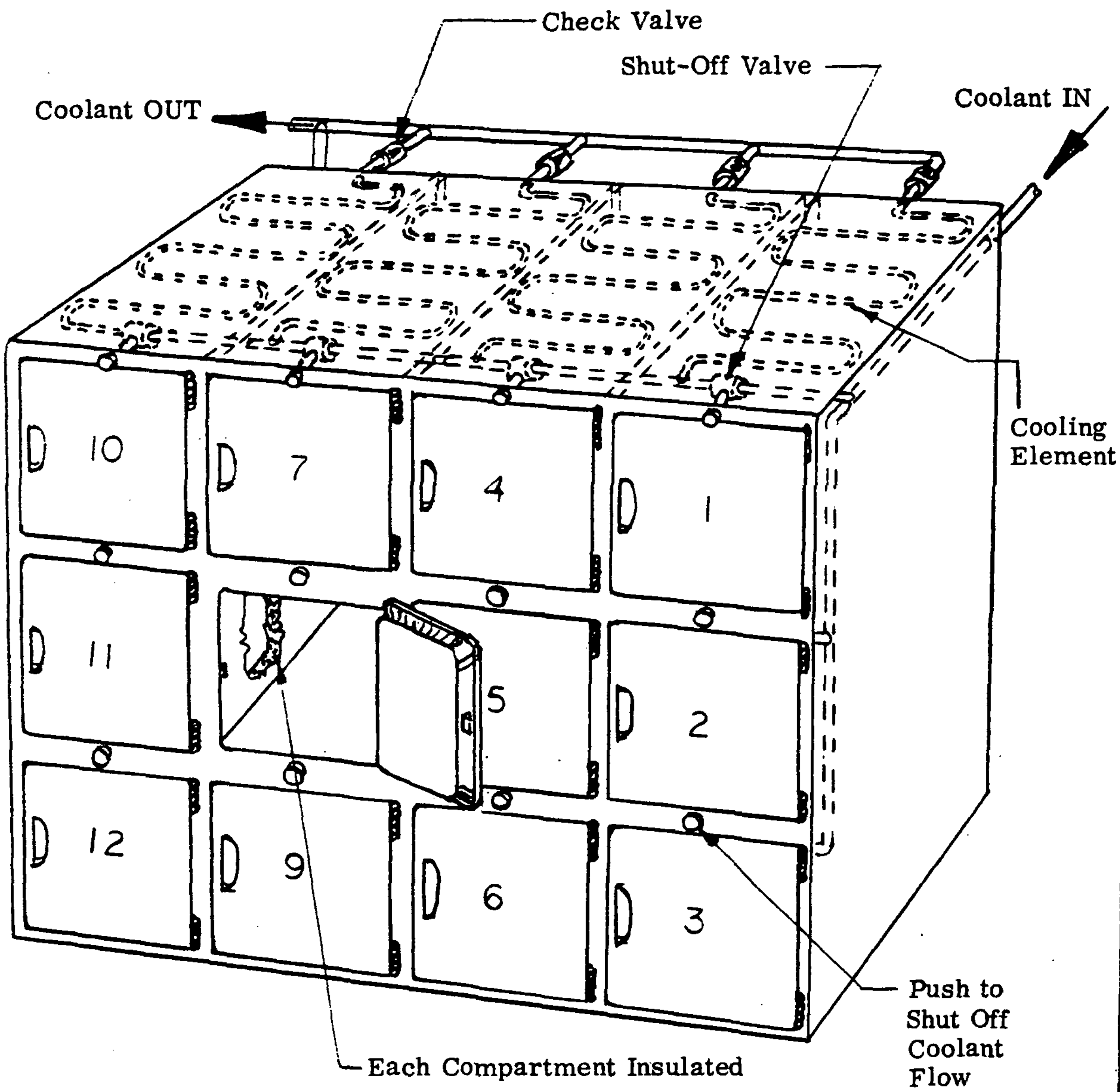
In this concept a suitable coolant is circulated through cooling coils located throughout the freezer compartment; the coolant collects heat and transports it to heat exchangers (space radiators) located on the outer surface of the spacecraft. One or more space radiators may be required if the vehicle lacks attitude control with respect to the sun; the coolant would automatically be routed to the proper radiator.

Further development will be required to qualify this concept for space usage; however, it would be applicable to both partial- and zero-g conditions.

D— 2.1.6 A

FOOD SYSTEM STUDY SKETCH

Title: Compartmentized Space Radiator Freezer Individually Insulated

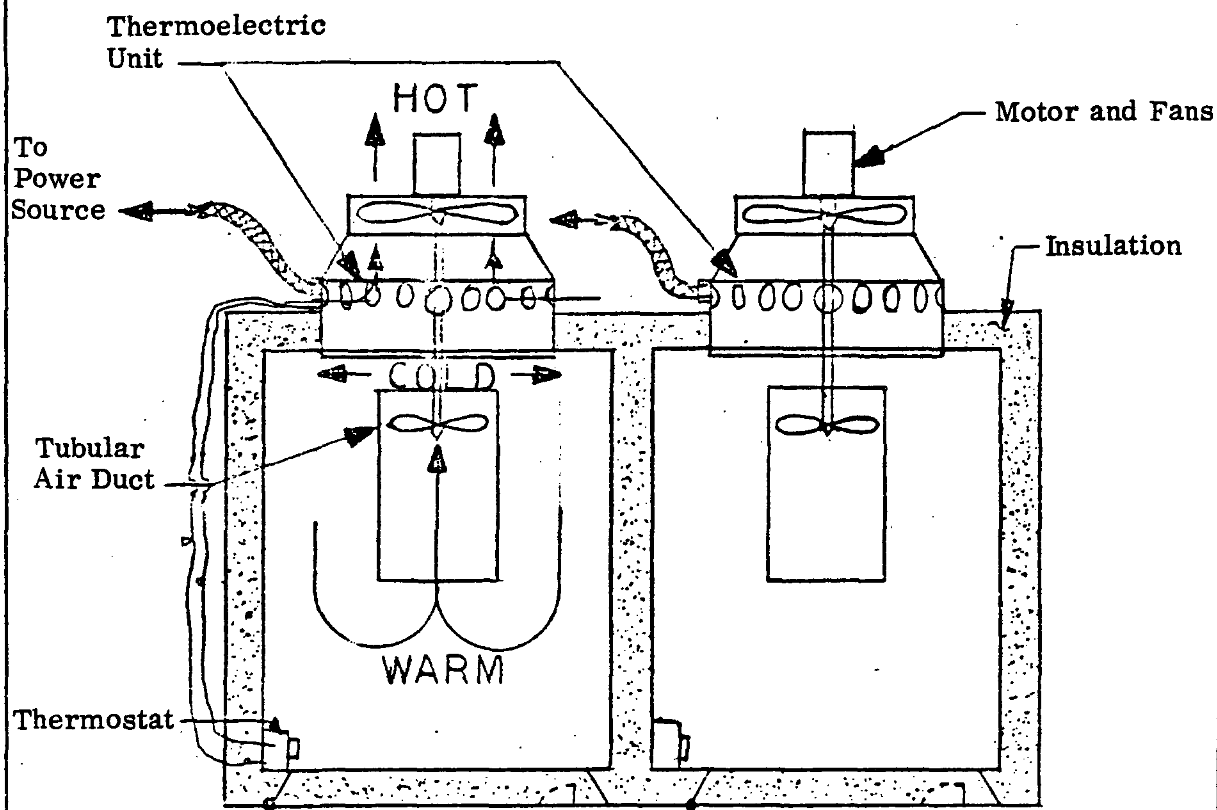


The compartmentized freezer consists of multiple individual compartments. Each is separately insulated and has its own cooling unit, complete with a shut-off valve and check valve. This provides the capability of closing down each compartment as it becomes empty, thereby reducing the cooling load.

D— 2.1.6 B

FOOD SYSTEM STUDY SKETCH

Title: Thermoelectric Freezer



One Thermoelectric Unit Required For Each Compartment

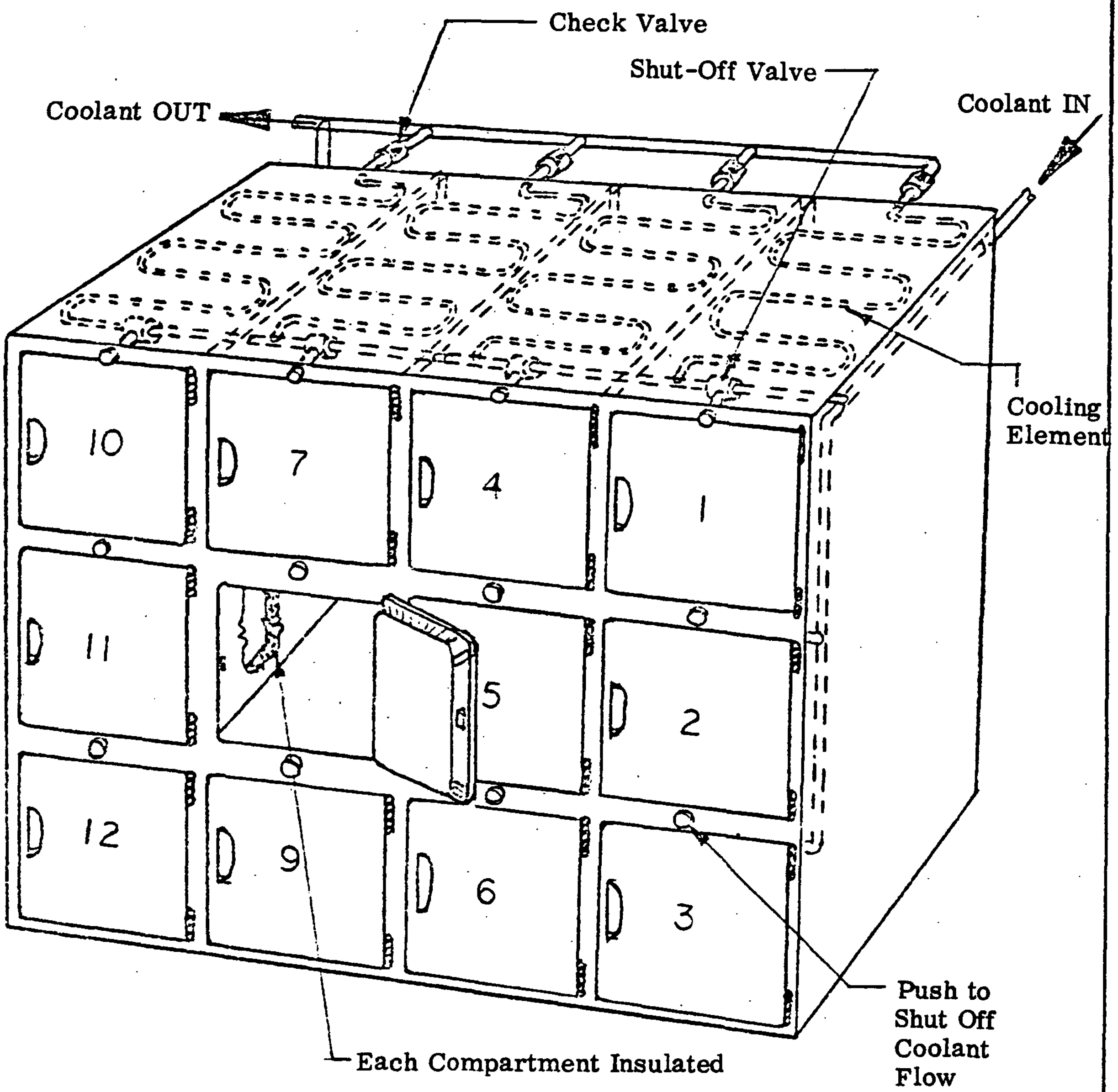
This concept utilizes the solid state thermoelectric modules to transfer heat from the cold storage area. Thermoelectric modules consist of a cold junction (a plate that absorbs heat from the load) and a hot junction (a heat sink where heat is rejected). A semi-conductor material interfaces with both junctions and causes heat to be transferred from cold to hot.

This concept is applicable for both zero- and one-g usage, and will require considerable development effort.

D— 2.1.7 A

FOOD SYSTEM STUDY SKETCH

Title: Compartmentized Thermoelectric Freezer Individually Insulated

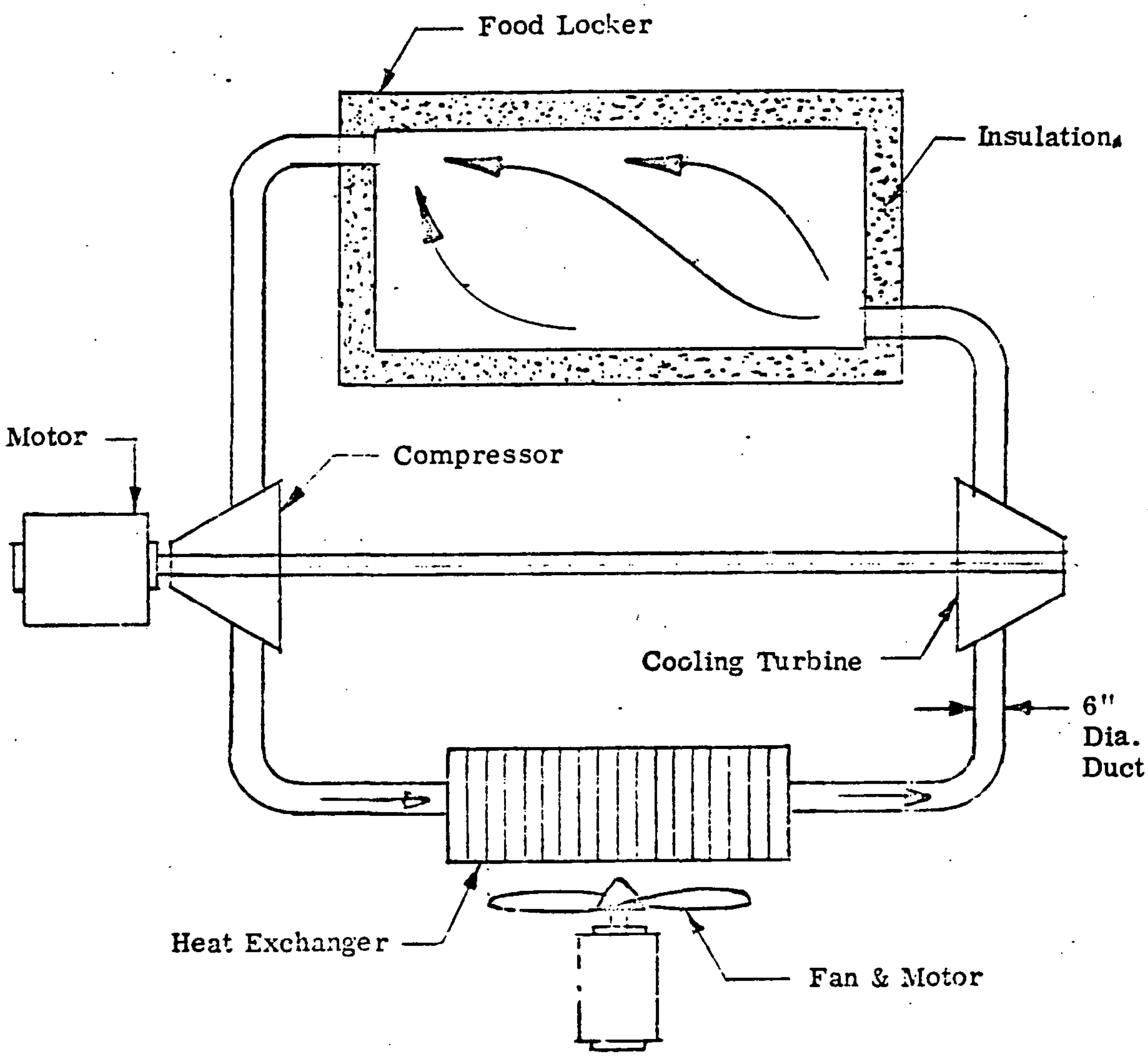


The compartmentized freezer consists of multiple individual compartments. Each is separately insulated and has its own cooling unit, complete with a shut-off valve and check valve. This provides the capability of closing down each compartment as it becomes empty, thereby reducing the cooling load.

D— 2.1.7 B

FOOD SYSTEM STUDY SKETCH

Title: Turbo-Compressor/Air Cycle Freezer



This system consists of an insulated food locker motor and compressor, heat exchanger and fan, cooling turbine, and associated air ducts.

Air is compressed, passed through a heat exchanger and cooling turbine through the food locker and back to the compressor. This cycle is repeated as required by a thermostatic control system. The air ducts are approximately 6 inches in diameter.

Further development is required to perfect this system.

D— 2.1.8

2.2 Candidate Refrigerator Techniques

a. Concept: Solid CO_2 Refrigerator (2.2.1)

Concept Description: This concept would rely on the heat of sublimation associated with solid CO_2 to maintain storage temperatures of 40°F in the refrigerator devices.

Technical Analysis: The concept has a high crew-time rating because it inherently requires continuous attention. In addition, accumulations of gaseous carbon dioxide in the vehicle will have a serious impact on the crew safety rating, therefore this concept was discarded.

b. Concept: Heat Sink Refrigerator (2.2.2)

Concept Description: The refrigerated food is maintained inside an insulated locker at temperatures that vary from an initial value of +35°F to a final temperature of +45°F. The refrigerated food is loaded into the locker on "Day 1" of the mission with an initial temperature. The refrigeration effect is directly related to the thermal capacity of the food mass within the locker. That is, as heat leaks through the insulated walls of the locker, the internal energy of the food (temperature) increases very slightly. The thickness and quality of the insulation is sized so that the upper temperature range experienced in the locker occurs on the final day of the mission or coincident with the arrival of the resupply ship. Thus, the shorter the resupply period, the more effective is the concept.

Technical Analysis: The mathematical analysis of this concept will predict the required thickness of insulation needed to limit the temperature within the locker to a maximum of 45°F. The analysis is based on an initial installed food temperature of 35°F and a thermal conductivity for the foam insulation of .025 Btu/hr ft °F. Foam insulation was chosen over superinsulation since the superinsulation, although far superior in insulative properties, requires an evacuated environment to maintain its effectiveness. Should the double-wall superinsulation chamber develop a leak, the performance of the freezer or refrigerator concept would be severely degraded; that is, excessive heat flows penetrating the locker interior would prematurely drive the temperature of the refrigerated food beyond the maximum acceptable level for safe storage.

The results of the Interim Study analysis indicated that the heat sink refrigerator concept is not feasible because the required insulation thicknesses were in excess of 12 feet, hence the concept was discarded.

c. Concept: Cryogenic Expansion Refrigerator (2.2.3)

Concept Description: A suitable liquid cryogen is allowed to expand and vaporize in a heat exchanger device located within the refrigerator compartment. The resulting volume of gas can be collected for further utilization or it can be vented to space. Liquid nitrogen, hydrogen, ammonia or a suitable commercial refrigerant can be used.

Technical Analysis: The total enthalpy required to bring liquid nitrogen to the boiling point and vaporize it amounts to about 90 Btu per pound of nitrogen. (Compare this to 1430 Btu/lb for LH_2 or 1076 Btu/lb for water.) Consequently, the weight penalty associated with storing liquid nitrogen is very large. The use of liquid hydrogen would reduce the weight of the cryogenic storage tanks, but would inherently acquire operability penalties associated with complex valves, ducts, and heat exchangers. Also, hydrogen leakage constitutes a serious fire or explosion hazard onboard the spacecraft. Other refrigerants such as liquid ammonia and commercial refrigerants are rejected for weight and safety penalties.

d. Concept: Water Sublimation Refrigerator (2.2.4)

Concept Description: The refrigerated food is maintained at 40°F inside an insulated locker. The locker walls contain 4 inches of foam insulation. The cooling configuration within the locker consists of an aluminum sheet structure and a circuit of continuous coolant tubes. The aluminum sheets isolate the frozen food from the inner surface of the foam-insulation walls of the locker. The coolant tubes are integral with these sheets. Heat leaking through the foam walls is intercepted by the aluminum sheets while the coolant flowing through the tubes collects the heat and directs it away from the refrigerator locker.

The water sublimation equipment receives the warm coolant fluid as it leaves the refrigerator locker and extracts heat from it. The coolant is then redirected back to the cooling circuit within the locker. The sublimation unit consists of an ice chamber wherein the ice continuously flows from an area where new ice crystals are being formed to an area where sublimation continuously degrades the surface of the ice mass. Circulating water in contact with the ice surface sustains the recrystallization portion of the process. A vacuum line or overboard vent connected to the sublimation chamber sustains the vaporization portion of the process. The coolant tubes leading from the locker are in direct contact with the sublimating ice surface; the coolant temperature is effectively lowered as the heat (of sublimation) is transferred to the sublimating ice layers.

Technical Analysis: The concept yields refrigerator configurations that have comparatively compact volumes, but weight is high. Crew acceptance and safety factors are considered good, although the development risk and time to perfect a workable sublimating unit will be considerable. Operability problems are inherent only in the initial start-up of the sublimation processes. Once the ice layer is established, the sublimation/recrystallization processes require little attention. The power required for this concept is primarily used to drive the pump in the sublimator water loop.

e. Concept: Vapor Compression Refrigerator (2.2.5)

Concept Description: This concept requires a vapor compressor, an evaporative heat exchanger, a condensing heat exchanger, and an expansion valve. This refrigeration principle is very nearly identical to a commercial household unit. However, it would be necessary to create and develop an artificial gravity field within which the condensing heat exchanger and perhaps the evaporative heat exchanger would operate. That is, a centrifugal heat exchanger device would be needed to overcome the problems associated with zero-g phase separation. Since the centrifugal heat exchangers would necessarily interface with stationary coolant lines, complex rotating seals will be required. For all but the smallest storage concepts, a space radiator line would also interface with the vapor compression machinery.

Technical Analysis: This concept was discarded for its inherent complexity, development time, weight, and power penalties.

f. Concept: Space Radiator Refrigerator (2.2.6)

Concept Description: The refrigerated food is maintained at 40°F inside an insulated locker. The locker walls contain 4 inches of foam insulation.

The cooling configuration within the locker consists of an aluminum sheet structure and a circuit of continuous coolant tubes. The aluminum sheets isolate the refrigerated food from the inner surface of the foam-insulation walls of the locker. The coolant tubes are integral with these sheets. Heat leaking through the foam walls is intercepted by the aluminum sheets while the coolant flowing through the tubes collects the heat and directs it away from the refrigerator locker.

The space radiator located on the outer surface of the vehicle receives the warm coolant fluid and extracts heat from it. The fluid is then recirculated back into the cooling circuit within the locker. One or more space radiators may be required if the vehicle lacks attitude control with respect to the sun; the coolant would automatically be routed to the proper radiator using diverter valves to accomplish the switching. Because the coolant flow rates are so small, the pump charges a pressurized accumulator once every 4-hour cycle.

Technical Analysis: Development risk for this concept is considered low. The weight and volume penalties are comparable to the thermoelectric and sublimation concepts. A power requirement of 50 watts for all refrigerator sizes is considered sufficient to operate the diverter valves and other momentary functions. Because coolant flow rates are minuscle, very little power is required to transport the coolant; the power requirements for this concept are smallest of all the active refrigerator concepts.

g. Concept: Thermoelectric Refrigerator (2.2.7)

Concept Description: The refrigerated food is maintained at 40°F within an insulated locker. The locker walls contain 4 inches of foam insulation. Any heat leaking into the locker will be transferred to the air circulating within the refrigerator locker. The circulating air will be cooled using commercially available thermoelectric modules operating as heat pumps. The module is a solid state device that transfers heat from its colder junction (a plate that absorbs heat from the load) to a hot junction (a heat sink where heat is rejected) using electrical energy to sustain the phenomenon. Forced convection air-cooled fins or a liquid cooled sink must be used to remove heat energy from the hot junction allowing it to operate at designed temperature levels. Two fans are required to effectively remove heat from the refrigerator locker interior. The interior fan circulates air across the cold junction exposed at the rear of the locker interior. The exterior fan is used to cool the hot junction fins protruding from the rear of the refrigerator locker. A special power supply is required to operate the modules.

Technical Analysis: The development risk for this concept is the lowest of the active refrigerators; commercially available refrigerator units are a common reality. However, because the heat pumping capability of the thermoelectric module is severely degraded with increasing temperature differences (ambient minus load temperature), a great number of individual thermoelectric modules are required to sufficiently cool the circulating air within the refrigerator locker. The consequence of this performance degradation results in a refrigerator concept that requires a large amount of power to operate the thermoelectric modules. The weight and volume penalties are comparable with other refrigerator concepts although the mass of the power supply offsets the benefits of not having a liquid transport loop and attendant equipment.

h. Concept: Turbo-Compressor/Air Cycle Refrigerator (2.2.8)

Concept Description: This concept utilizes air as the refrigerant. Air is compressed in a suitable compressor; the compressed air is cooled in a heat exchanger and then allowed to expand down to ambient cabin pressure. The cooler air leaving the expansion process is ducted to the refrigerator interior providing cooling and circulation simultaneously.

Technical Analysis: Development risk for this concept is low, but volume and power penalties are very high; although this method of achieving a refrigeration effect is primarily used onboard aircraft to cool cabins and electronic equipment, the air cycle refrigerator cannot be simply transposed into the spacecraft environment without major consequences. It is the interaction with the ambient environment that makes the air cycle attractive onboard high velocity aircraft. That is, the typical heat exchanger in an aircraft is cooled with high velocity air collected by an expedient ram-air intake. The cooling is achieved with virtually no power penalty. Alternatively, the space oriented option is to provide for a separate motor and blower or employ a separate liquid coolant transport line connected to a space radiator, a water sublimator or similar sink.

In Data Book II, the Concept Back-Up Information Sheet for Concept 2.2.8, it was shown in a sample analysis that 18 hp was typically required to operate the air compressor in an air-cycle refrigeration unit. Again, the space environment implementation of the compression process would be accomplished with a separate motor and compressor rated for the 18 hp assignment. However, onboard an aircraft the compression process inherently exists within the many stages of the gas turbine power plant (engine); it is common practice to simply tap an available compressor stage for the desired flow. In addition, 18 hp is a relatively small percentage to demand from the total output of the aircraft power plant.

i. Concept Evaluation Summary and Technical Data

The concepts are summarized in Table III-4 below with the rating factors and study/discard decision as derived in the Selection Rationale Sheets of Data Book - Book III.

TABLE III-4

CONCEPT EVALUATION SUMMARY

FUNCTIONAL NO.: 2.2	SUBSYSTEM SUB-FUNCTION TITLE: Refrigerator Concepts	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
2.2.1	Solid CO_2 Refrigerator	6.9	X		-		
2.2.2	Heat Sink Refrigerator	10.7		X	-	X	
2.2.3	Cryogenic Expansion Refrigerator	7.45	X		-		
2.2.4	Water Sublimation Refrigerator	11.8		X	-		X
2.2.5	Vapor Compression Refrigerator	8.0	X		-		
2.2.6	Space Radiator Refrigerator	10.8		X	-		X
2.2.7	Thermoelectric Refrigerator	10.6		X	-		X
2.2.8	Turbo-Compressor/Air Cycle Refrigerator	11.4		X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Water Sublimation Refrigerator (Concept 2.2.4). Detailed data for this concept are presented on Element Concept Data Sheets 2.2.4.1 through 2.2.4.13 and 2.2.4.18 through 2.2.4.29 in Data Book - Book I.

Additional analysis is presented under Concept 2.2.4 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figures III-74, III-75, and III-76 following.

2) Technical Data - Space Radiator Refrigerator (Concept 2.2.6). Detailed data for this concept are presented on Element Concept Data Sheets 2.2.6.1 through 2.2.6.13 and 2.2.6.18 through 2.2.6.29 in Data Book - Book I.

Additional analysis is presented under Concept 2.2.6 in Back-Up Information Sheets, Data Book - Book II.

Curves of Weight and Volume Versus Crew Size are presented in Figures III-77 and III-78 following.

3) Technical Data - Thermoelectric Refrigerator (Concept 2.2.7). Detailed data for this concept are presented on Element Concept Data Sheets 2.2.7.1 through 2.2.7.13 and 2.2.7.18 through 2.2.7.29 in Data Book - Book I.

Additional analysis is presented under Concept 2.2.7 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figures III-79, III-80 and III-81 following.

4) Technical Data - Turbo-Compressor/Air Cycle Refrigerator (Concept 2.2.8). Detailed data for this concept are presented on Element Concept Data Sheets 2.2.8.1 through 2.2.8.17 in Data Book - Book I.

Additional analysis for this concept is presented in the Back-Up Information Sheets, Concept 2.2.8, Data Book - Book II.

Curves of Power, Weight and Volume for the Turbo-Compressor/Air Cycle Refrigerator are presented in Figure III-82 following.

j. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above.

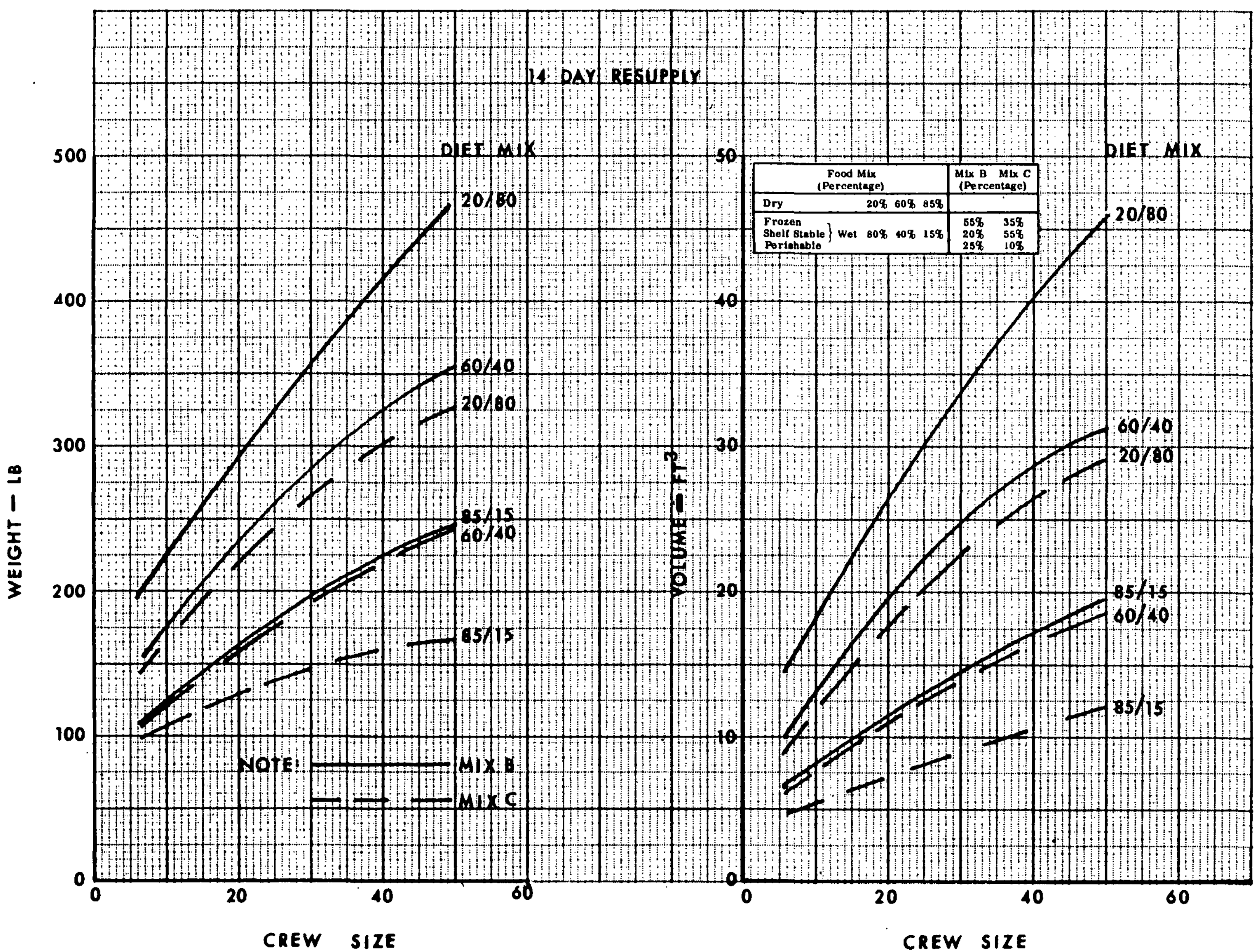
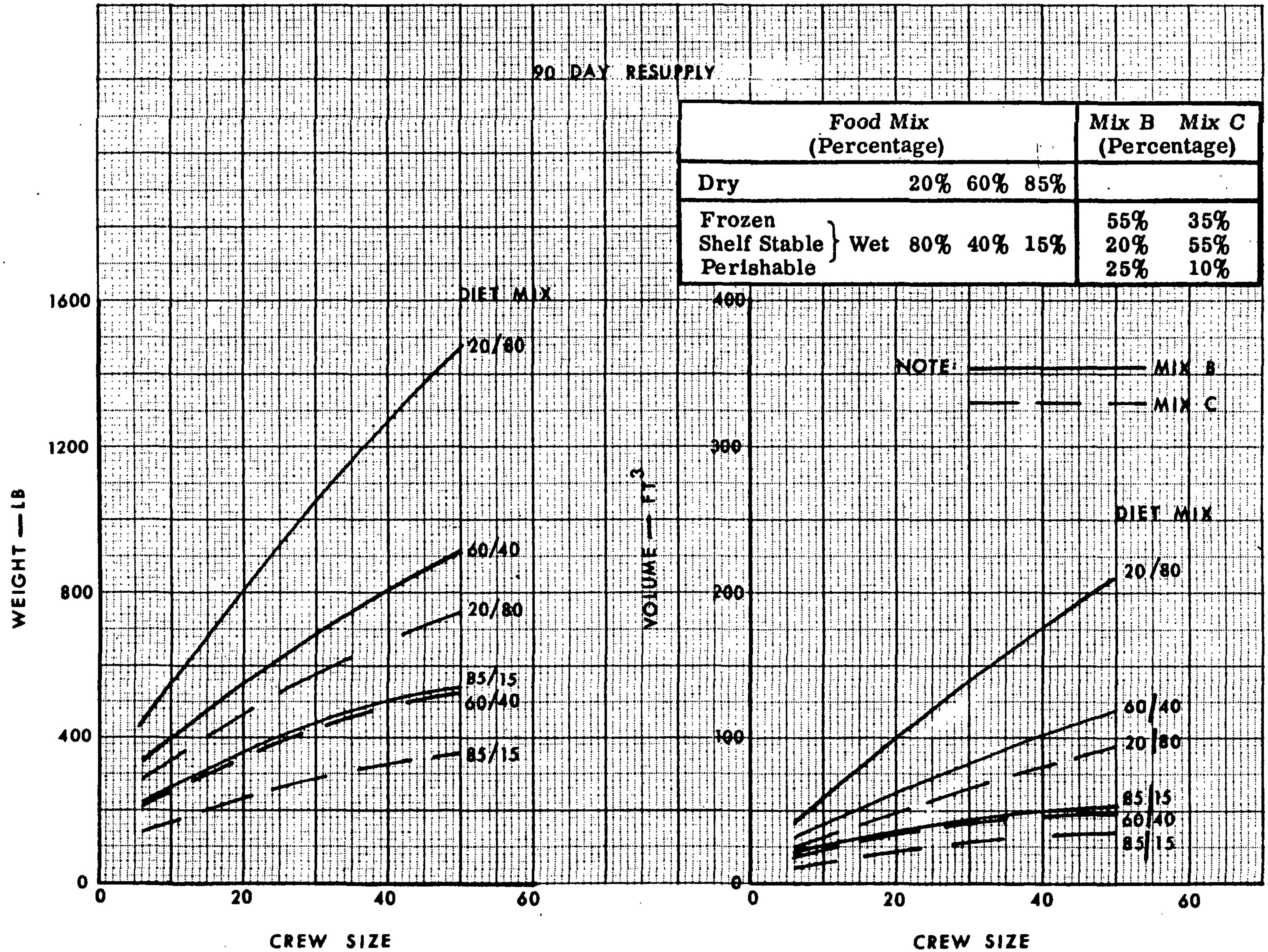
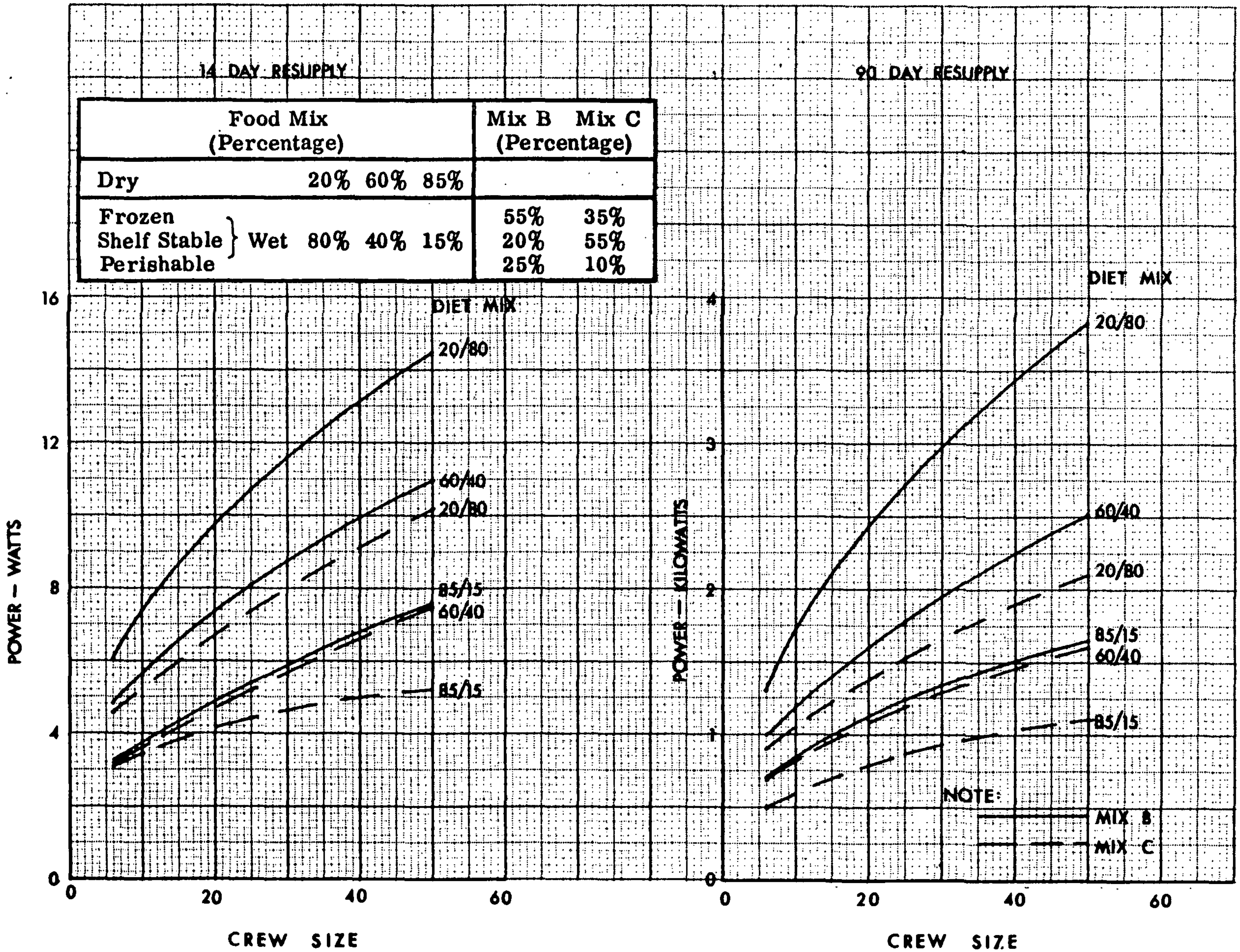


Figure III-74. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 14 Day Resupply Water Sublimation Concept - Refrigerator Only



Food Mix (Percentage)					Mix B (Percentage)	Mix C (Percentage)
Dry		20%	60%	85%		
Frozen	Wet	80%	40%	15%	55%	35%
Shelf Stable					20%	55%
Perishable					25%	10%

Figure III-75. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 90 Day Resupply
Water Sublimation Concept - Refrigerator Only



Food Mix (Percentage)					Mix B (Percentage)	Mix C (Percentage)
Dry		20%	60%	85%		
Frozen	Wet	80%	40%	15%	55%	35%
Shelf Stable					20%	55%
Perishable					25%	10%

Figure III-76. Total Operating Power Versus Crew Size and Diet Mix - 14 and 90 Day Resupply Water Sublimation Concept - Refrigerator Only

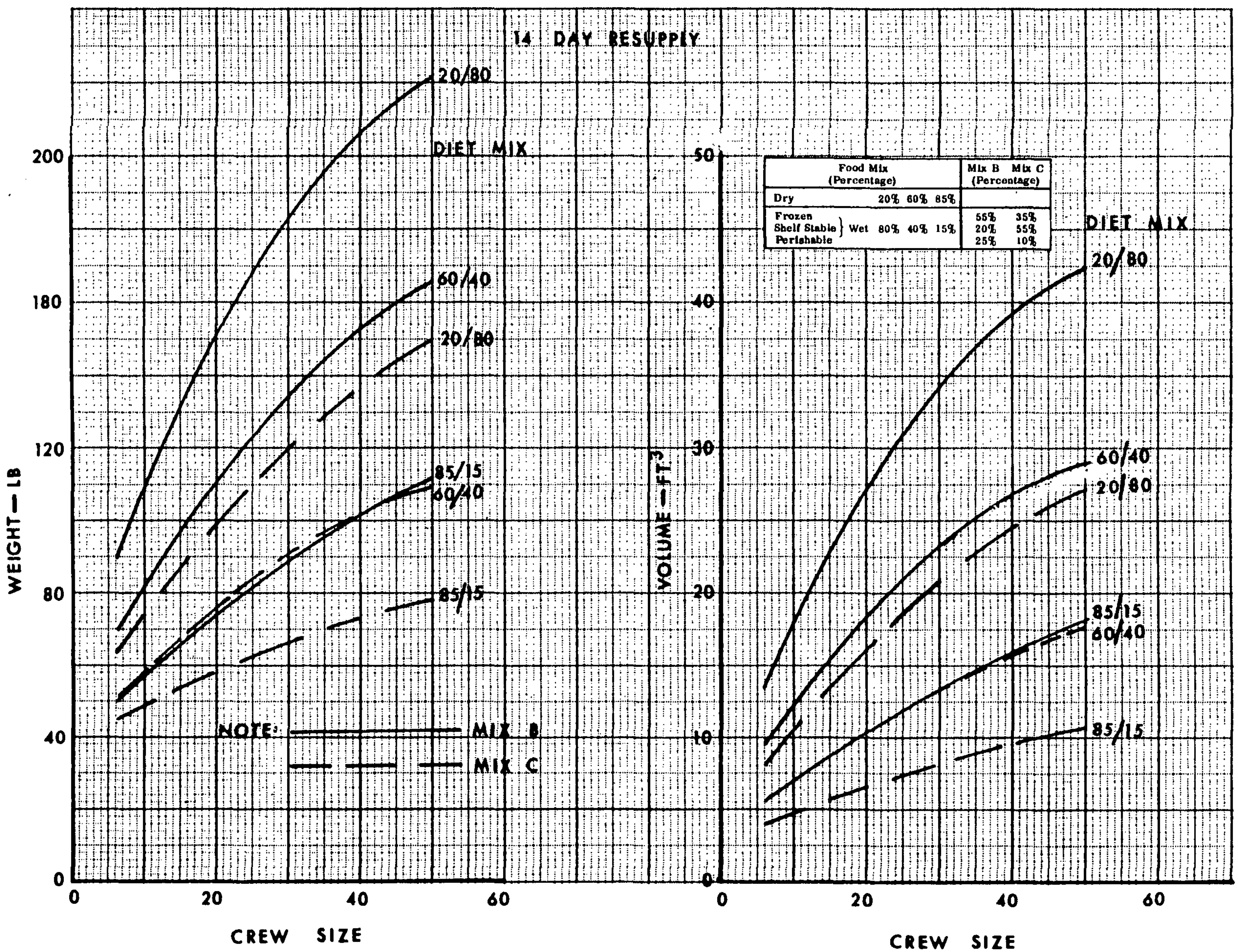


Figure III-77. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 14 Day Resupply Space Radiator Concept - Refrigerator Only

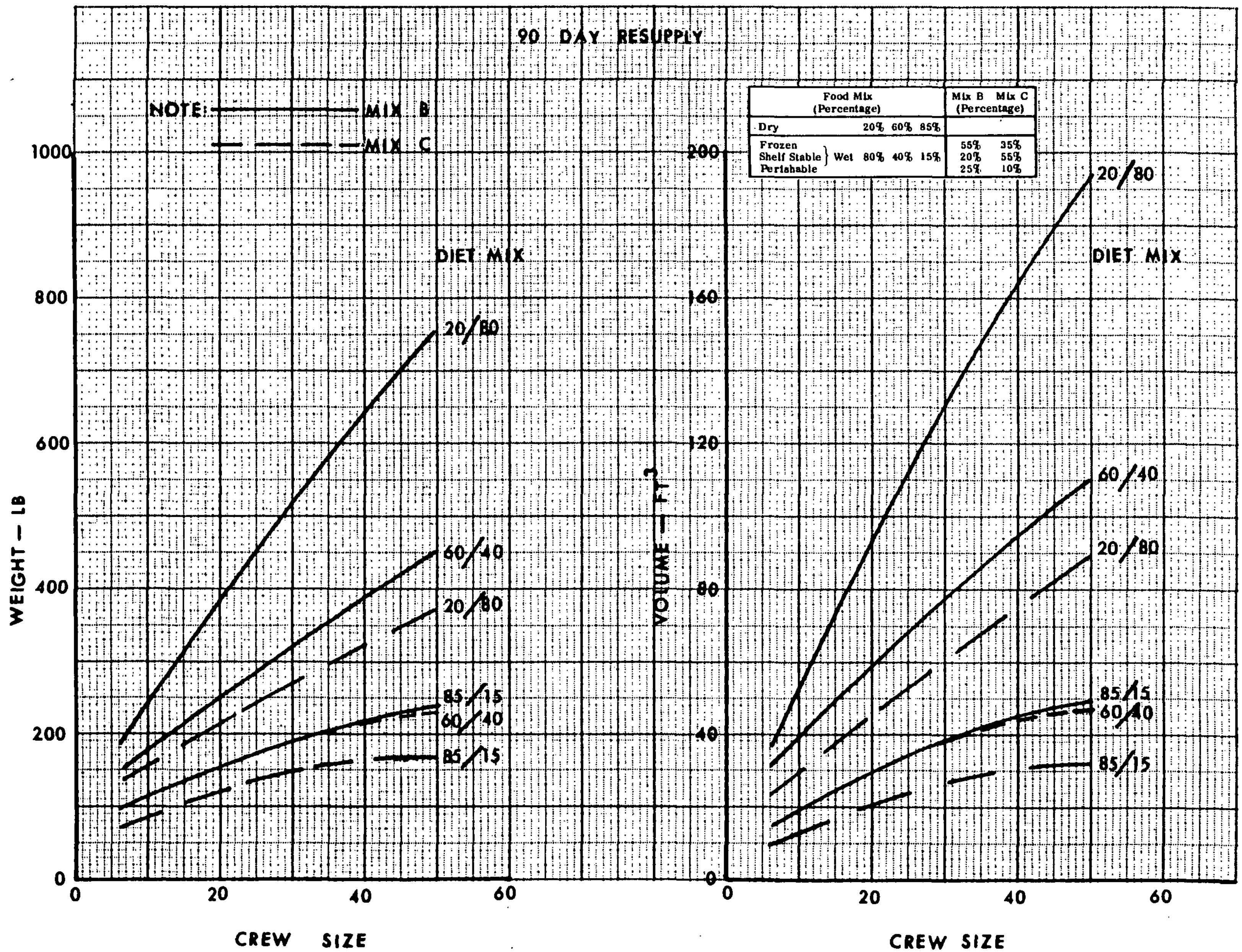


Figure III-78. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 90 Day Resupply Space Radiator Concept - Refrigerator Only

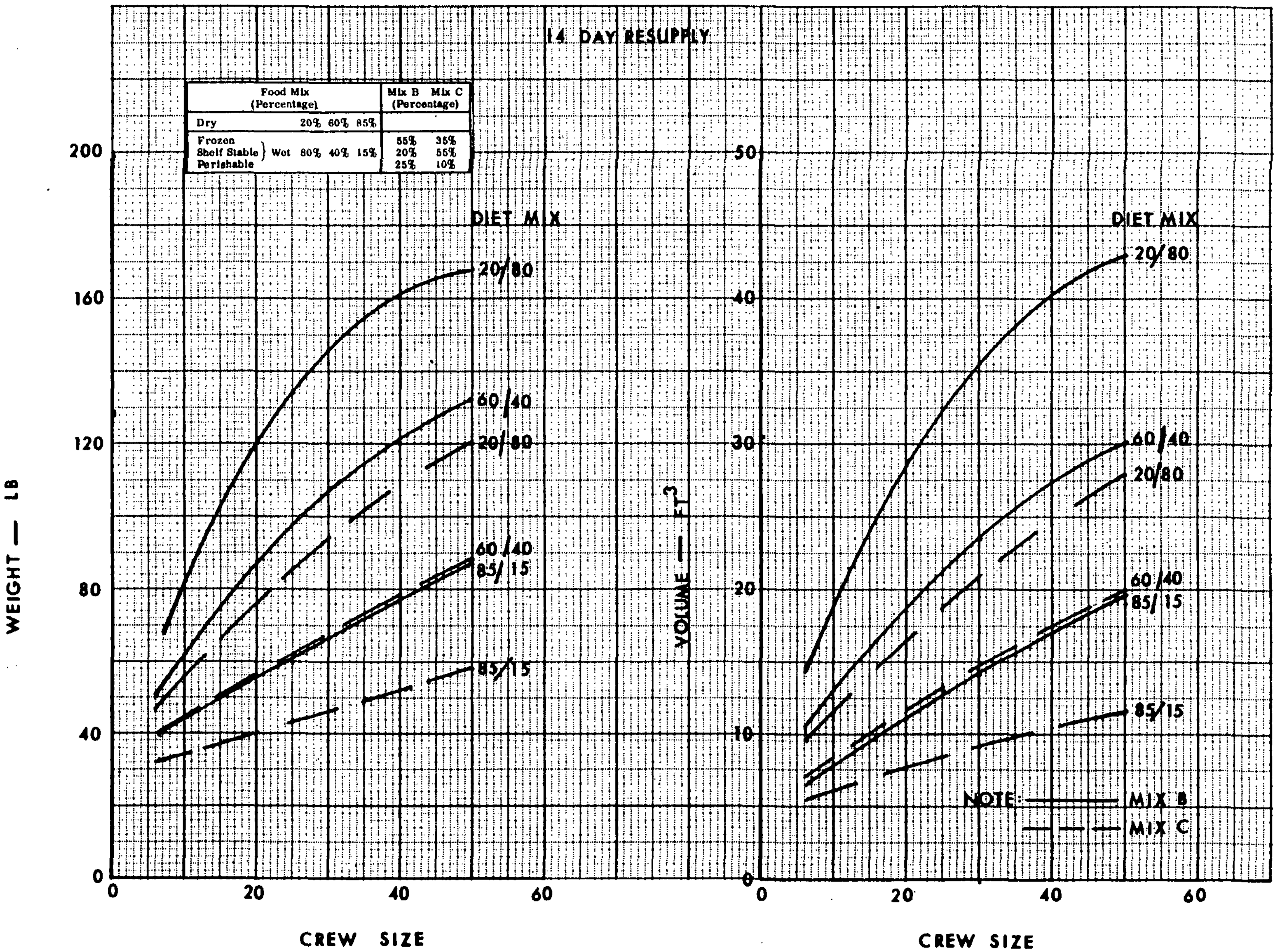
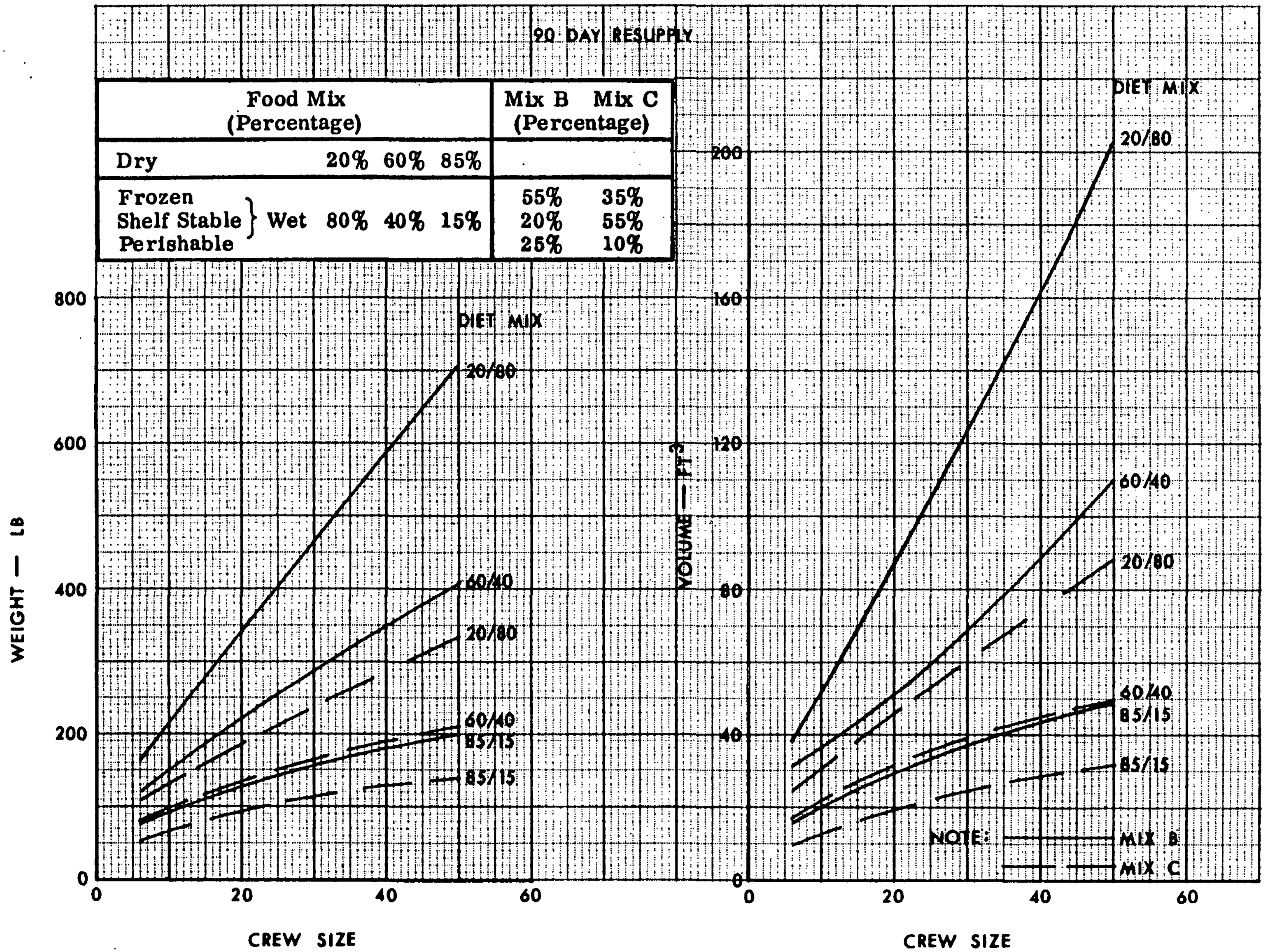
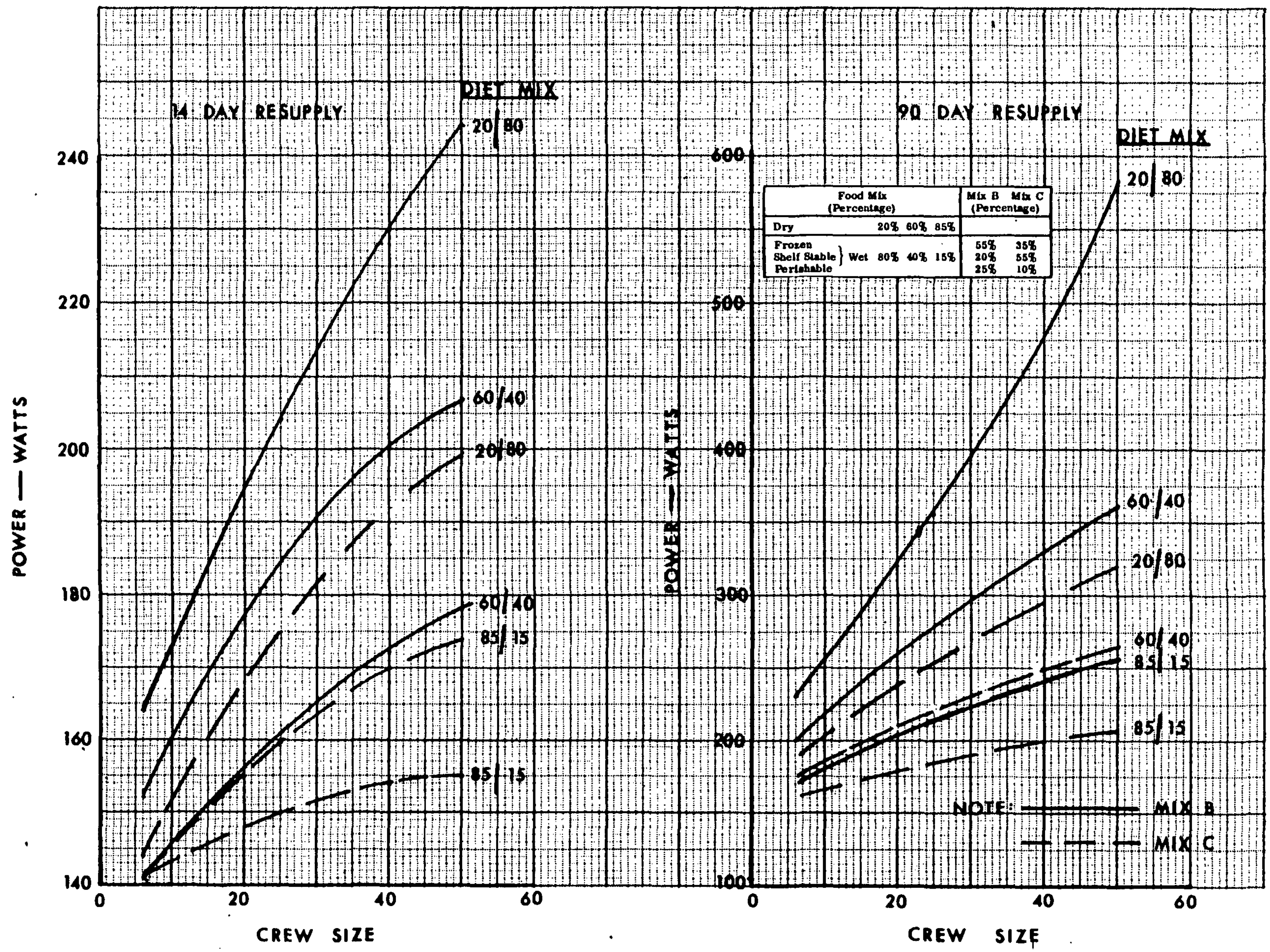


Figure III-79. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 14 Day Resupply Thermoelectric Concept - Refrigerator Only



Food Mix (Percentage)				Mix B (Percentage)	Mix C (Percentage)
Dry	20%	60%	85%		
Frozen } Wet	80%	40%	15%	55%	35%
Shelf Stable } Wet				20%	55%
Perishable } Wet				25%	10%

Figure III-80. Total Installed Weight and Volume Versus Crew Size and Diet Mix - 90 Day Resupply
Thermoelectric Concept - Refrigerator Only



Food Mix (Percentage)					Mix B (Percentage)	Mix C (Percentage)
Dry		20%	60%	85%		
Frozen	Wet	80%	40%	15%	55%	35%
Shelf Stable					20%	55%
Perishable					25%	10%

Figure III-81. Total Operating Power Versus Crew Size and Diet Mix - 14 and 90 Day Resupply
Thermoelectric Concept - Refrigerator Only

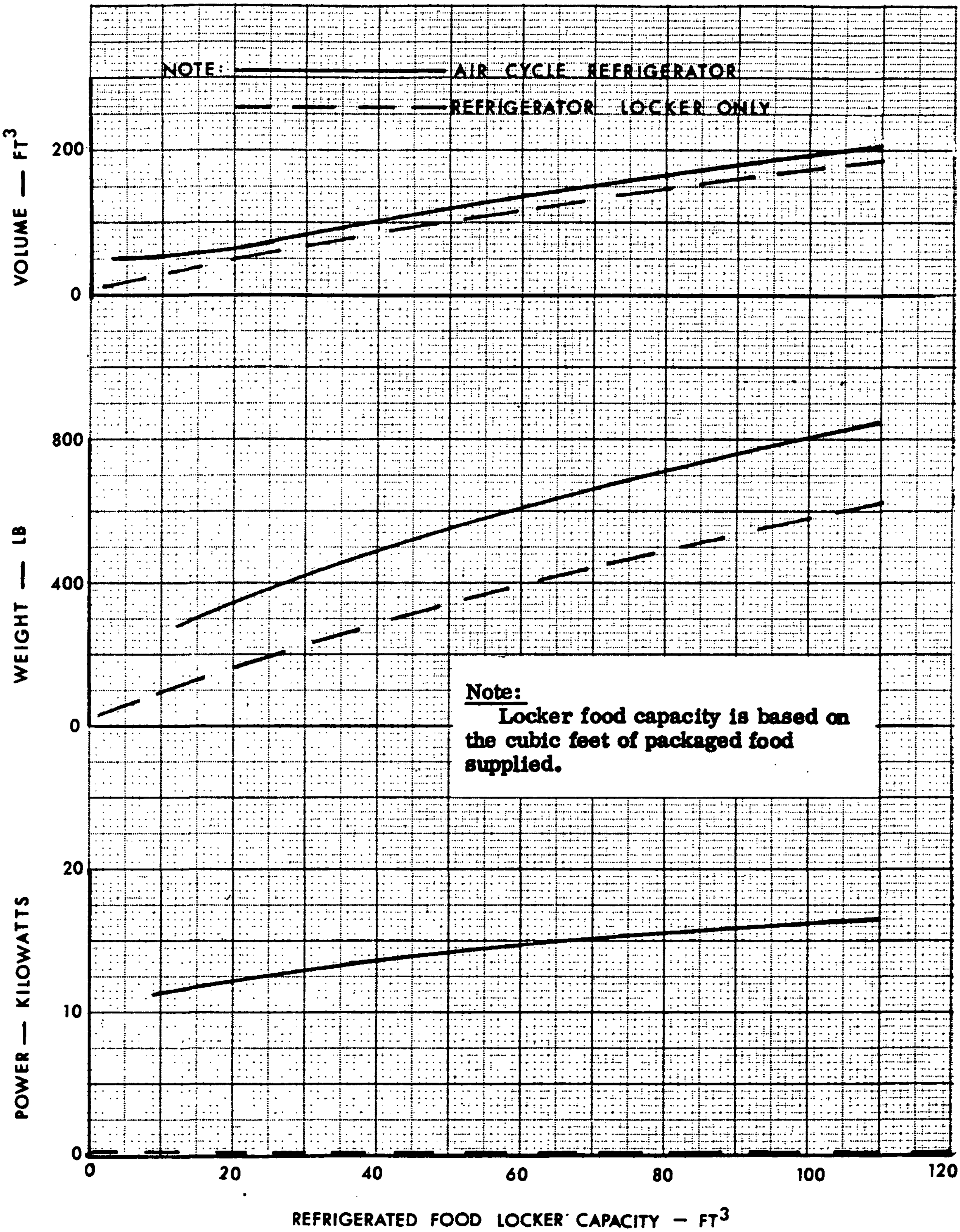
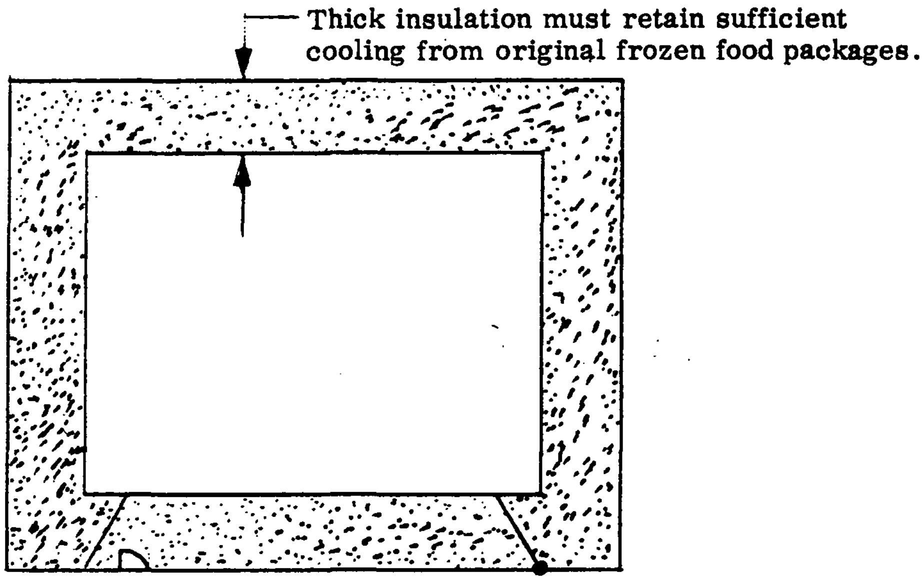


Figure III-82. Total Estimated Power, Weight, and Volume Versus Locker Food Capacity Air Cycle Concept - Refrigerator Only

FOOD SYSTEM STUDY SKETCH

Title: Heat Sink Refrigerator

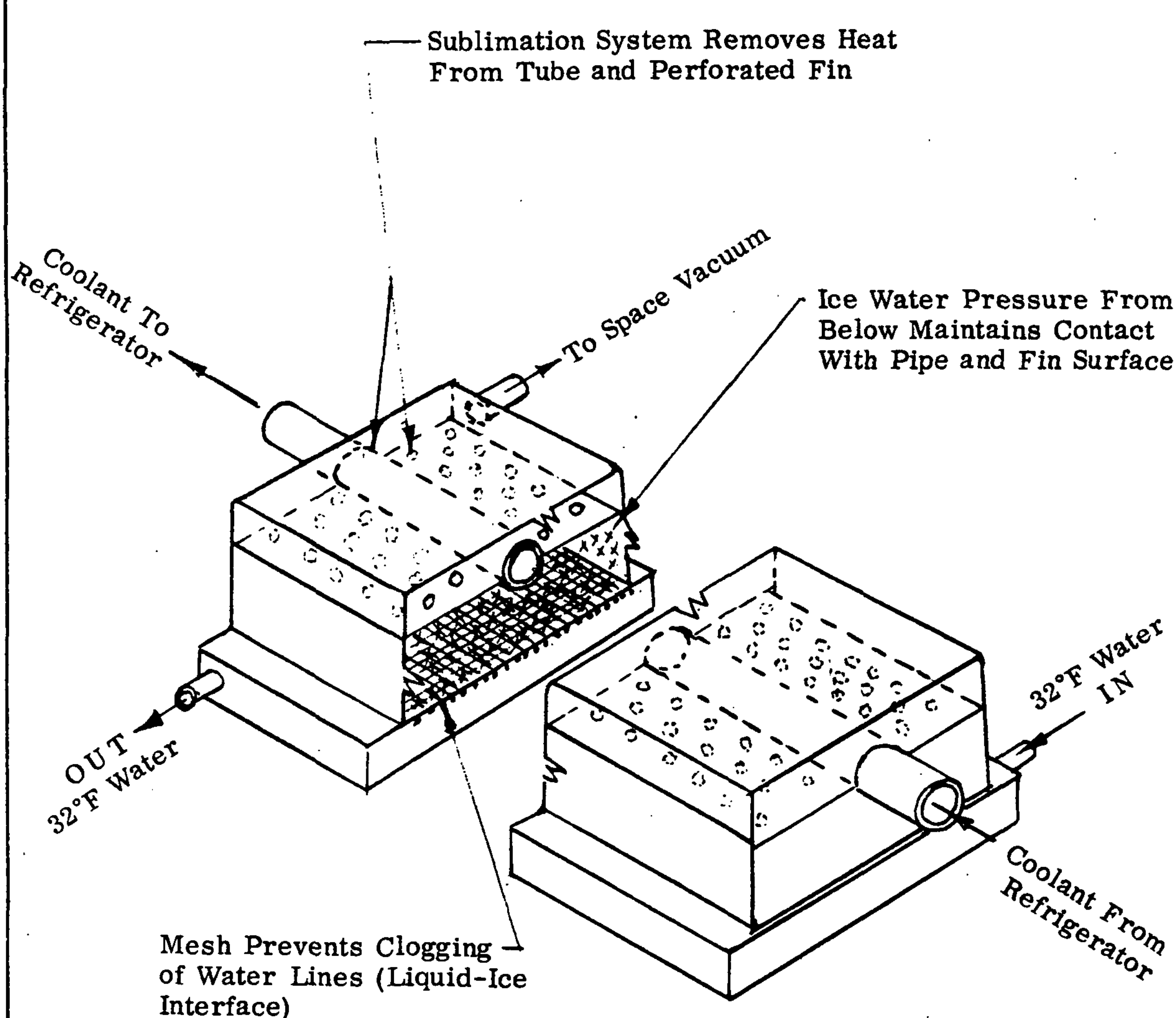


The thermal capacity of the frozen food at 40°F can be equated to the heat entering the cold compartment through leakage paths. Although the heat capacity of the food is small, the leakage rate can be attenuated by use of high performance insulation. For resupply period of no greater than two weeks, this concept may be valid. Applicable to both partial- and zero-g.

D— 2.2.2

FOOD SYSTEM STUDY SKETCH

Title: Water Sublimation Refrigerator Concept



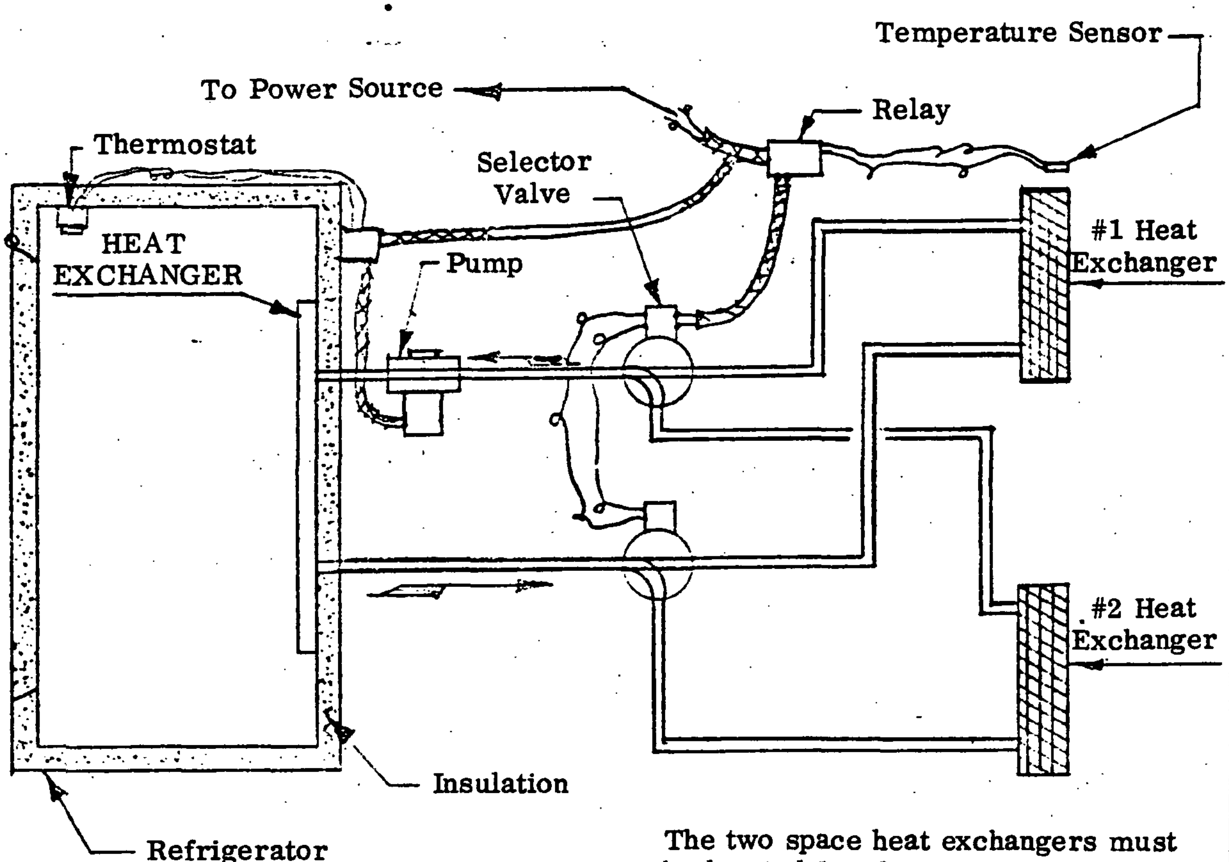
In this concept, a suitable coolant is circulated through a cooling coil located throughout the refrigerator compartment. The coolant collects heat and transports it to the sublimation heat exchanger located adjacent to the unit. A sublimation technique compatible with the zero-g environment is used to remove the heat from the coolant.

The concept is inherently small and lightweight. Operability, crew acceptance, and safety factors are considered good.

D— 2.2.4

FOOD SYSTEM STUDY SKETCH

Title: Space Radiator Refrigerator



The two space heat exchangers must be located 180 degrees apart on the outside of the Space Station.

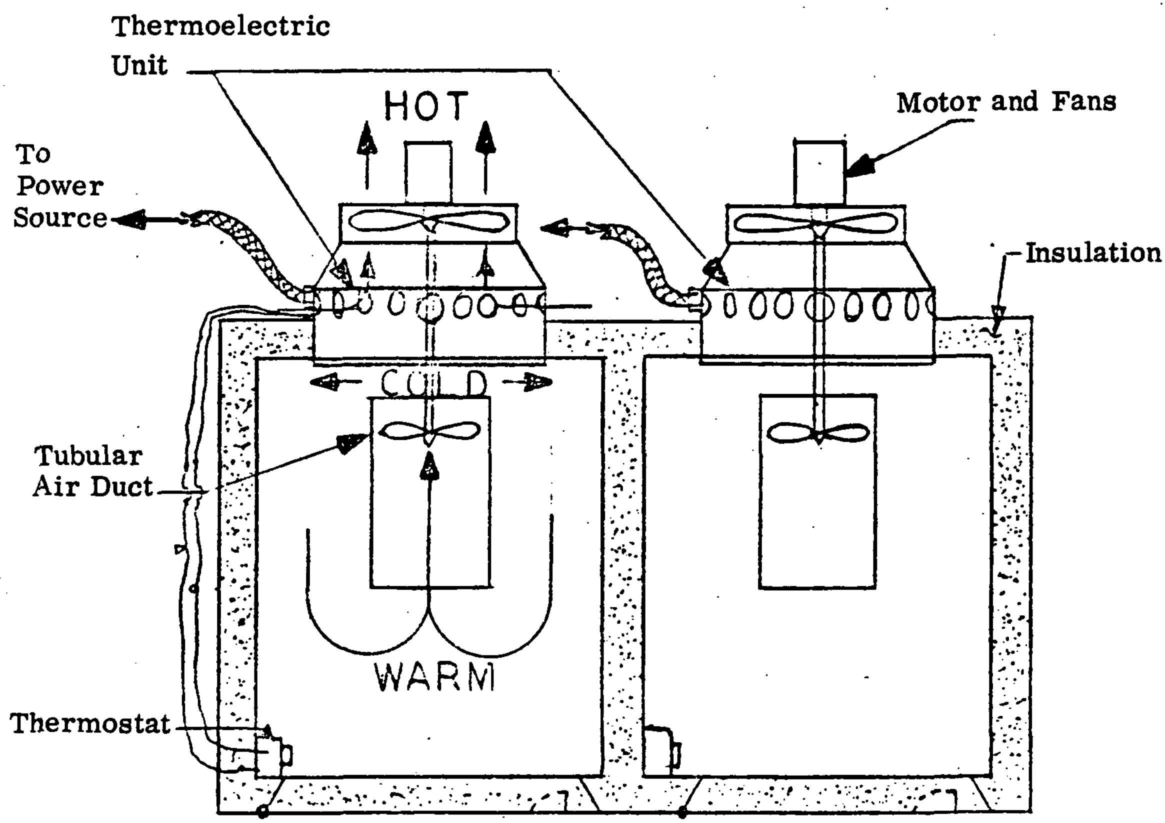
In this concept a suitable coolant is circulated through cooling coils located throughout the refrigerator compartment; the coolant collects heat and transports it to heat exchangers (space radiators) located on the outer surface of the spacecraft. One or more space radiators may be required if the vehicle lacks attitude control with respect to the sun; the coolant would automatically be routed to the proper radiator.

Further development will be required to qualify this concept for space usage; however, it would be applicable to both partial- and zero-g conditions.

D— 2.2.6

FOOD SYSTEM STUDY SKETCH

Title: Thermoelectric Refrigerator



One Thermoelectric Unit Required For Each Compartment

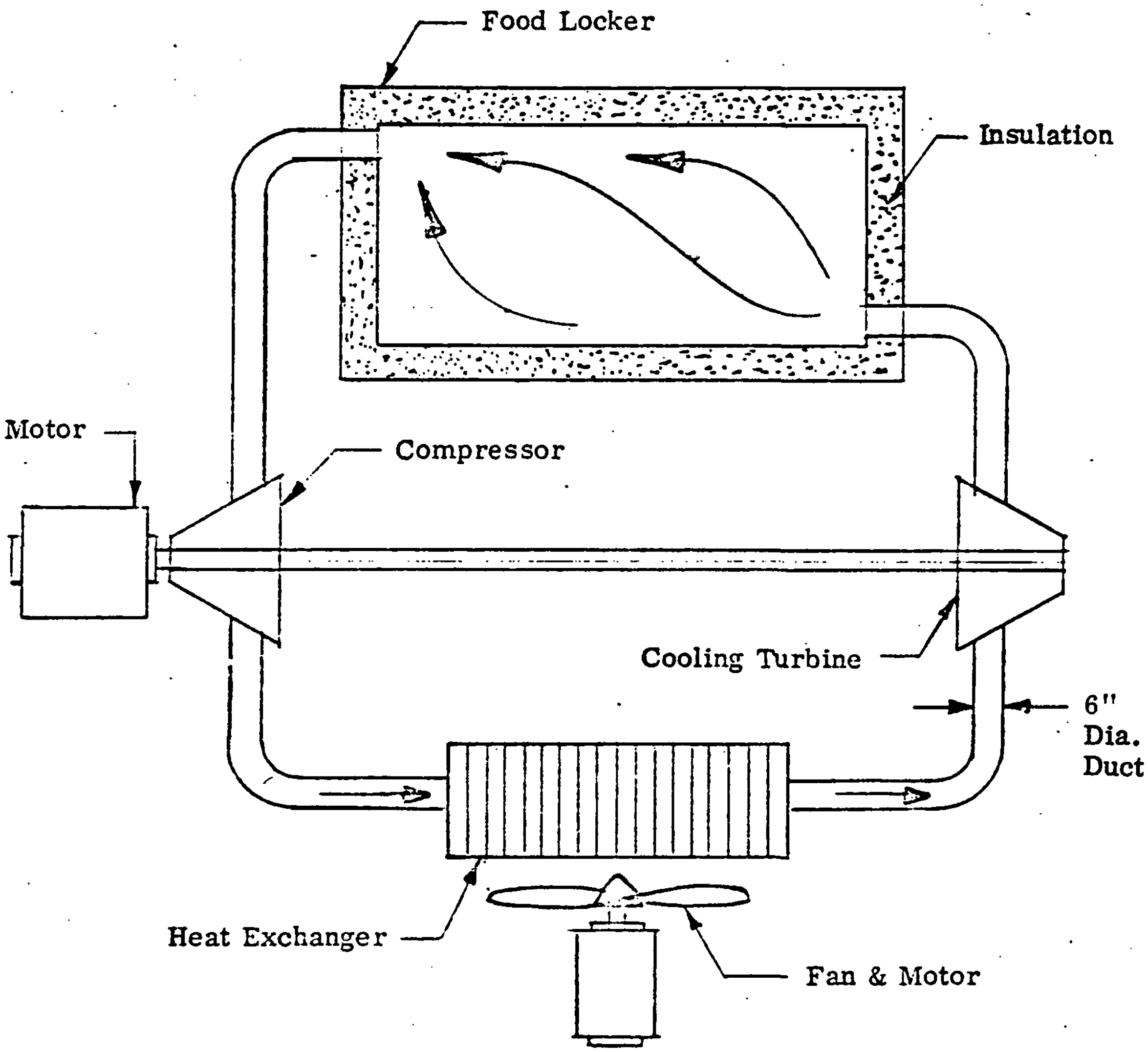
This concept utilizes the solid state thermoelectric modules to transfer heat from the cold storage area. Thermoelectric modules consist of a cold junction (a plate that absorbs heat from the load) and a hot junction (a heat sink where heat is rejected). A semi-conductor material interfaces with both junctions and causes heat to be transferred from cold to hot.

This concept is applicable for both zero- and one-g usage, and will require considerable development effort.

D— 2.2.7

FOOD SYSTEM STUDY SKETCH

Title: Turbo-Compressor/Air Cycle Refrigerator



This system consists of an insulated food locker motor and compressor, heat exchanger and fan, cooling turbine, and associated air ducts.

- Air is compressed, passed through a heat exchanger and cooling turbine through the food locker and back to the compressor. This cycle is repeated as required by a thermostatic control system. The air ducts are approximately 6 inches in diameter.

Further development is required to perfect this system.

D— 2.2.8

2.3 Candidate Ambient Storage Techniques

a. Concept: Storage Locker/Store Room (2.3.1)

Concept Description: This concept consists of a rigid locker or store room for storage at ambient temperatures. A cooling coil connected to the refrigeration circuit may be required in the event of temperature overshoots. Food packages are stacked in a predetermined arrangement and restrained on shelves using zero-g retention means.

Technical Analysis: This concept is expedient, simple, and requires little development effort.

b. Concept: Flexible Storage (2.3.2)

Concept Description: This concept consists of an elastic netting material or extensible membrane fastened to a convenient bulkhead or deck in the vehicle. When it is fastened at one point the storage concept becomes a free-floating pendulum. When the material is fastened at multiple locations, the storage facility gradually recedes towards the wall as the food packages are retrieved from this storage concept.

Technical Analysis: The concept is not complicated and requires little development time. High crew time required to retrieve a specific compliment of stored food restrained haphazardly behind an elastic net.

c. Concept: Extravehicular Storage (2.3.3)

Concept Description: This concept utilizes the external surfaces of the spacecraft to store food packages. The packages would be protected and insulated from the environmental rigors of space.

Technical Analysis: This concept is downgraded primarily because of the unusual safety risks associated with EVA food retrieval.

d. Concept Evaluation Summary and Technical Data

The concepts are summarized in Table III-5 below with the rating factors and study/discard decision as derived in the Selection Rationale Sheets of Data Book - Book III.

TABLE III-5

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 2.3	TITLE: Ambient Storage Concepts	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
2.3.1	Storage Locker/Store Room, Rigid	14.4		X	-		X
2.3.2	Flexible Storage	13.2		X	-		X
2.3.3	Extravehicular Storage	5.3	X		-		

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Ambient Food Storage Locker - Rigid Concept (Concept 2.3.1). Detailed data for this concept are presented on Element Concept Data Sheets 2.3.1.1 through 2.3.1.18 and 2.3.1.25 through 2.3.1.40 in Data Book - Book I.

Additional analysis is presented under Concept 2.3.1 in Back-Up Information Sheets, Data Book - Book II.

Curves of Weight and Volume Versus Crew Size are presented in Figures III-83 and III-84.

2) Technical Data - Ambient Food Storage - Flexible Concept (Concept 2.3.2). Detailed data for this concept are presented on Element Concept Data Sheets 2.3.2.1 through 2.3.2.18 and 2.3.2.25 through 2.3.2.40 in Data Book - Book I.

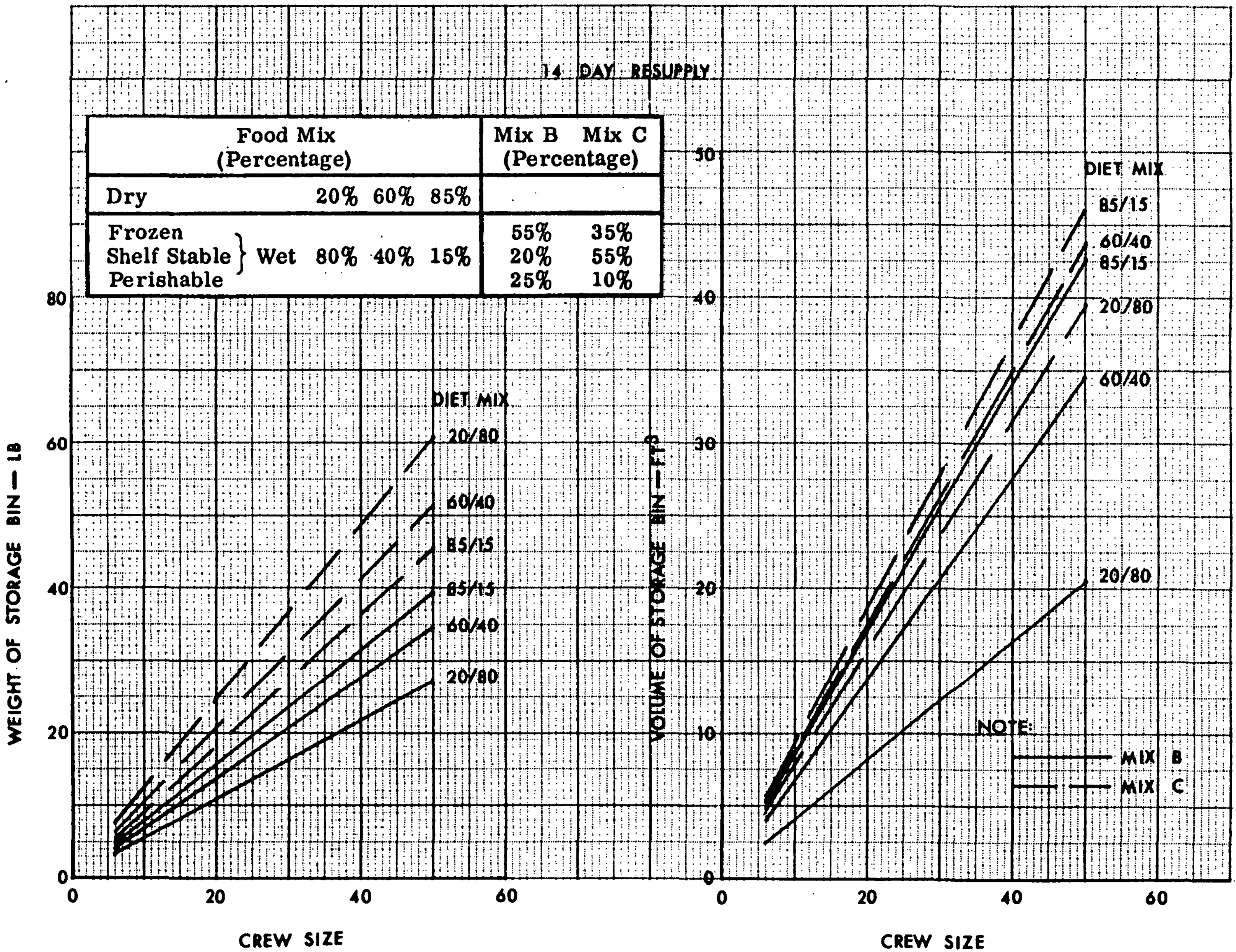
Additional analysis is presented under Concept 2.3.2 in Back-Up Information Sheets, Data Book - Book II.

Curves of Weight Versus Crew Size are presented in Figure III-85.

e. Applicable Sketches

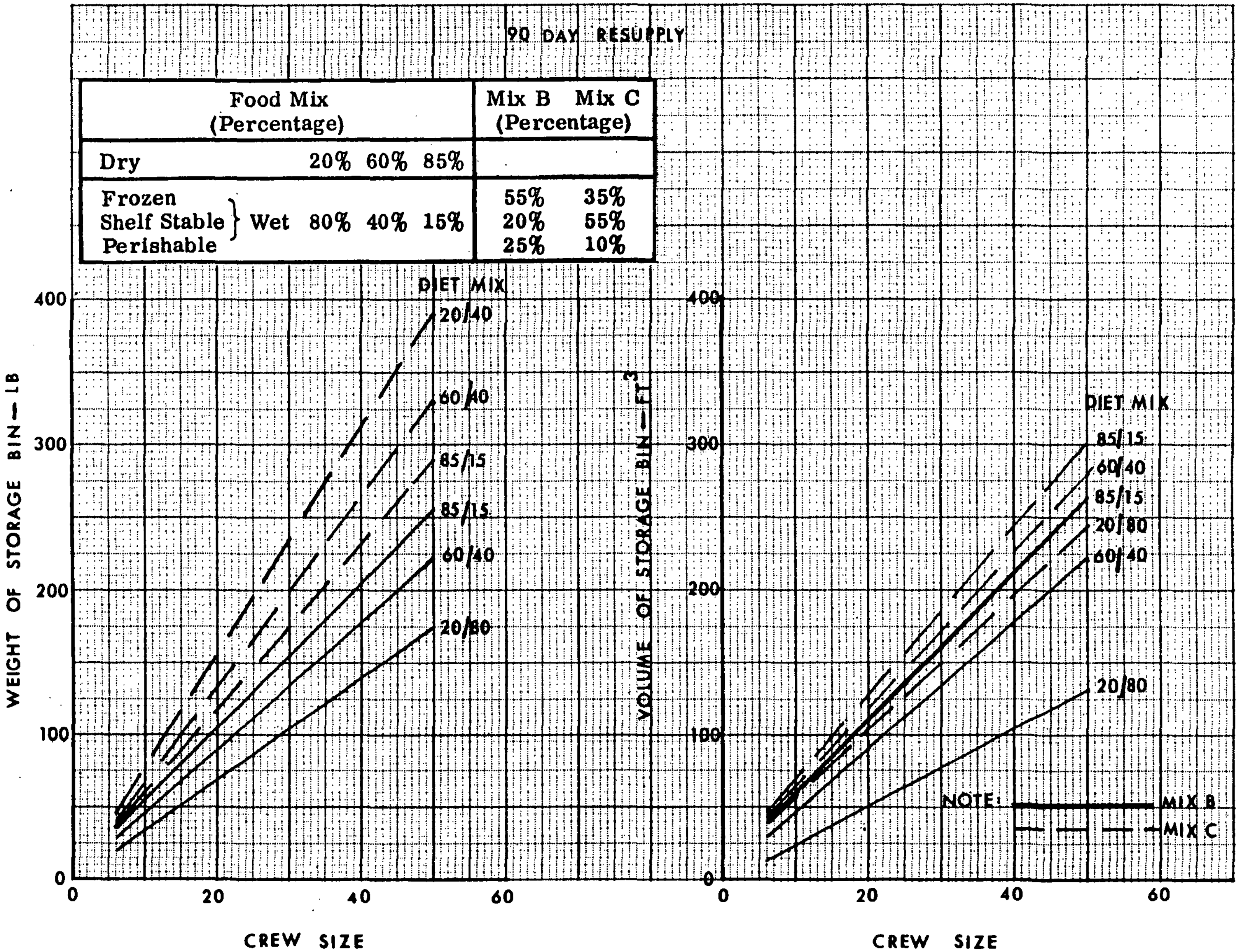
The following sketches depict equipment concepts for the techniques described above.

4⊕



Food Mix (Percentage)				Mix B (Percentage)	Mix C (Percentage)
Dry	20%	60%	85%		
Frozen } Wet	80%	40%	15%	55%	35%
Shelf Stable } Wet				20%	55%
Perishable } Wet				25%	10%

Figure III-83. Total Installed Dry Weight and Volume Versus Crew Size and Diet Mix For Ambient Storage Locker - Rigid Concept 14 Day Resupply



Food Mix (Percentage)					Mix B (Percentage)	Mix C (Percentage)
Dry		20%	60%	85%		
Frozen Shelf Stable Perishable	Wet	80%	40%	15%	55% 20% 25%	35% 55% 10%

Figure III-84. Total Installed Dry Weight and Volume Versus Crew Size and Diet Mix
For Ambient Storage Locker - Rigid Concept
90 Day Resupply

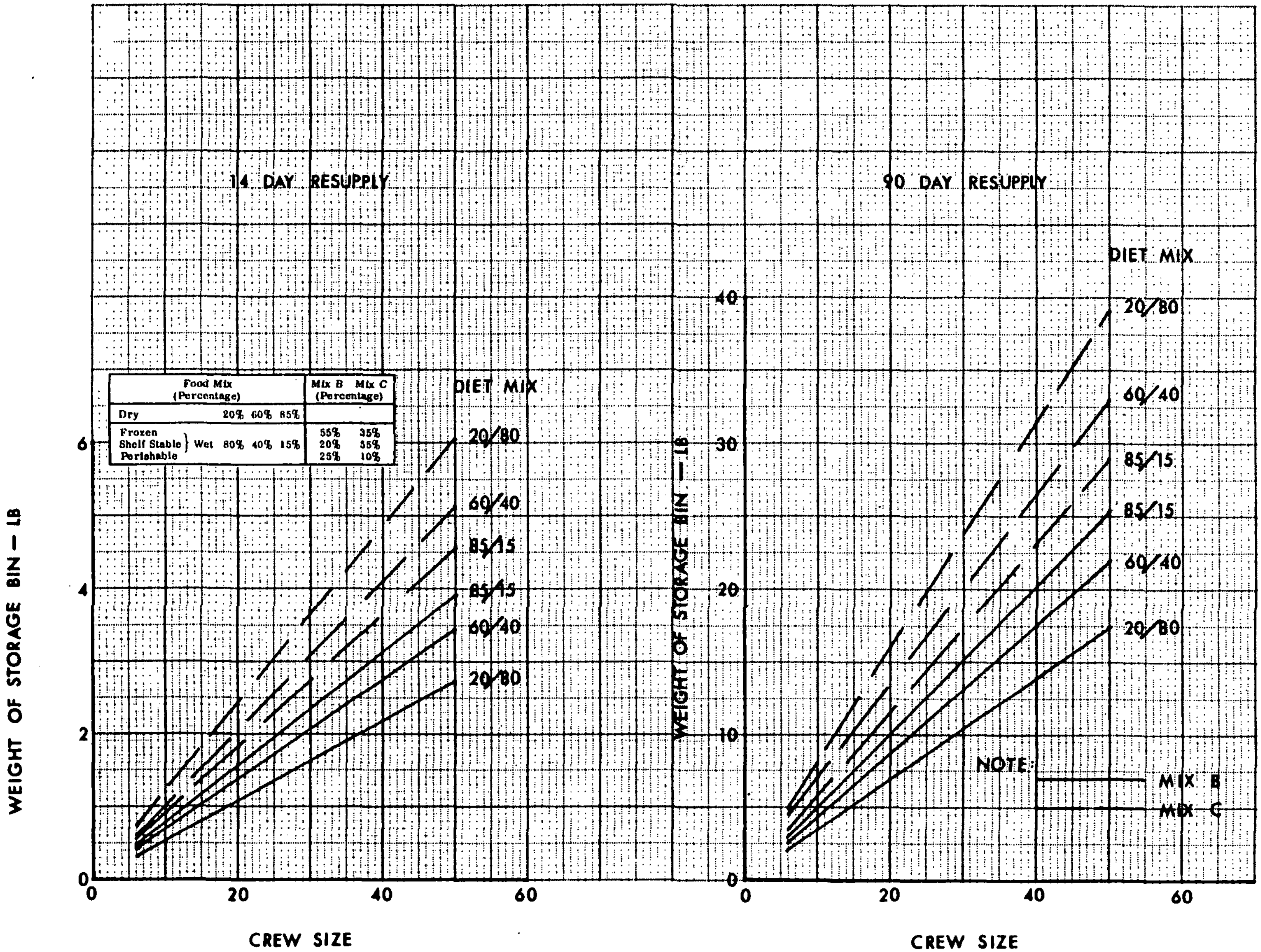
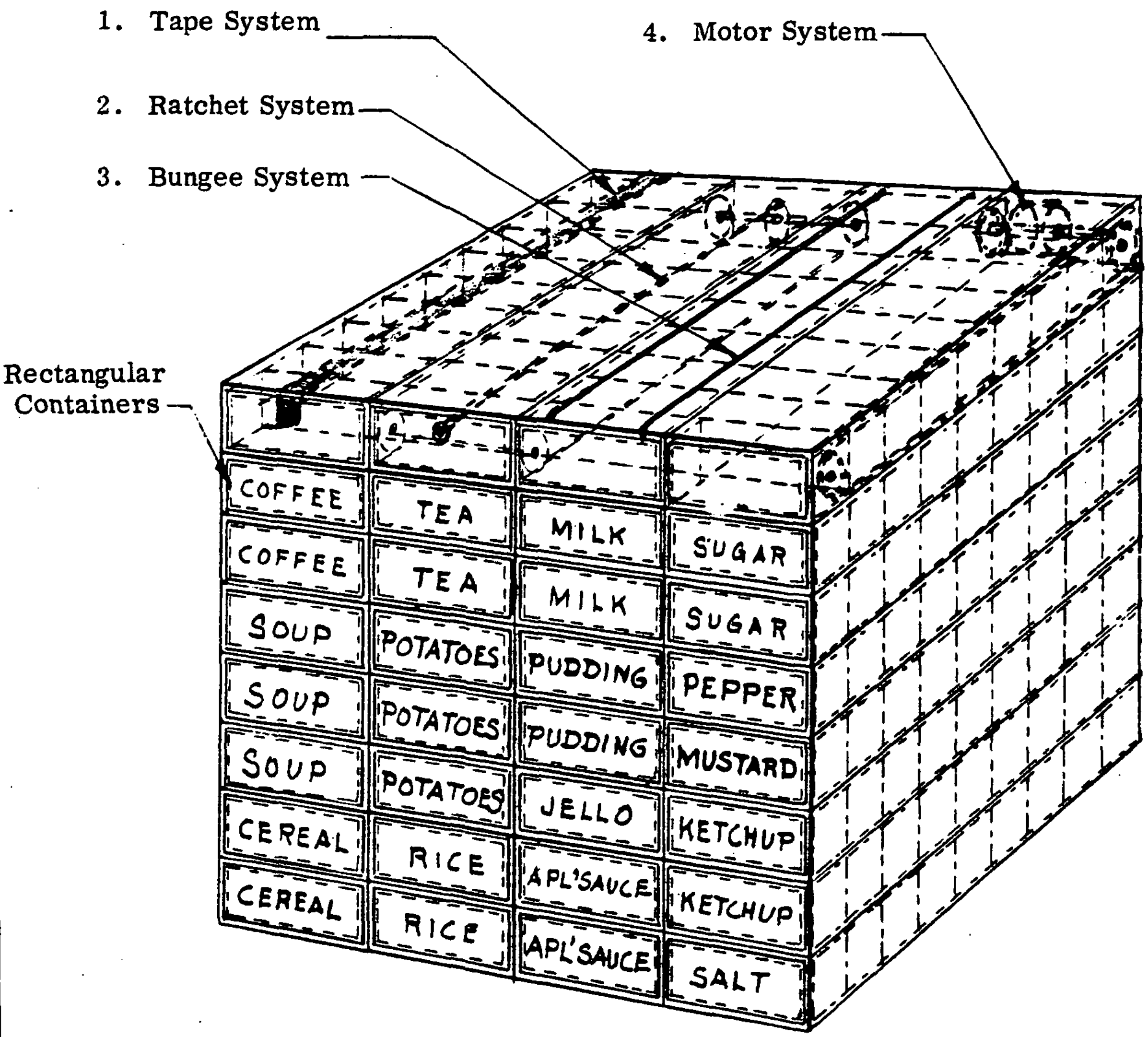


Figure III-85. Total Installed Dry Weight Versus Crew Size and Diet Mix
Ambient Storage - Flexible Concept
14 and 90 Day Resupply

FOOD SYSTEM STUDY SKETCH

Title: Storage Locker/Store Room



ALTERNATE DISPENSING TECHNIQUES

1. Open door, pull tape, tear off one container.
2. Open door, pull plunger, ratchet advances one container.
3. Open door, bungee advances one container.
4. Open door, motor advances one container

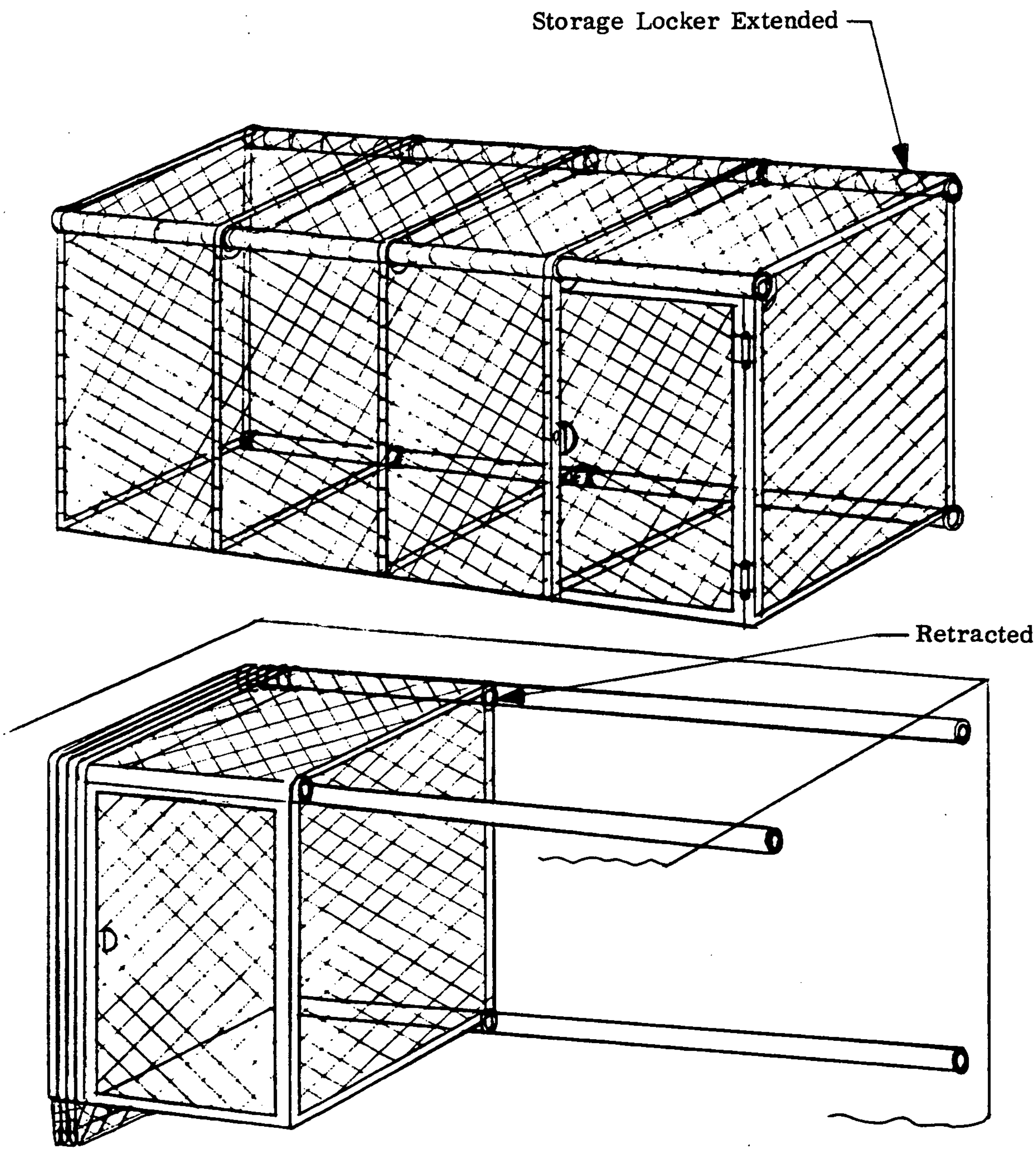
In this sketch, four systems of obtaining food from a rigid food locker are depicted. System #1 is the lightest, most reliable system requiring no power.

All of these systems are applicable for zero- to one-g usage.

D— 2.3.1

FOOD SYSTEM STUDY SKETCH

Title: Flexible Storage



In this concept, the locker is made of nylon netting with frames that slide on a tubular structure. A door provides access to the packages. As the contents are used, the frames will slide along the tubes reducing the locker size until the size is equal to the door size.

This concept can be used in both zero- and one-g applications.

D— 2.3.2

3.0 Provide For Preparation - Functional Subsystem Area 3.0

This function is concerned with providing concepts and techniques of meal preparation onboard the Space Station/Base. The primary requirements considered in the evaluation of each concept included applicability to operation in a zero-g environment, safety, convenience, and crew time. The preparation subsystem was subdivided into three areas for a complete evaluation. The first area concerns itself with the powered preparation equipment. Individually, paragraph 3.1 evaluates only the source of energy used to power food warming ovens and other powered equipment, while paragraph 3.2 evaluates candidate oven/food warming concepts. Paragraph 3.3 includes powered accessories that perform the various support functions concurrent with food warming.

The second area — paragraphs 3.4 through 3.8 — encompasses the preparation counters, bars, cabinets, and utensils. Concepts peculiar to debris control, body restraints, and food conveyences described in paragraphs 3.9 through 3.11 comprise the third subdivision. Each concept selected for study is accompanied by an evaluation summary.

3.1 Candidate Power Source Techniques

a. Concept: Electrical Power Source (3.1.1)

Concept Description: This concept is the common electrical supply used to activate most spacecraft equipment requiring electrical power. The source of electrical generation is irrelevant; it is assumed this source will handle peak demands.

Technical Analysis: The electrical supply concept has a high crew acceptability rating and is readily available onboard the spacecraft. This concept is compatible with more food heating devices than any other concept of supplying power. Because the electrical source of power has the lowest development risk of any concepts studied, all food heating devices and techniques were designed using the electrical power concept.

b. Concept: Solar Energy Source (3.1.2)

Concept Description: A heat exchanger used conjunctively with a suitable solar reflector would transfer energy into a primary thermal transport circuit. The transport circuit would duct the energy from the external equipment and into the spacecraft to transfer the energy to a secondary or interloop liquid transport line. The interloop will be pumped through the food heating device where the heat energy is extracted and transferred to the food.

Technical Analysis: This source of power was discarded for its weight, volume, and reliability penalties. The concept requires a solar reflector, a solar heat exchanger, an interloop heat exchanger, two transport lines, and two pumps, and a suitable heat extractor located within the food heating device. In addition, a controlling scheme is required to operate the reflector orientation and tracking system if the vehicle lacks attitude control with respect to the sun. Food preparation schedules must be properly sequenced onboard an earth orbiting vehicle so that food heating functions would be performed during the sunlit phase of its orbit. Exposure to high velocity microparticles would continuously degrade the performance of the solar reflector. This power source is not compatible with most food heating devices.

c. Concept: Waste Heat From Other Subsystems (3.1.3)

Concept Description: Liquid heat transport circuits would be used to transfer waste heat rejected from other subsystems into a heat extractor located in the food heating device.

Technical Analysis: It is assumed that water will be selected as the heat transport medium for the majority of life support and other spacecraft subsystems primarily because it is nontoxic. The only disadvantage of water stems from its maximum practical operating temperature of 193°F at 10 psia. (Pressurization would create a serious steam ejection hazard in the event of gross leakage or structural failure of the water circuit). Consequently, the size of the heat transfer equipment needed to extract energy in sufficient quantities would result in relatively large food heating devices and increased food heating time. This power source is highly compatible with the flash-steam heating device only.

d. Concept: Isotope Energy Source (3.1.4)

Concept Description: A liquid heat transport circuit is employed to transfer thermal energy from an isotope heater to a heat extracting device located in the food heating concept.

Technical Analysis: Because the food heating devices will not be operated continuously, it is assumed that energy will be tapped from an existing isotope source remotely located in the EC/LS system, the waste management system, or main thermal supply system. Assuming the main thermal supply system will provide a 1200°F/1600°F temperature capability, a silicone base heat transport interloop would be required to accommodate the high isotope surface temperatures; in addition, there would be an interloop heat exchanger requirement to transfer heat to the secondary transport fluid which in turn circulates through the food heating device. Both the interloop and secondary circuits would require pumps, insulation, sensors, and controls. This portion of the concept is discarded for high contamination hazard, high weight and reliability penalties. Likewise, a 700°F local isotope source typically located in the EC/LS system would be rejected on identical grounds. However, an isotope loop maintained at about 200°F would be discarded on the basis of weight, volume, and compatibility penalties not unlike the waste heat concept previously discussed.

e. Concept: Nuclear Reactor Source (3.1.5)

Concept Description: A liquid heat transport circuit is used to transfer thermal energy from a 375°F/500°F secondary loop of a nuclear reactor to a heat exchanger located in the food heating device.

Technical Analysis: Because of the constant radiation hazard inherent in the operation of a reactor onboard a manned spacecraft, the crew quarters and the reactor compartment are traditionally located at extreme distances from one another. This results in extremely long transport lines. In addition, all liquid transport lines leaving the reactor area would require radiation detection monitors and interloop isolation techniques to protect the crew and equipment from possible nuclear reactor contamination. The weight and reliability penalties associated with this concept make it uncompetitive.

f. Concept: Chemical Reaction Source (3.1.6)

Concept Description: A chemical reaction is maintained in a suitable vessel wherein heat energy is generated and temporarily stored. Energy can be transferred to the food heating device by conduction or high temperature transport fluid.

Technical Analysis: This concept was discarded because of its high development risk, low crew safety, and operability ratings.

g. Concept: Fossil Fuel Source (3.1.7)

Concept Description: Processed or unprocessed fossil fuels such as gas, oil, powdered coal would be fed or metered into a suitable combustion vessel. Energy can be transferred to the food heating compartment by conduction, radiation, or high temperature transport fluid.

Technical Analysis: This concept is incompatible with spacecraft safety standards.

h. Concept: Combination Power Source, Electrical, and Solar (3.1.8)

Concept Description: This combination of power sources utilizes the onboard electrical system in conjunction with the solar reflector concept for food heating (see Concepts 3.1.1 and 3.1.2). The addition of a secondary electrical power capability would provide for food heating during the dark phase of orbiting missions when the solar energy source would be totally eclipsed.

Technical Analysis: The concept would inherently retain the weight, volume, and complexity penalties associated with the solar energy source concept, in addition to the new penalties introduced with the electrical heating capability.

i. Concept: Combination Power Source, Electrical and Nuclear (3.1.9)

Concept Description: This combination of power sources utilizes the onboard electrical system in conjunction with the nuclear reactor source for food warming (see Concepts 3.1.1 and 3.1.5).

Technical Analysis: The addition of electrical heating capability will not improve the uncompetitive position of the nuclear reactor concept for power. The combination will not reduce the operability penalties involved.

j. Concept: Combination Power Source, Electrical, and Isotope (3.1.10)

Concept Description: This combination of power source utilizes the onboard electrical system in conjunction with a 200°F local isotope loop for food heating (see Concepts 3.1.1 and 3.1.4).

Technical Analysis: The addition of the electrical heating capability will not result in a uniquely improved power source concept; an (electrical) augmentation of the local isotope concept will deteriorate into a superfluous isotope augmentation of the onboard electrical supply when practical heating techniques are evaluated.

k. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-6 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III- 6

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 3.1	SUB-FUNCTION TITLE: Power Source For Food Heating	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.1.1	Electrical Power Source	16.0		X	-		X
3.1.2	Solar Energy Source	7.7	X				
3.1.3	Waste Heat From Other Subsystems	8.5	X				
3.1.4	Isotope Energy Source	8.75	X				
3.1.5	Nuclear Reactor Source	6.3	X				
3.1.6	Chemical Reaction Source	6.4	X				
3.1.7	Fossil Fuel Source	6.7	X				
3.1.8	Combination Power Source, Electrical and Solar Concepts	7.8	X				
3.1.9	Combination Power Source, Electrical and Nuclear Concept	5.9	X				
3.1.10	Combination Power Source, Electrical and Isotope	8.5	X				

Technical data resulting from a numerical analysis will be circumvented due to the extensive nature of the foregoing concepts. Selection of a power source concept will be based on professional judgments.

3.2 Candidate Food Heating Devices Techniques

a. Concept: Hot Air Convective Heating Oven (3.2.1)

Concept Description: Air is circulated through insulated food compartments after it has been heated to approximately 350°F/400°F. The heated air impinges upon the external surface of the food containment concept and raises the temperature accordingly. Recirculation of the air is accomplished with a fan or blower.

Technical Analysis: The concept of heating with a forced convection medium is an effective and flexible means of heating food; the thermal effectiveness of this concept is independent of the gravitational environment. The onboard electrical power source concept will be used for this oven because it is the only source compatible with the air heating requirement. Other power sources such as chemical reaction and fossil (gas) fuels are unacceptable for spacecraft service.

b. Concept: Microwave Heating Oven (3.2.2)

Concept Description: Food is warmed to proper temperatures by directing microwave energy to an insulated food cavity. Waves are contained within the cavity with suitable shielding, door seals, and interlocking door circuits.

Technical Analysis: Microwave heating ovens require a minimum of development effort; warm-up and cooking time is immediate, and the technique is highly crew acceptable. Power is directed into the food so there is no emission of heat from the oven surfaces. The onboard electrical source is the only power concept compatible with the microwave heating oven.

c. Concept: Resistance Heating Oven (3.2.3)

Concept Description: This heating concept primarily relies on the radiation heat transfer mechanism emanating from electrically heated quartz elements to heat the food mass. The device will function just as a household broiling oven would save for the convection coefficients absent in a zero-g environment.

Technical Analysis: Because of the inherent lack of immediate contact with the food or containers, the quartz rods are relatively free to radiate energy in all directions; consequently, heating efficiency decreases while the power requirement increases to accomplish the food heating function. This concept of food heating may require food mixing to prevent temperature gradients and surface scorching. Also, plastic packaging concepts cannot be used in this heating oven. The safety factor is considered poor because of the high temperature quartz plates and possible burn hazard they present.

d. Concept: Dielectric Heating (3.2.4)

Concept Description: This concept requires the food mass to be heated in a special container. The lateral sides or walls of the container are non-electrical conducting whereas the metallic end plates of the food container act as electrode plates. A high-frequency potential is applied to the metallic end plates and the food is heated by rapid molecular agitation.

Technical Analysis: It is difficult to control the maximum temperature of the food. Since different foods and food combinations have different dielectric constants, a bulky power converter is required. This concept is compatible with the onboard electrical power supply only.

e. Concept: Wrap-On Heating Jacket (3.2.5)

Concept Description: This concept consists of an external wrap-on jacket with flexible resistance elements imbedded near the surface. The jacket (a composite of thermal insulation and suitable matrix containing the heating elements) is wrapped around the food container and fastened snugly. Temperature sensors are imbedded in the jacket to monitor and control the heating process. Food is heated by thermal conduction to a temperature well below the 193°F saturation point of water at 10 psia to preclude excessive pressures in the containers.

Technical Analysis: The overall system efficiency is high provided the external heating jacket can be placed in close contact with the food or container. This implies that soft or semi-soft container concepts would seriously degrade the heating performance of the wrap-on jacket. However, recent developments (see food heating Concept 3.2.6) have circumvented the rigid container requirement, resulting in a more flexible application of the "external" resistance heating concept. On the relative strength of this recent application, the external heating jacket concept is rated uncompetitive.

f. Concept: Self-Heating Food Package (3.2.6)

Concept Description: The heating mechanism for this concept relies on the electrical resistance circuit made by slotting a sheet of aluminum foil so that the remaining foil material forms continuous electrical paths. The slotted piece of aluminum foil is then integrated with the proposed food packaging concept. When electrical power is applied directly to the food package, the aluminum foil instantaneously creates a uniform heat of predesigned intensity over its whole area, which is immediately transmitted to the food in the package. Soft and semi-soft plastic food packages can be retained on a vertical or horizontal surface with thermally insulated clipboard retention clamps. The clamps provide electrical power as well as zero-g retention means. Likewise, rigid food containers can be inserted into expedient locations above the preparation area where detents or spring fingers provide for power and retention requirements. A slightly different approach to the self-heating concept is the self-heating ceramic food container; heat is provided by resistance heating elements imbedded in the ceramic container.

Technical Analysis: The self-heating package concept is compatible with generally all container shapes and materials. Operability is excellent; weight, power, and volume are very competitive. This concept requires a small amount of development effort. Crew size applicability rating is acceptable only for the smaller crew sizes. This concept is compatible with the onboard electrical power supply only.

g. Concept: Induction Heating of Foods (3.2.7)

Concept Description: Metallic food containers are placed within a cylindrical envelope described by a wound helical induction coil. When an alternating current flows through the induction coil, a magnetic field is developed in all directions. Any metal part or conductive material placed within the coil will heat up without physical contact with the coil. The heating phenomenon is similar to that which occurs in an electrical transformer.

Technical Analysis: This concept requires an auxiliary power converter; metallic containers are mandatory; large penalties associated with power and weight; food stirring may be required to eliminate cold spots in larger containers.

h. Concept: Conduction Heating Oven (3.2.8)

Concept Description: The conduction oven concept would be designed with small compartments to contain individual food packages. These compartments would be separated from each other and independently lined with resistance heating elements. The assumption is to provide intimate contact between the surfaces of the packages and heated compartment thus establishing the conductive coupling.

Technical Analysis: Although the individual compartments do provide for effective coupling of heater and food packages, they also provide a considerable mass which must be heated concurrently with the food. A considerable volume penalty is also inherent in the compartment concept. This concept has a direct impact on packaging materials and packaging sizes; the concept is not flexible enough to heat large food masses in bulk configurations.

i. Concept: Probe-Type Resistance Heating (3.2.9)

Concept Description: Heat is released directly into the food by means of a resistance heated food probe. The heat is transferred entirely by conduction between solid and liquid, thus eliminating any air gap in the coupling between heating source and heated food package. The external wall of the food package would be at a lower temperature; lower heat losses and increased efficiency would result without an increase in system weight. Since the probe must penetrate the container wall, temperatures on the surface of the probe must not exceed the 193°F boiling point (at 10 psia) so as to preclude bubbling and splattering.

Technical Analysis: For any given set of restraints on food mass, package shape, cooking time, and maximum temperature, there is an optimum sized surface area for the electrically heated probe. Accordingly, preliminary investigations indicate that a 30% to 39% package ullage must be provided so that probe insertion does not cause food spill-over. Unfortunately, this volume restriction on packaging severely impacts on the size of the freezer as well as other food storage facilities. Constant cleansing of the heating probe results in low crew acceptability.

j. Concept: Pressure Cooker Heating (3.2.10)

Concept Description: This concept relies upon the high rate of heat transfer associated with the boiling/condensing phenomenon occurring inside a common pressure cooker (pressurized chamber).

Technical Analysis: Development risk for this concept must be considered as high. It would be necessary to centrifugally create a gravity field within the heating chamber to overcome the problems of zero-g boiling. Safety factors, operability, and crew acceptance would penalize this concept. In addition, food packaging concepts must be designed to minimize food seepage and water penetration.

k. Concept: Flash Steam Heating (3.2.11)

Concept Description: Water that has been heated to approximately 200°F is introduced into a low pressure food chamber through suitable dispersion nozzles where it immediately flashes into a vapor phase. The nozzles ensure that the high velocity stream impinges upon the food packages, thus increasing the heat transfer mechanism. A pressure of about 7 psia is maintained inside the sealed heating chamber by controlled metering to a vacuum source.

Technical Analysis: Assuming the internal pressure is maintained by venting the steam chamber to space vacuum, makeup water must be provided and pumped back into the power source circuit (the waste heat loop or 200°F local isotope loop); or, assuming the internal pressure is maintained by evacuation pumping, the vapor can be condensed and recovered for reuse. Both alternatives have large weight, development, and operability penalties.

l. Concept: Direct Exposure to Solar Energy (3.2.12)

Concept Description: Food is heated rapidly by exposing it directly to solar energy that has been collected and concentrated into a high intensity ray.

Technical Analysis: This concept is discarded because of the high development risk and low crew acceptability.

m. Concept: Combination Microwave and Resistance Heating (3.2.13)

Concept Description: This concept combines the speed and effectiveness of the microwave warming oven plus the capability to broil or brown foods in the manner of a radiant or resistance oven. The concept is a microwave oven fitted with suitable quartz elements for the browning capability.

Technical Analysis: The addition of the browning capability further enhances the crew acceptability of the ordinary microwave oven (Concept 3.2.2). Weight and volume increases are imperceptible; power required for the radiant capability is only slightly more than the comparable microwave-only concept.

n. Concept: Combination Hot Air Convection and Resistance Heating Oven (3.2.14)

Concept Description: This concept combines the effectiveness of the hot air convective oven plus the capability to broil or brown food in the manner of a radiant or resistance oven. The concept is a hot air convection oven fitted with a suitable quartz element for the browning capability.

Technical Analysis: The addition of the browning capability further enhances the crew acceptance of the ordinary hot air convection oven (Concept 3.2.1). Weight and volume increases are imperceptible; power required for the radiant capability is in the same order as the comparable "convection-only" concept.

o. Concept: Electrically Heated Food Tray (3.2.15)

Concept Description: Frozen food packages or canned foods are placed in suitable cavities located in the food tray. The cavities provide intimate contact with the food packages so that zero-g retention and conductive food heating are accomplished. The cavities are lined with resistance heating elements that are independently operated with suitable controls located on the tray or on the counter adjacent to the tray location. Power is provided through external contact plates located on the tray/counter interface.

Technical Analysis: This concept, which is currently being utilized on the NASA SKYLAB Program, is felt to have particular merit on missions involving small crew sizes.

p. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-7 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-7

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 3.2	SUB-FUNCTION TITLE: Food Heating Devices and Techniques	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.2.1	Hot Air Convective Heating Oven	11.8		X	-		X
3.2.2	Microwave Heating Oven	11.4		X	-		X
3.2.3	Resistance Heating Oven	10.0		X	-		X
3.2.4	Dielectric Heating Oven	(9.0)	X				
3.2.5	Wrap-On Heating Jacket	(9.4)	X				
3.2.6	Self-Heating Food Package	13.2		X	-		X
3.2.7	Induction Heating of Foods	8.0	X				
3.2.8	Conduction Heating Oven	8.2	X				
3.2.9	Probe-Type Resistance Heating	6.3	X				
3.2.10	Pressure Cooker Heating	6.3	X				
3.2.11	Flash Steam Heating	(9.0)	X				
3.2.12	Direct Exposure To Solar Energy	8.0	X				
3.2.13	Combination Microwave and Resistance Heating Oven	11.7		X	-		X
3.2.14	Combination Hot Air Convection and Resistance Heating Oven	12.2		X	-		X
3.2.15	Electrically Heated Food Tray			X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Hot Air Convective Heating Oven (Concept 3.2.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.2.1.1 through 3.2.1.3 in Data Book - Book I.

   Additional analysis is presented under Concept 3.2.1 in Back-Up Information Sheets, Data Book - Book II.

   Curves of Power, Weight and Volume Versus Crew Size are presented in Figure III-86.

2) Technical Data - Microwave Heating Oven (Concept 3.2.2). Detailed data for this concept are presented on Element Concept Data Sheets 3.2.2.1 through 3.2.2.3 in Data Book - Book I.

Additional analysis is presented under Concept 3.2.2 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figure III-87.

3) Technical Data - Resistance Heating Oven (Concept 3.2.3). Detailed data for this concept are presented on Element Concept Data Sheets 3.2.3.1 through 3.2.3.3 in Data Book - Book I.

Additional analysis is presented under Concept 3.2.3 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figure III-88.

4) Technical Data - Self-Heating Food Package (Concept 3.2.6). Detailed data for this concept are presented on Element Concept Data Sheets 3.2.6.1 through 3.2.6.3 in Data Book - Book I.

Additional analysis is presented under Concept 3.2.6 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figure III-89.

5) Technical Data - Combination Microwave/Resistance Heating Oven (Concept 3.2.13). Detailed data for this concept are presented on Element Concept Data Sheets 3.2.13.1 through 3.2.13.3 in Data Book - Book I.

Additional analysis is presented under Concept 3.2.13 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figure III-90.

6) Technical Data - Combination Hot Air Convection/ Resistance Heating Oven (Concept 3.2.14). Detailed data for this concept are presented on Element Concept Data Sheets 3.2.14.1 through 3.2.14.3 in Data Book - Book I.

Additional analysis is presented under Concept 3.2.14 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figure III-91.

7) Technical Data - Electrically Heated Food Tray (Concept 3.2.15). Detailed data for this concept are presented on Element Concept Data Sheets 3.2.15.1 through 3.2.15.3 in Data Book - Book I.

Additional analysis is presented under Concept 3.2.15 in Back-Up Information Sheets, Data Book - Book II.

Curves of Power, Weight and Volume Versus Crew Size are presented in Figure III-92.

q. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above.

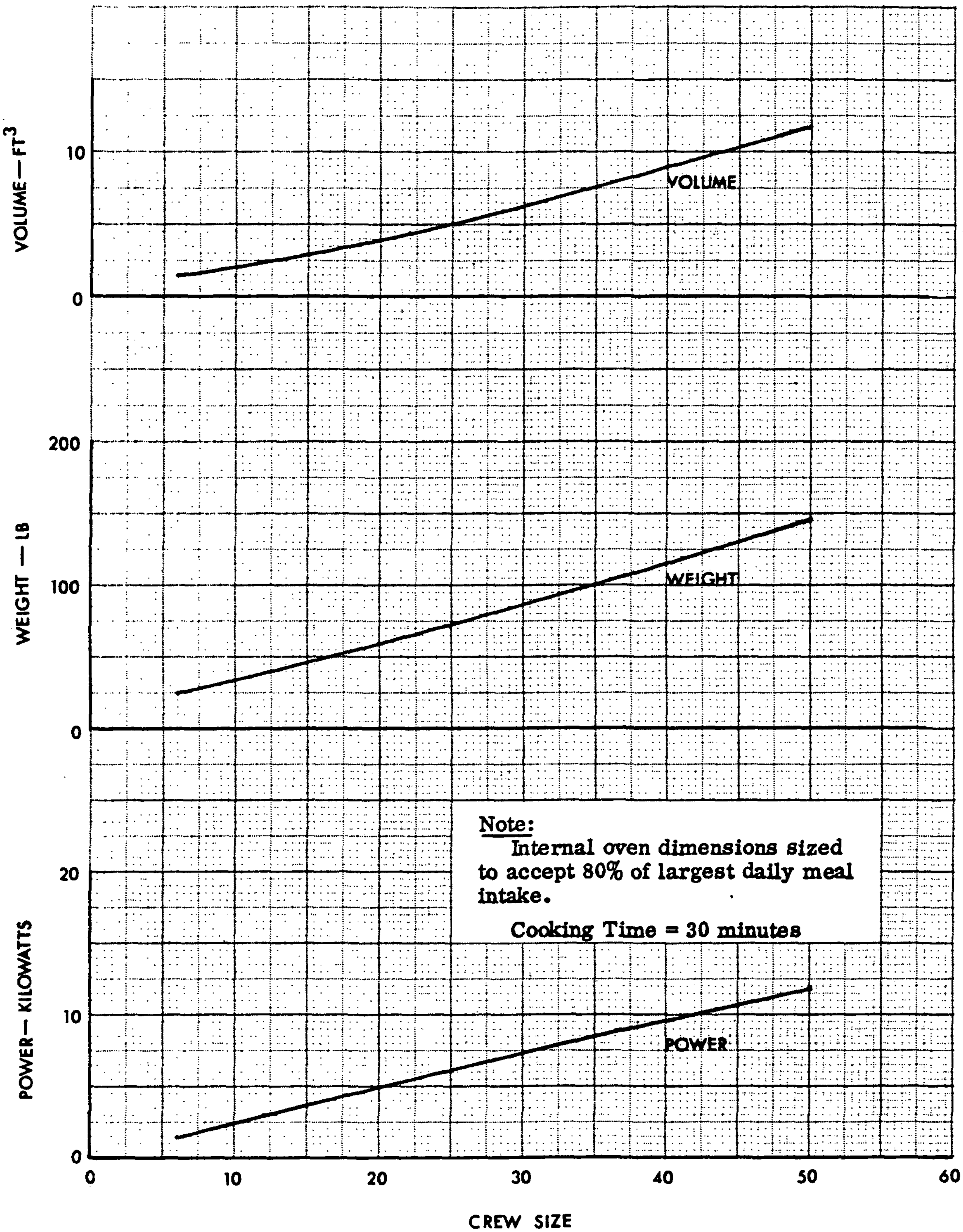


Figure III-86. Installed Total Power, Weight, and Volume Versus Crew Size For Hot Air Convection Warming Oven

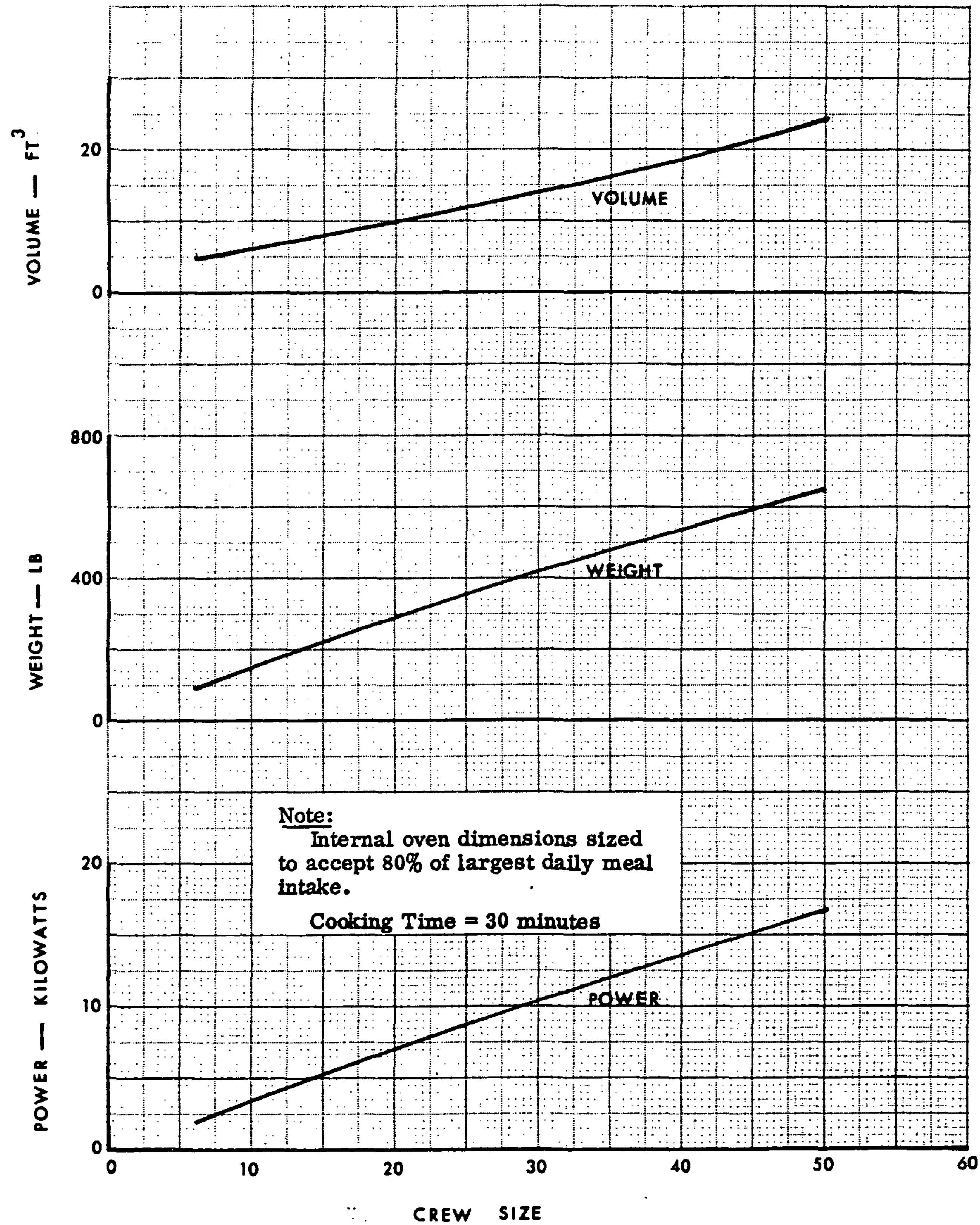


Figure III-87. Installed Total Power, Weight, and Volume Versus Crew Size For Microwave Oven

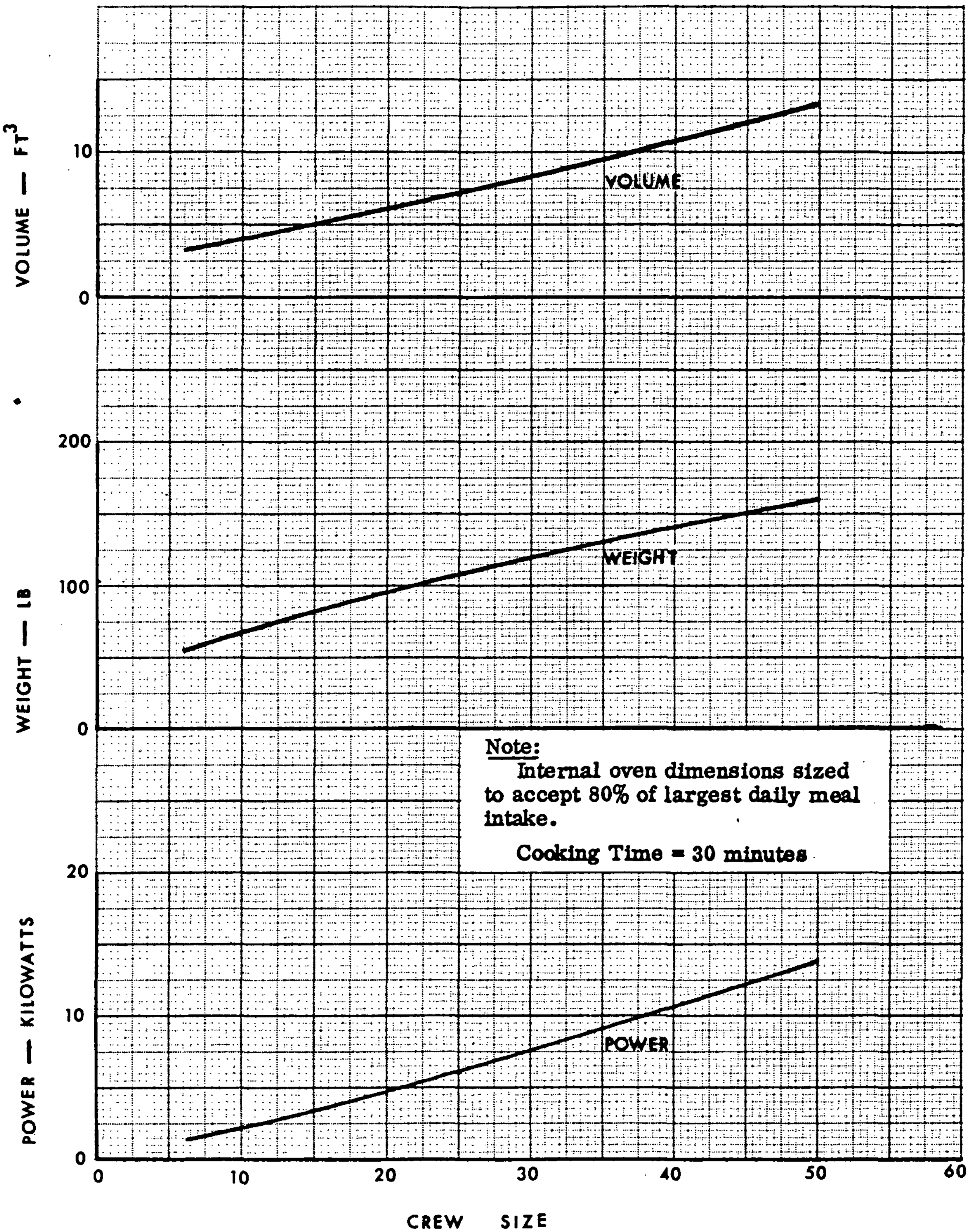


Figure III-88. Installed Total Power, Weight, and Volume Versus Crew Size For Resistance Warming Oven

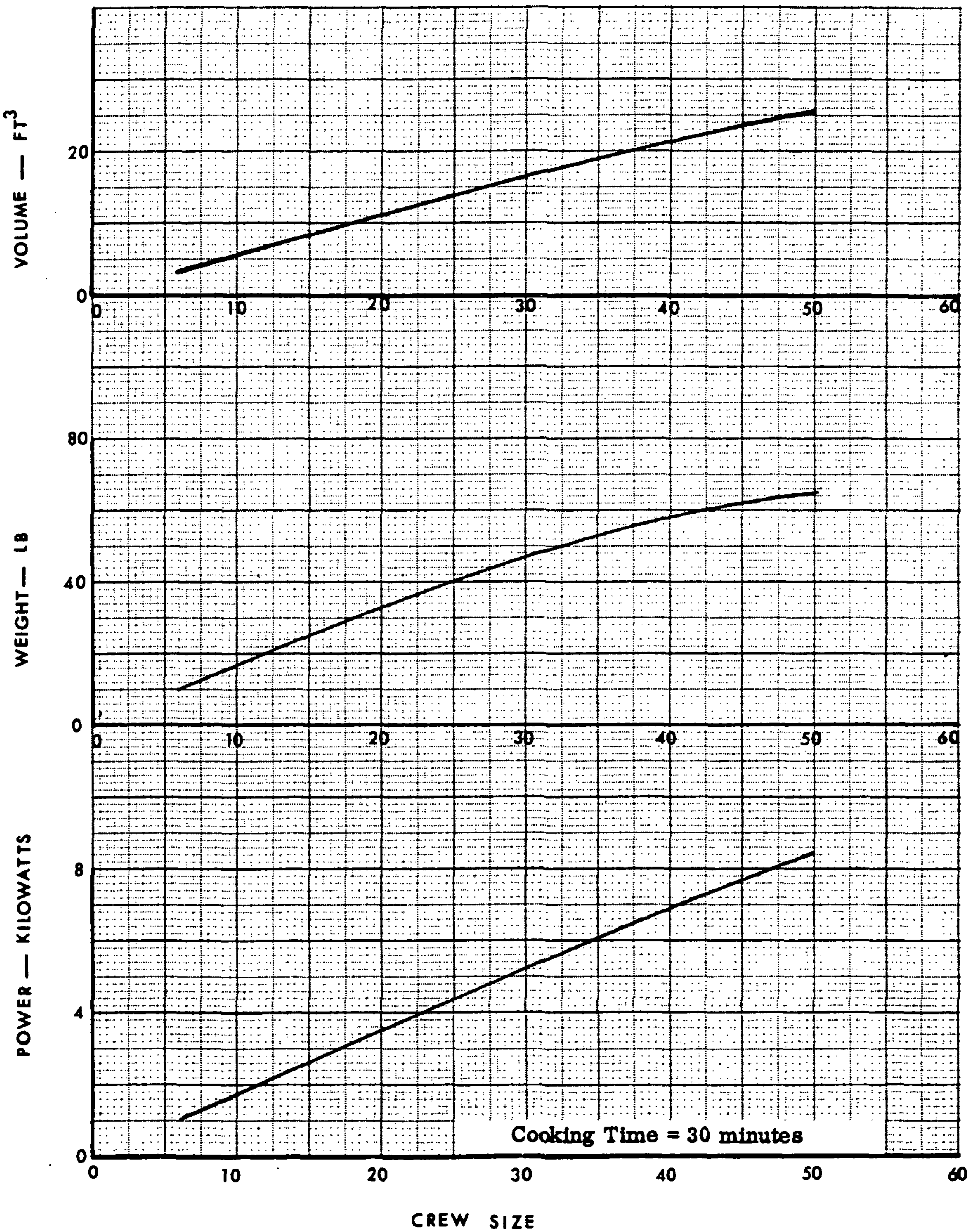


Figure III-89. Installed Total Power, Weight, and Volume Versus Crew Size For Self-Heating Food Packages

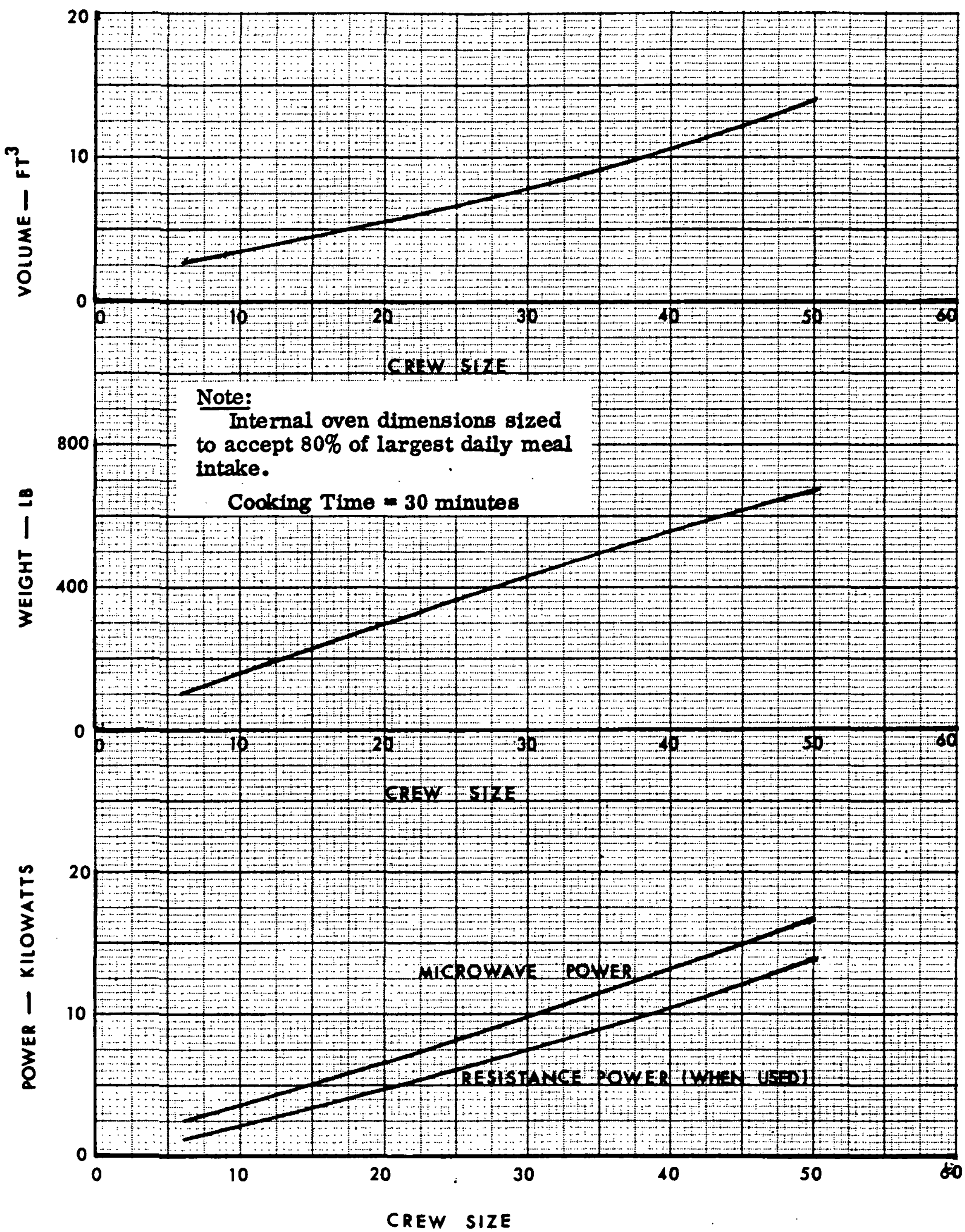


Figure III-90. Installed Total Power, Weight, and Volume Versus Crew Size For Combination Warming Oven (Microwave Plus Resistance)

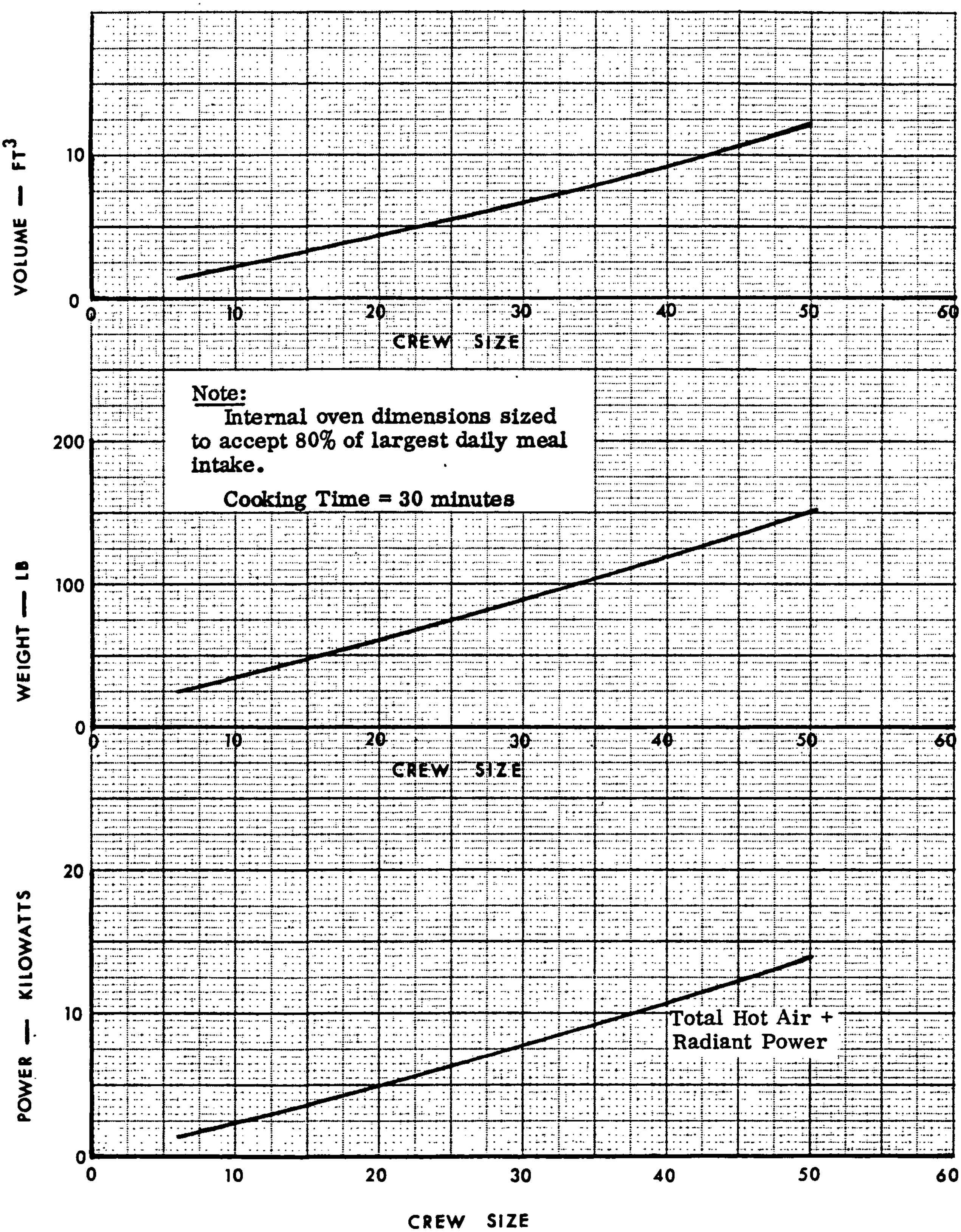


Figure III-91. Installed Total Power, Weight, and Volume Versus Crew Size For Combination Warming Oven (Hot Air Convection Plus Resistance)

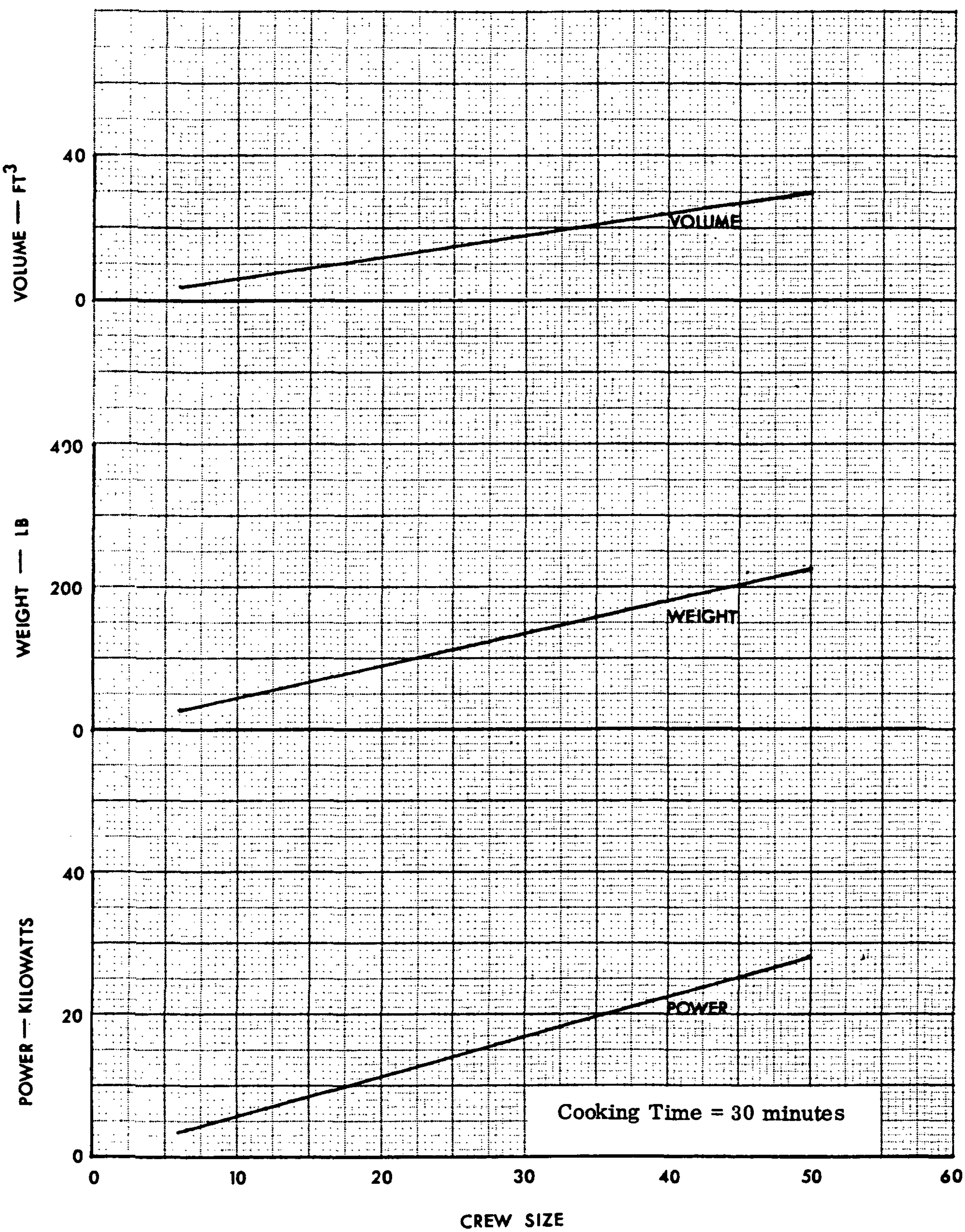
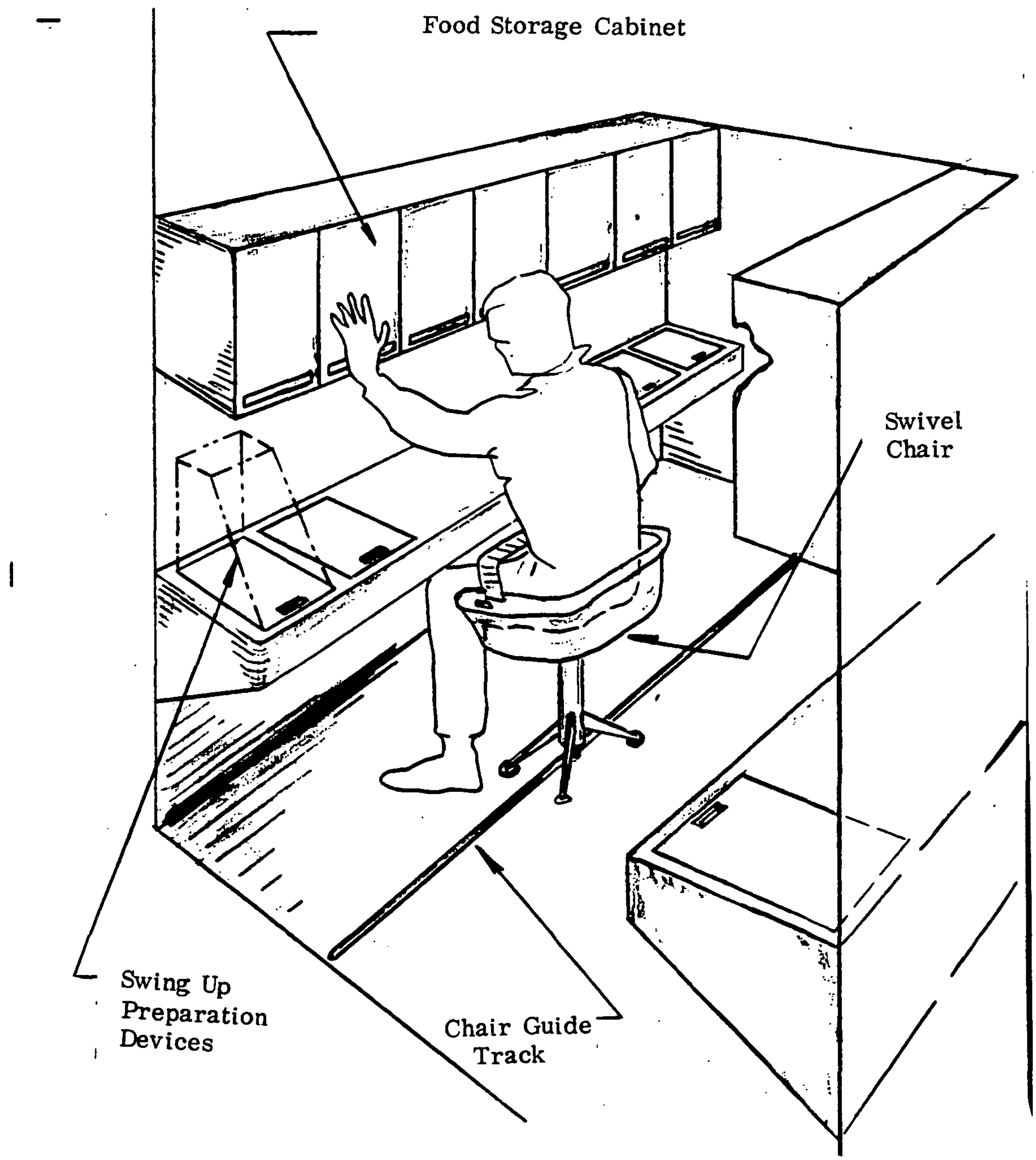


Figure III-92. Installed Total Power, Weight, and Volume Versus Crew Size For Electrically Heated Food Tray

FOOD SYSTEM STUDY SKETCH

Title: Provide For Preparation - Sit-Down Type Food Preparation Area

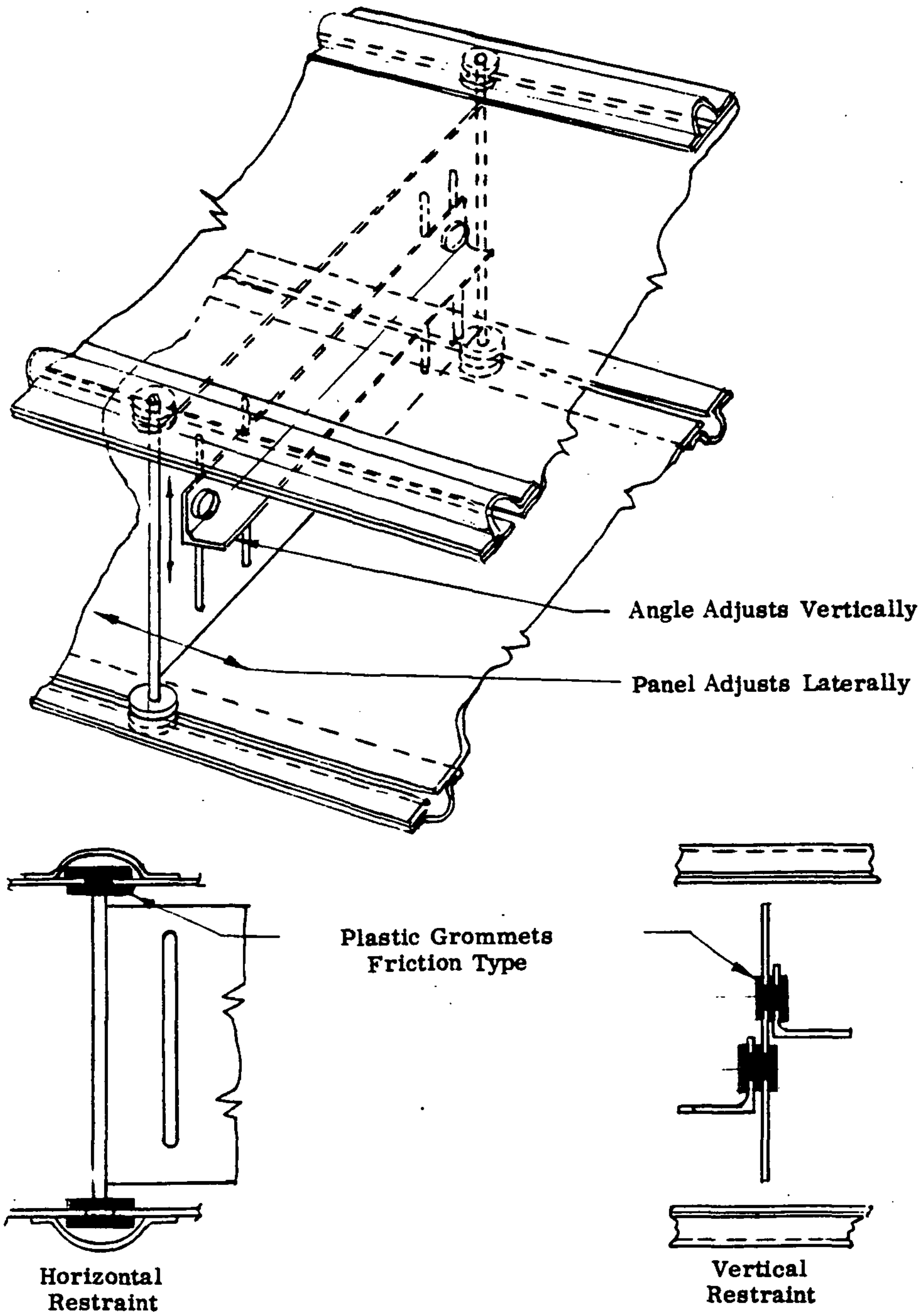


In this concept the galley crewman will be restrained in a maneuverable, swivel-type chair which is guided by a recessed track (may be surface guided). From a sitting position, the crewman can reach all cabinets and preparation device both in front of and behind him. He will prepare the meals and then serve them through a pass-through opening to the dining area. This is a zero-g concept for small crew sizes of 6 to 12 men.

D— 3.0

FOOD SYSTEM STUDY SKETCH

Title: Oven Restraints



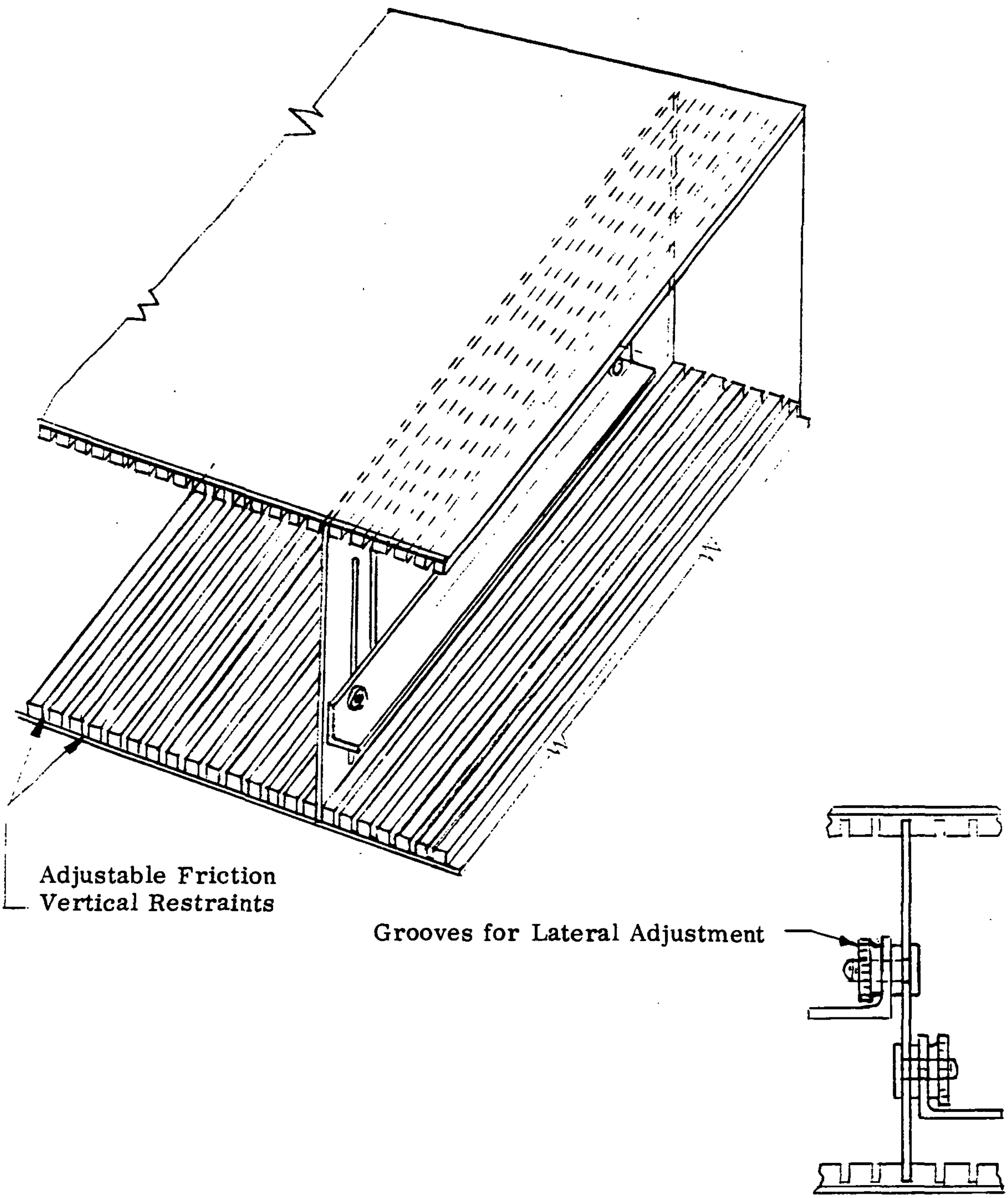
These types of restraints can be used in all the ovens. Complete lateral adjustment is provided for the panels which have vertical adjustable retention angles on both sides.

D— 3.2

(Sheet 1 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Oven Restraints



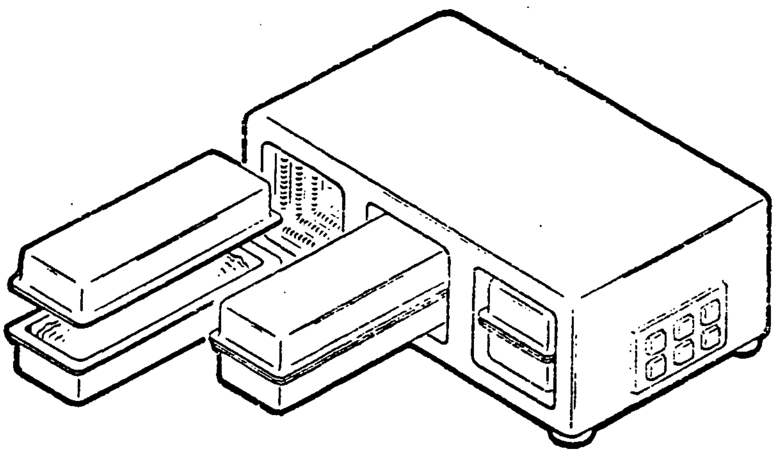
This system of restraints can be used in all the ovens. Lateral adjustment of the panels can be made in increments by sliding the panel in the next groove. Friction slides are provided for vertical adjustment on each panel.

D— 3.2

(Sheet 2 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques
Volume Restrained Baking Oven

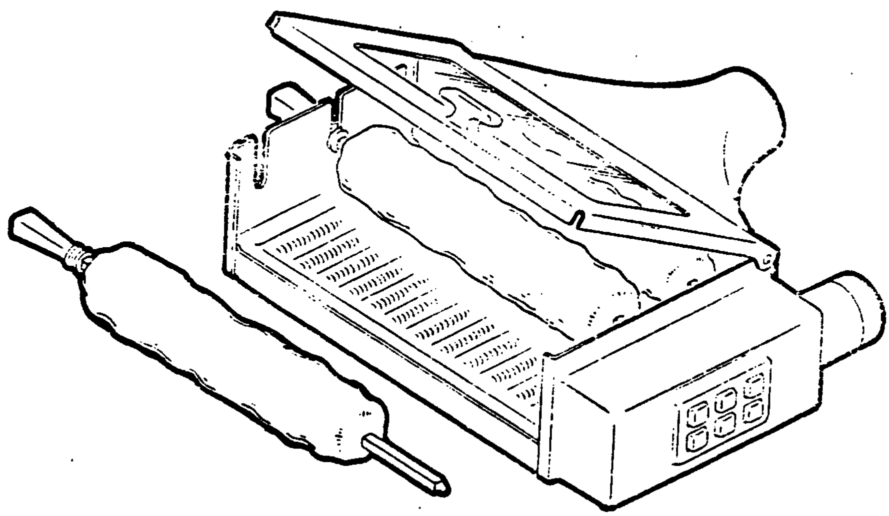


Individual loaf-sized vented containers are used to provide a volume restrained baking technique in zero-gravity. Presized frozen bread dough would be inserted in the container which is placed in an individually heated oven compartment. By restraining the volume, fresh bread, conventional in appearance, could be provided. This device would be considered for long duration missions having extended resupply rotation periods.

D— 3.2A

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques
Bread Baking Oven (Volume Unrestrained)



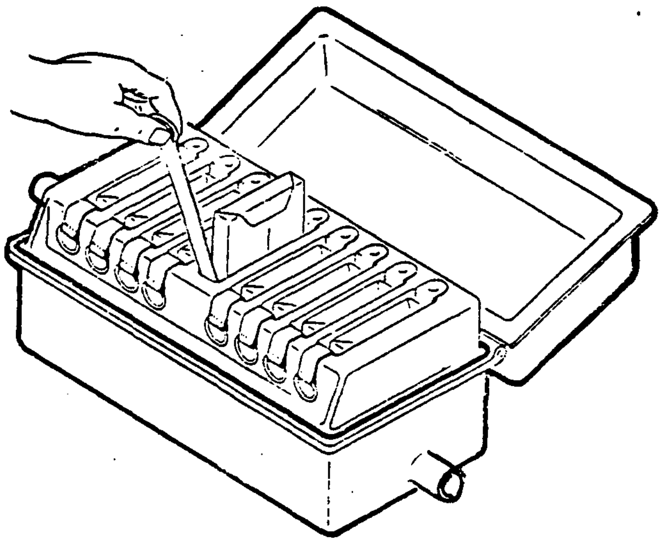
An oven is provided with several rotisseries. The dough is pre-prepared and attached to the rotisserie rods. The bread rotates as it bakes expanding uniformly in all directions.

This concept is primarily applicable to zero-gravity usage.

D— 3.2 B

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques - Individual Meal Portion Heater



The individual meal portion heater is a passively heated, compartmentized heat sink. It is heated by waste heat loop water circulation and is capable of accepting from one to twelve individual meal packages per unit.

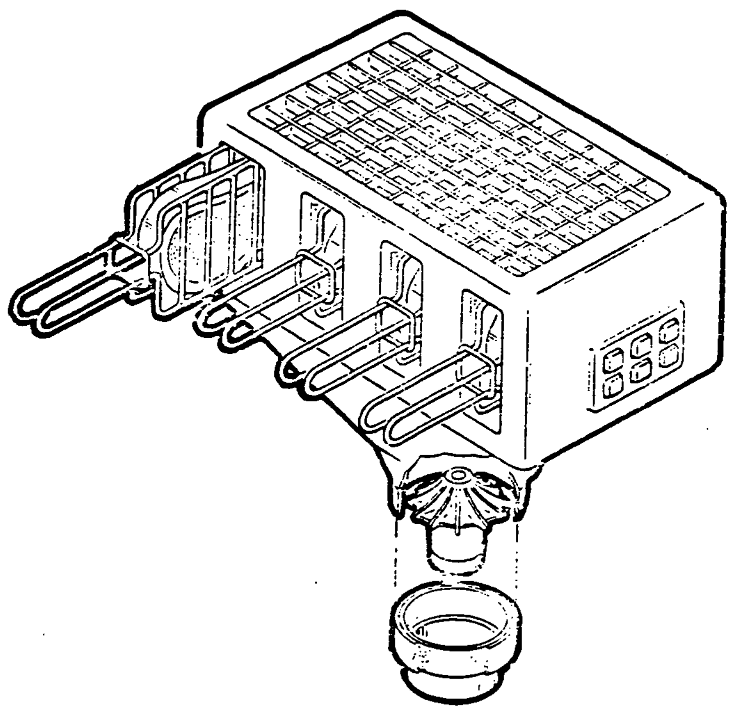
Its functional uses are to heat from ambient temperature, or to maintain in the warmed state, a packet which had been heated previously.

This concept will require minimum further development and is applicable for both zero-g and one-g usage.

D— 3.2C

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques - Broiler With Grease Control

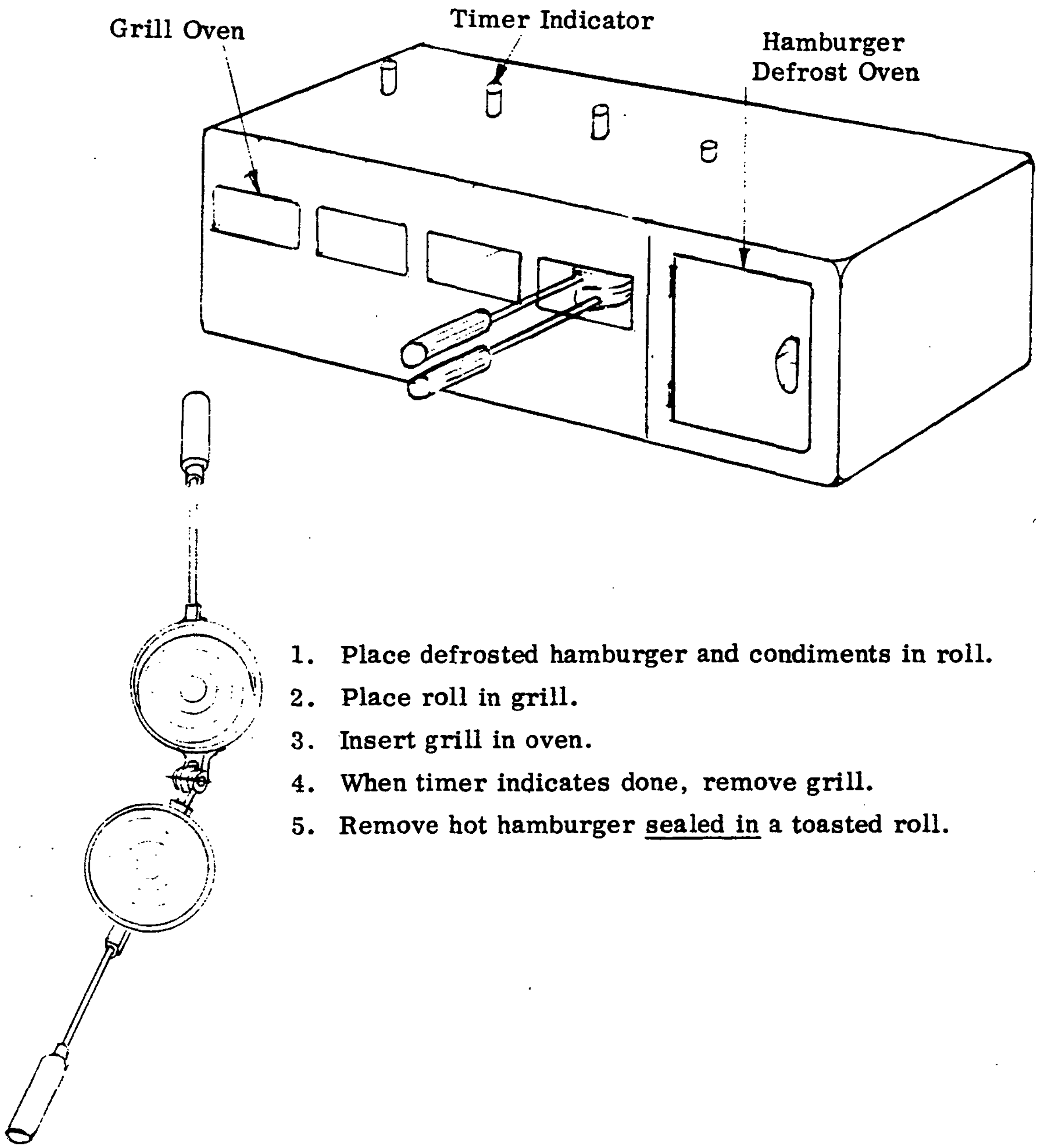


Steaks are clamped in grids and inserted between electric grilling elements. The heating elements are ducted so that airflow will enter the top and exhaust through a common duct at the bottom. A grease slinger, blower, and filter are located in the exit duct. The blower pulls air over the steaks capturing the grease. The slinger separates the grease from the air and stores it. The air returns to the cabin through a filter.

D—3.2D

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques - Hamburger Grill (Precooked)



1. Place defrosted hamburger and condiments in roll.
2. Place roll in grill.
3. Insert grill in oven.
4. When timer indicates done, remove grill.
5. Remove hot hamburger sealed in a toasted roll.

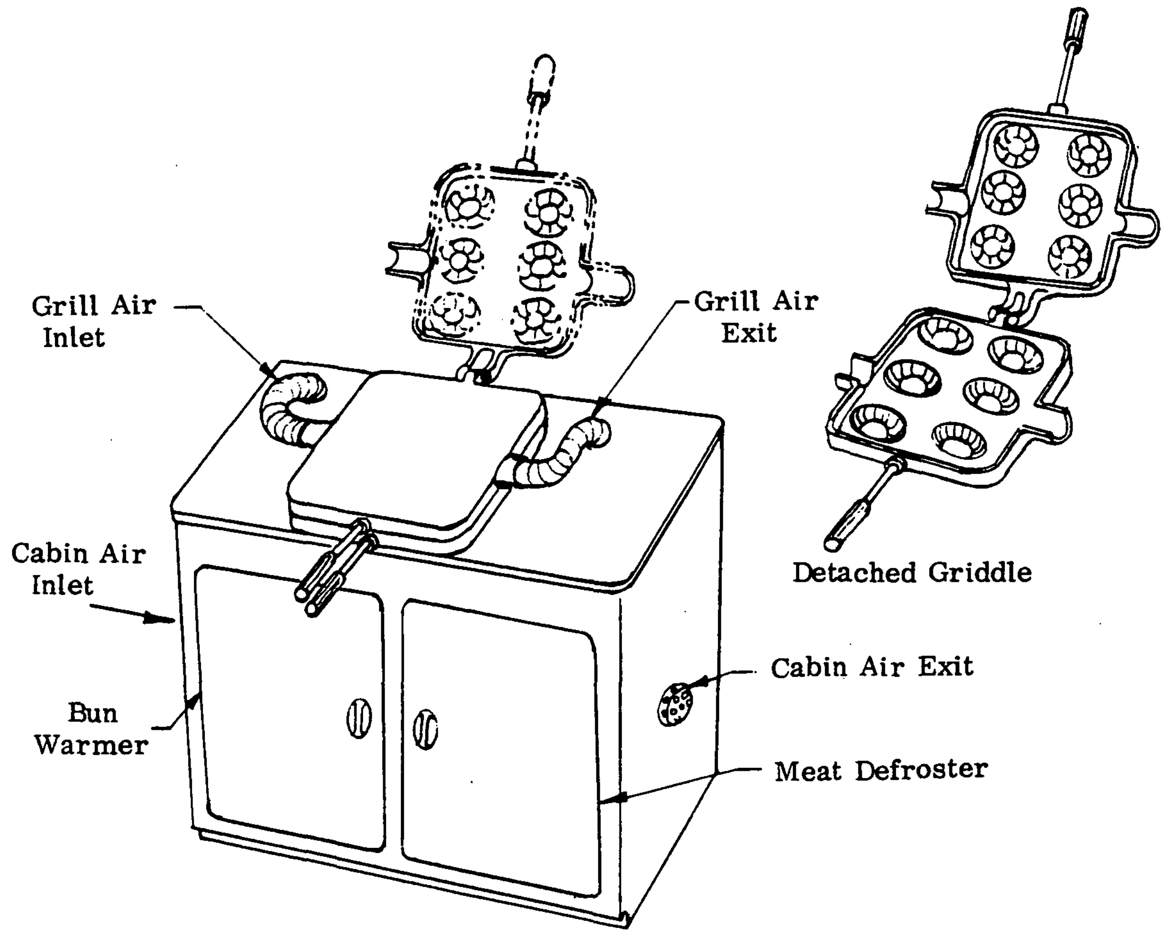
This system consists of a defrost oven with several toasting ovens. It will provide a hot hamburger sealed in a toasted roll with the condiments desired. This can be eaten with little or no spillage.

This unit may be wall mounted or counter top mounted. It is applicable for both zero- and one-g usage.

D— 3.2E

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques - Hamburger Grill



Grease Separator, Air Filter, Odor Control Unit and Fan Are in Cabinet

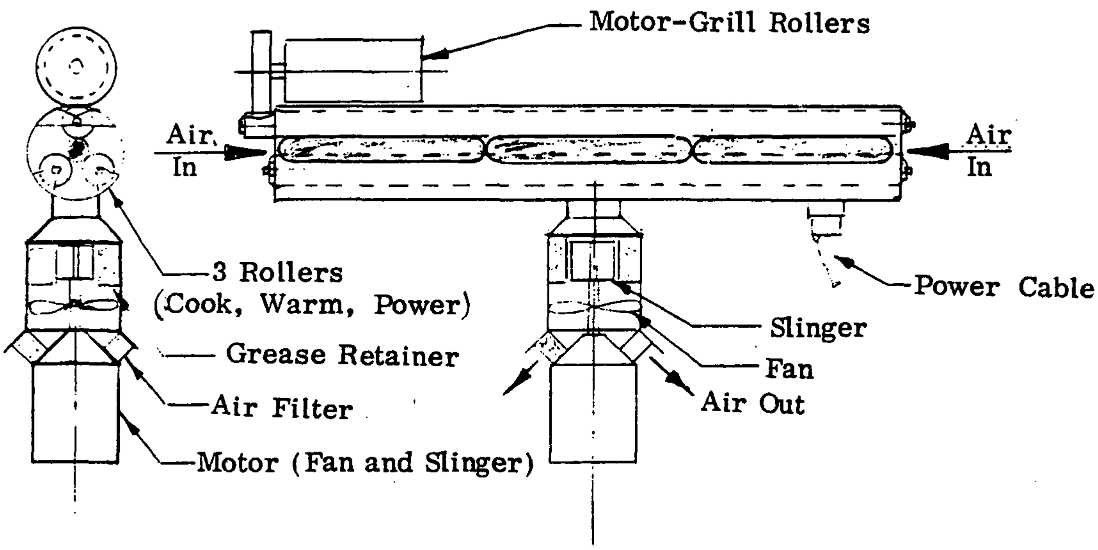
In this concept, a cabinet containing a blower, slinger, and grease filter provides air through a tube into and out of the hamburger grill to capture the grease. The grill separates to open for insertion or removal of the hamburger. The cabinet also contains an electric bun warmer and a meat defroster.

This concept is applicable for both zero- and one-g usage requiring a minimum of further development.

D— 3.2F

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques - Zero-G Frankfurter Grill



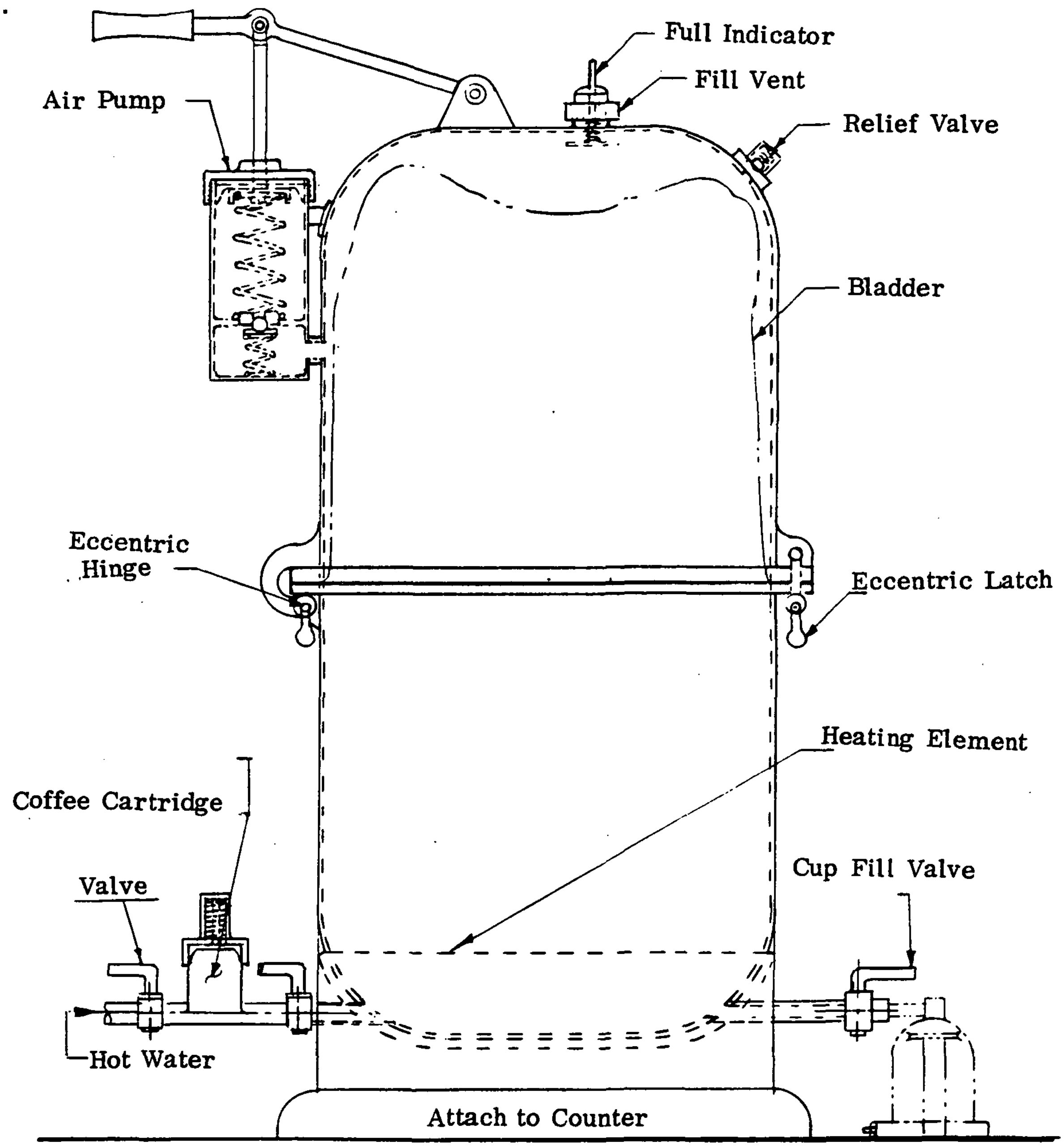
A method of grilling and keeping frankfurters warm is depicted. The grill will consist of three rollers. One roller is heated for grilling through the length of one frankfurter. A second roller is heated through its entire length to keep them warm. The third roller is used to captivate the frankfurters and it is rotated to heat them uniformly. A blower, slinger, and filter system is used to capture the grease. The airflow will transport the grease to the slinger and filter.

To grill a frankfurter, insert a fresh one in one end and obtain it at the other end as it completes its grilling cycle and is moved through the rollers due to the directional twist of the roller design

D— 3.2 G

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques - Coffee Urn



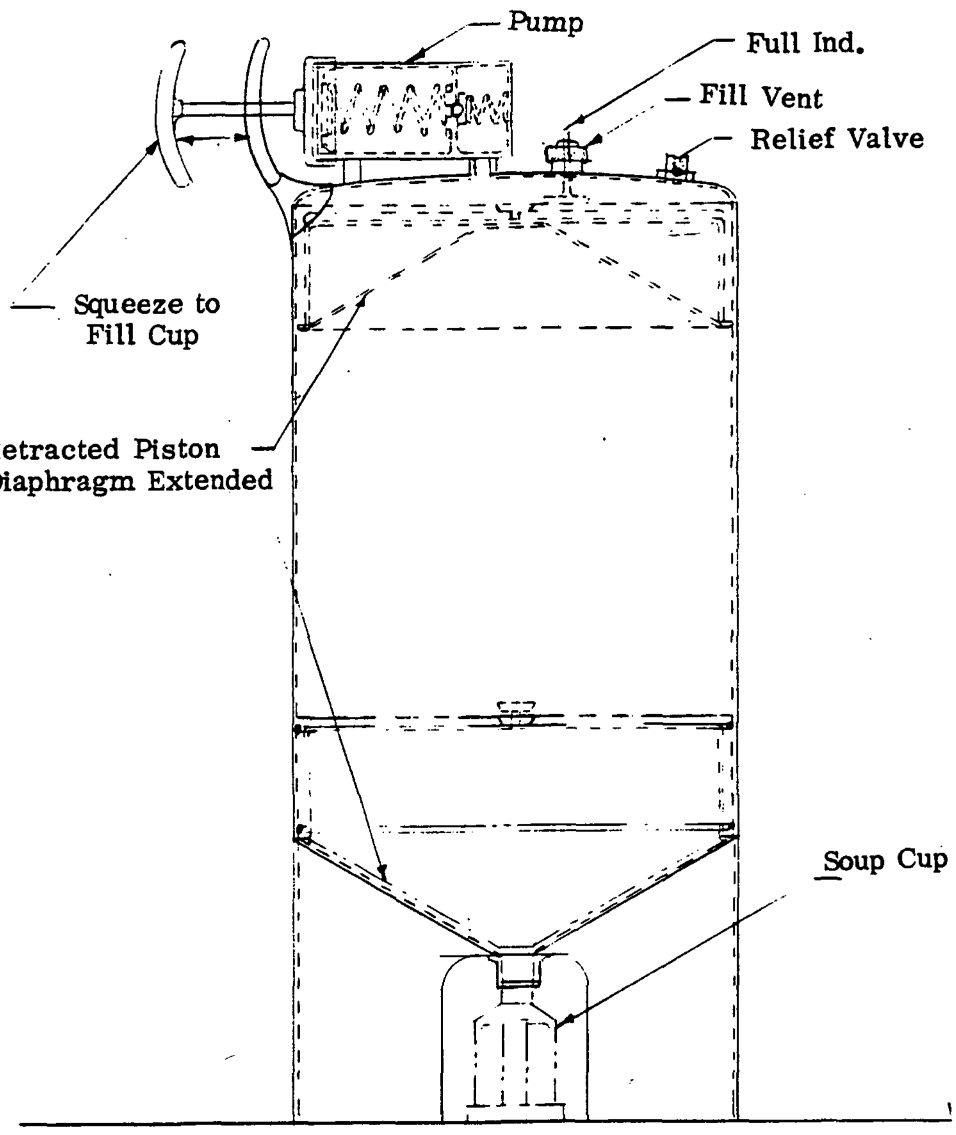
This urn is designed so that one cartridge of freeze dried coffee will make one urn of reconstituted coffee. The cartridge is placed in the hot water inlet so that the coffee is evenly mixed by the water as it enters the urn. One stroke of the pump will fill one coffee cup. A heating element is included to maintain the temperature of the coffee.

This is a zero-g concept requiring further development.

D– 3.2 H

FOOD SYSTEM STUDY SKETCH

Title: Food Heating Devices and Techniques - Soup Dispenser



This dispenser is designed so that it can be filled with chunky soup. One squeeze of air pump handle will fill one soup container.

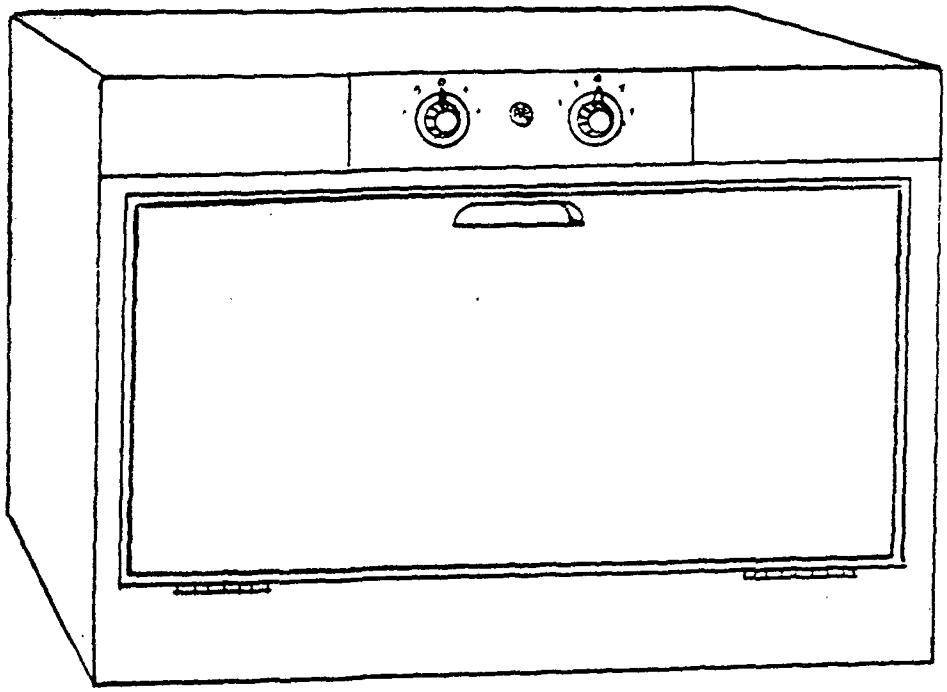
The air pump is used to move the piston which moves the soup out through the exit tube into the cup. When the piston reaches the end of the cylindrical portion, it stops, and a valve opens allowing the air to extend the diaphragm. The diaphragm is designed so that it will expand first around the outer periphery and last at the center. This will force out the last of the soup without damage to the chunks.

This is a zero-g concept which will require further development.

D— 3.2 i

FOOD SYSTEM STUDY SKETCH

Title: Hot Air Convective Heating Oven



Oven: 10 x 24 x 14 (inches)

Overall: 20 x 28 x 20 (inches)

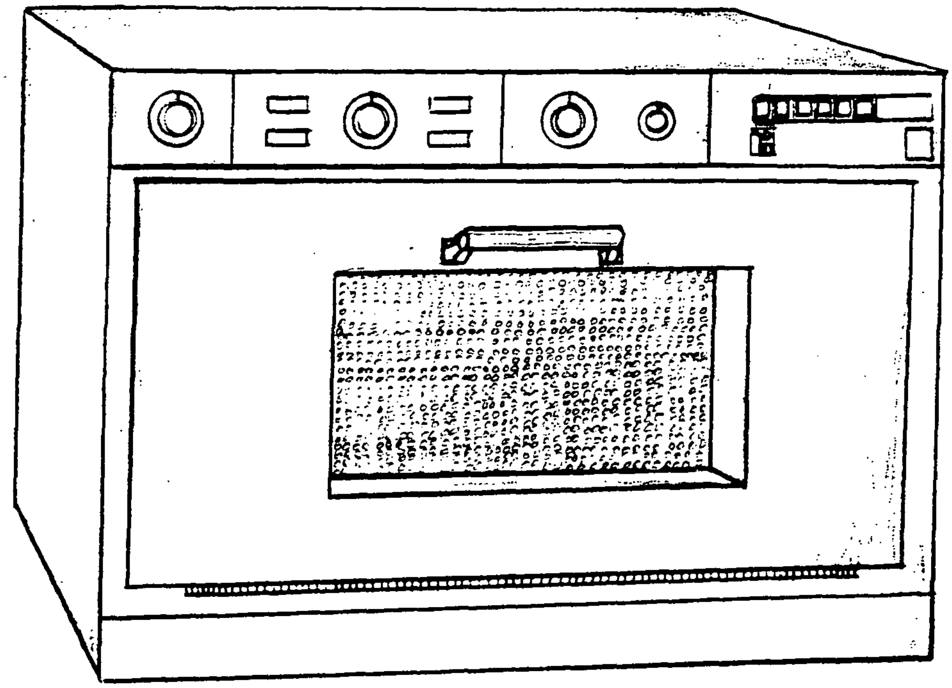
In this concept air is circulated through insulated food compartments after it has been heated to approximately 350°F/400°F. The heated air impinges upon the external surface of the food containment concept and raises the temperature accordingly. Recirculation of the air is accomplished with a fan or blower.

The concept of heating with a forced convection medium is an effective and flexible means of heating food; the thermal effectiveness of this concept is independent of the gravitational environment. This concept ranks high for crew acceptability, operability, and availability.

D— 3.2.1

FOOD SYSTEM STUDY SKETCH

Title: Microwave Heating Oven



Oven: 10 x 24 x 14 (inches)
Overall: 20 x 28 x 20 (inches)

Food is warmed to proper temperatures by directing microwave energy to an insulated food cavity. Waves are contained within the cavity with suitable shielding, door seals, and interlocking door circuits.

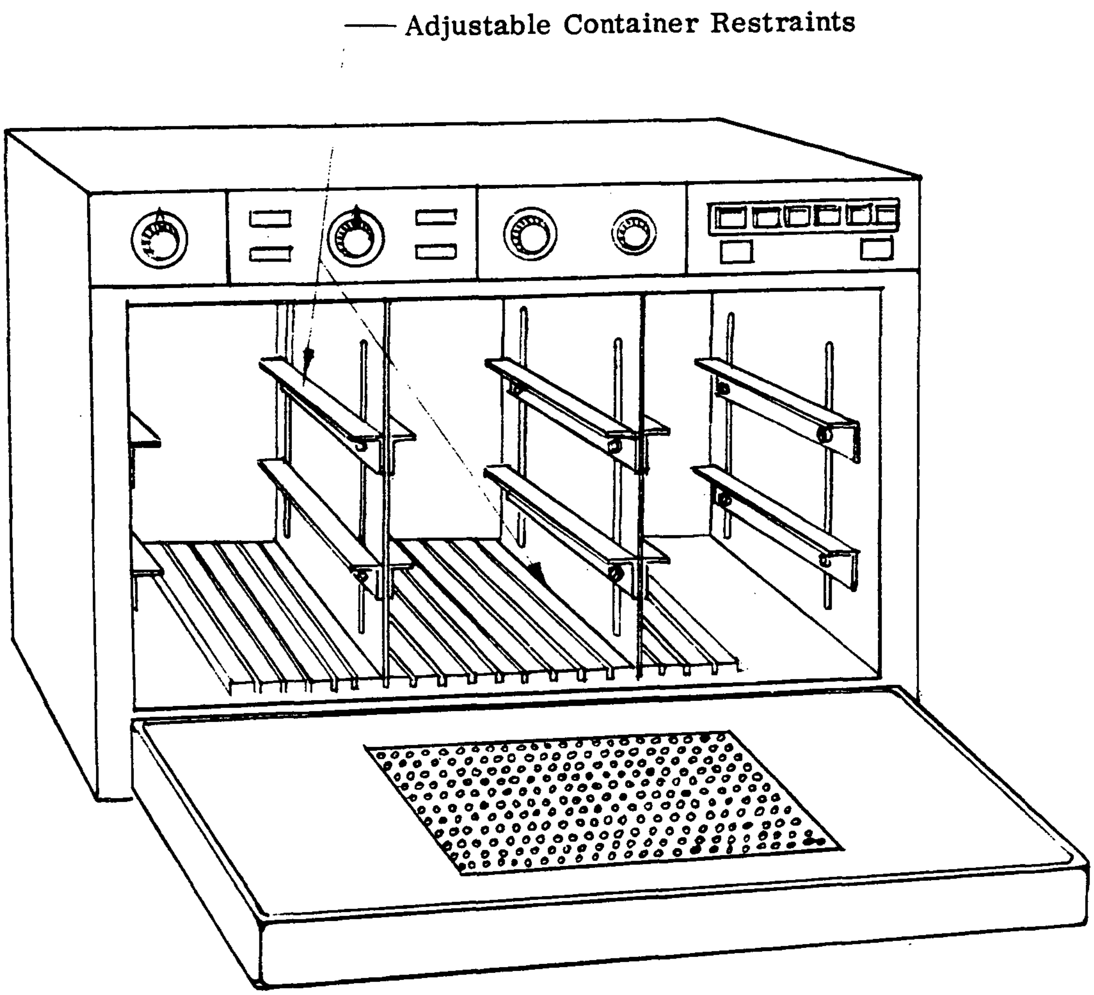
Microwave heating ovens require a minimum of development effort; warm-up and cooking time is immediate, and the technique is highly crew acceptable. Power is directed into the food so there is no emission of heat from the oven surfaces. The onboard electrical source is the only power concept compatible with the microwave heating oven.

D— 3.2.2

(Sheet 1 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Microwave Heating Oven (Adjustable Restraints)



This sketch shows the oven restraints in place in the oven. Adjustment is provided by friction in both the vertical and horizontal directions.

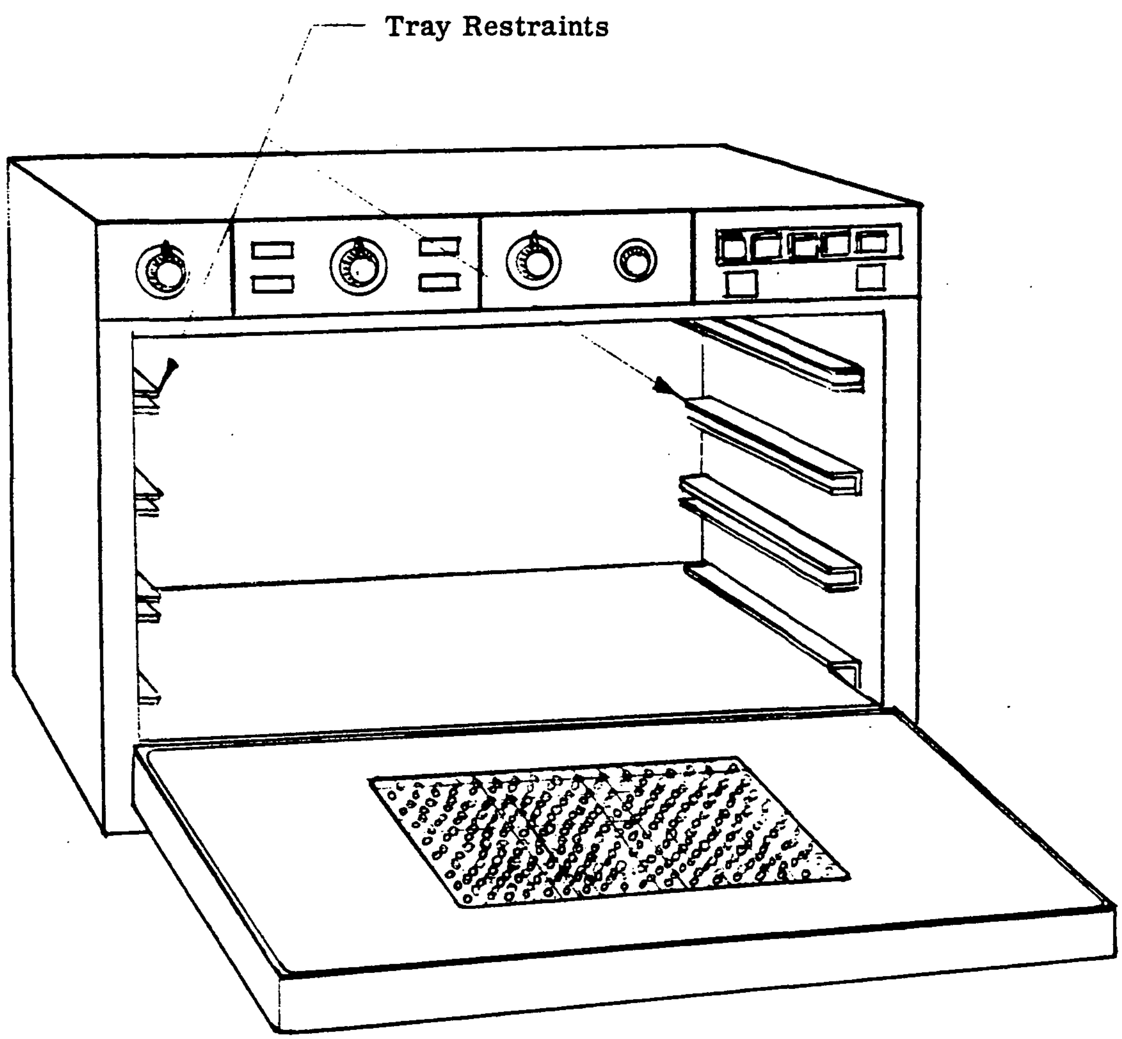
With this concept, various sizes of dishes or trays may be heated. This will be applicable for both zero- and one-g usage.

D— 3.2.2

(Sheet 2 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Microwave Heating Oven (Tray Restraints)



This sketch depicts tray restraints installed in the oven sides. The restraint opening is sized to hold a tray with a minimum amount of space between mating surfaces.

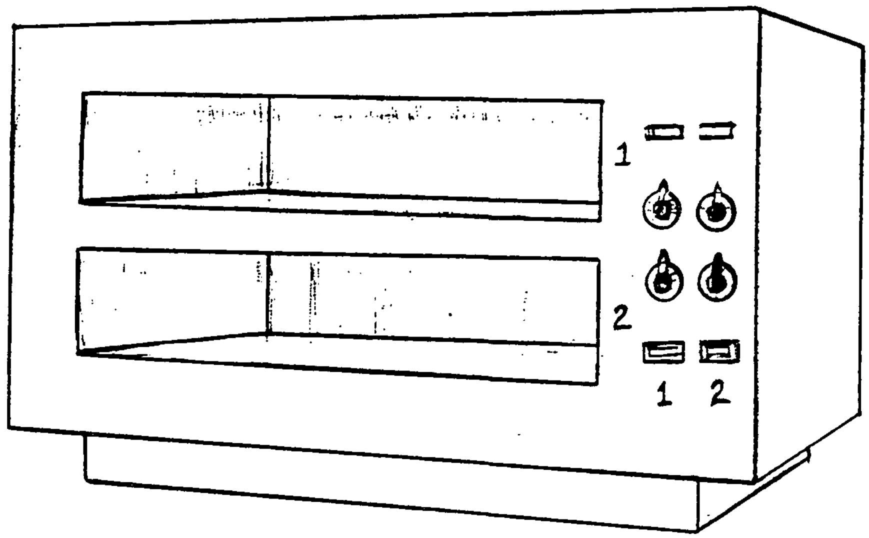
This concept is applicable for zero-g and one-g conditions.

D— 3.2.2

(Sheet 3 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Resistance Heating Oven



Each Oven: 4 x 25 x 14.5 (inches)

Overall: 18.5 x 24 x 29 (inches)

This heating concept primarily relies on the radiation heat transfer mechanism emanating from electrically heated quartz elements to heat the food mass. The device will function just as a household broiling oven would except for the convection coefficients absent in a zero-g environment.

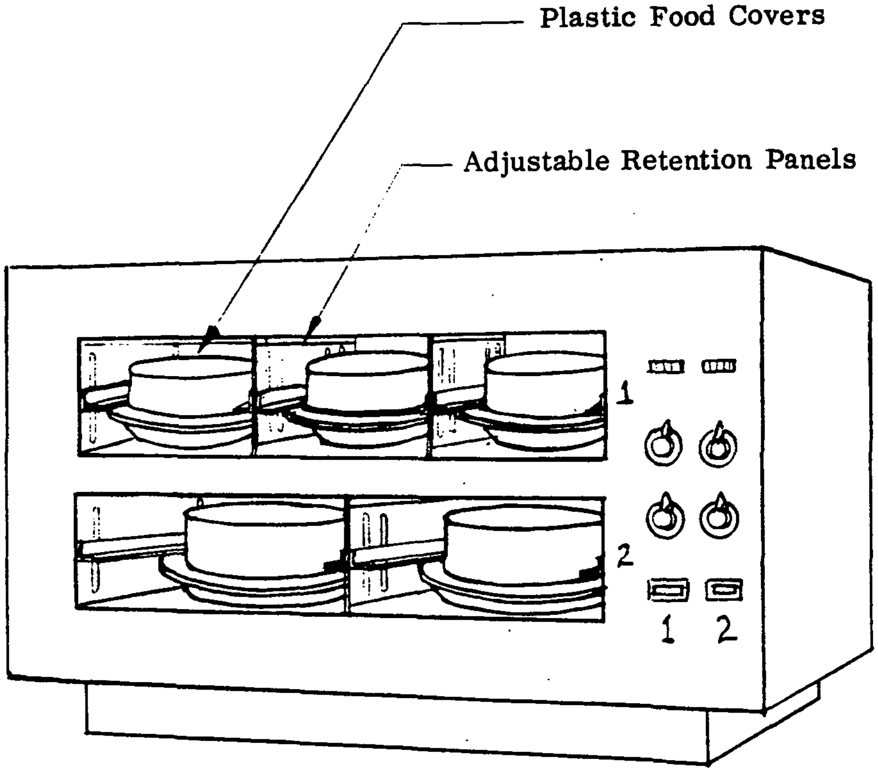
Because of the inherent lack of immediate contact with the food or containers, the quartz rods are relatively free to radiate energy in all directions; consequently, heating efficiency decreases while the power requirement increases to accomplish the food heating function. Plastic packaging concepts cannot be used in this heating oven.

D— 3.2.3

(Sheet 1 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Resistance Heating Oven (Retention Devices)



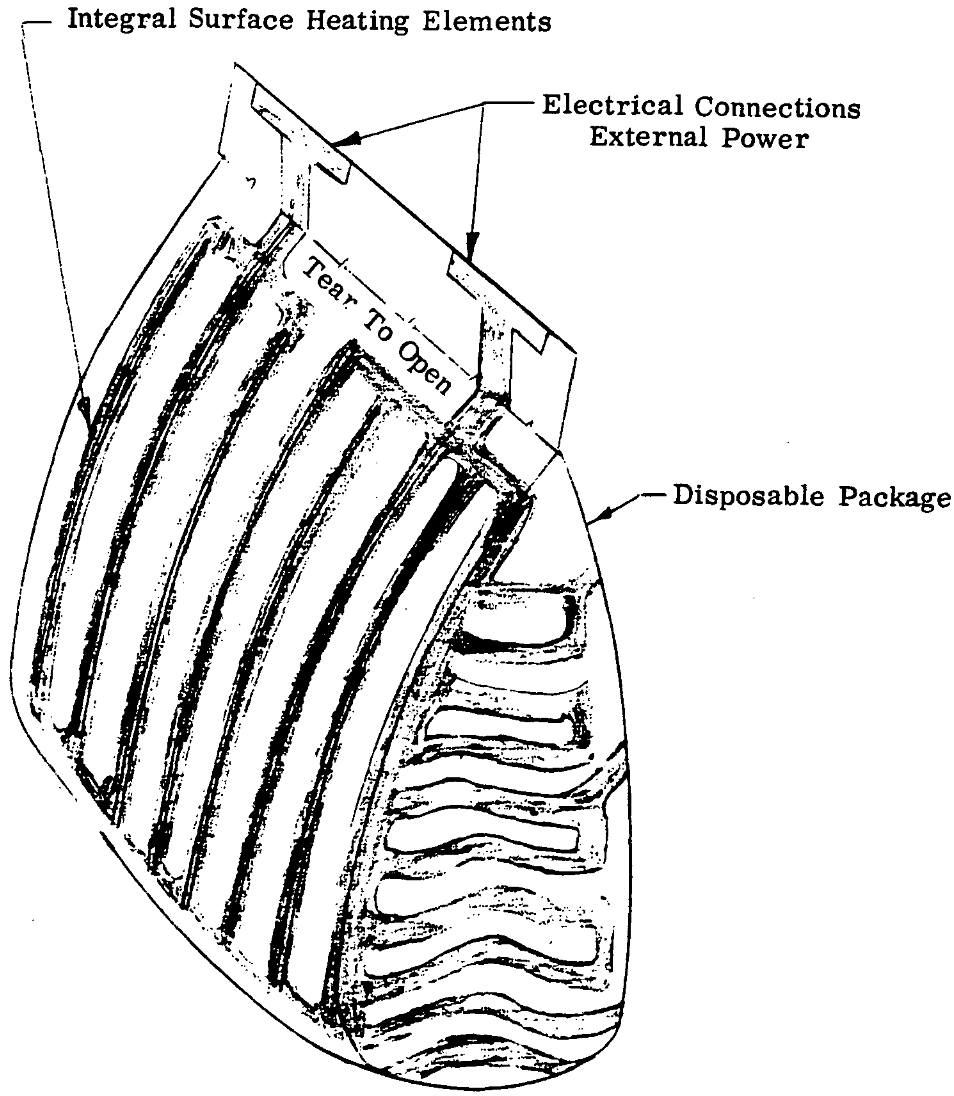
This illustration depicts the adjustable friction retention devices in operation in a resistance heating oven.

D— 3.2.3

(Sheet 2 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Self-Heating Food Package



A slotted piece of aluminum foil is integrated with the proposed food packaging concept. When electrical power is applied directly to the food package, the aluminum foil instantaneously creates a uniform heat of predesigned intensity over its whole area; this heat being immediately transmitted to the food in the package. Soft and semi-soft plastic food packages can be retained on a vertical or horizontal surface with thermally insulated clip-board retention clamps. The clamps provide electrical power as well as zero-g retention means. Likewise, rigid food containers can be inserted into expedient locations above the preparation area where detents or spring fingers provide for power and retention requirements.

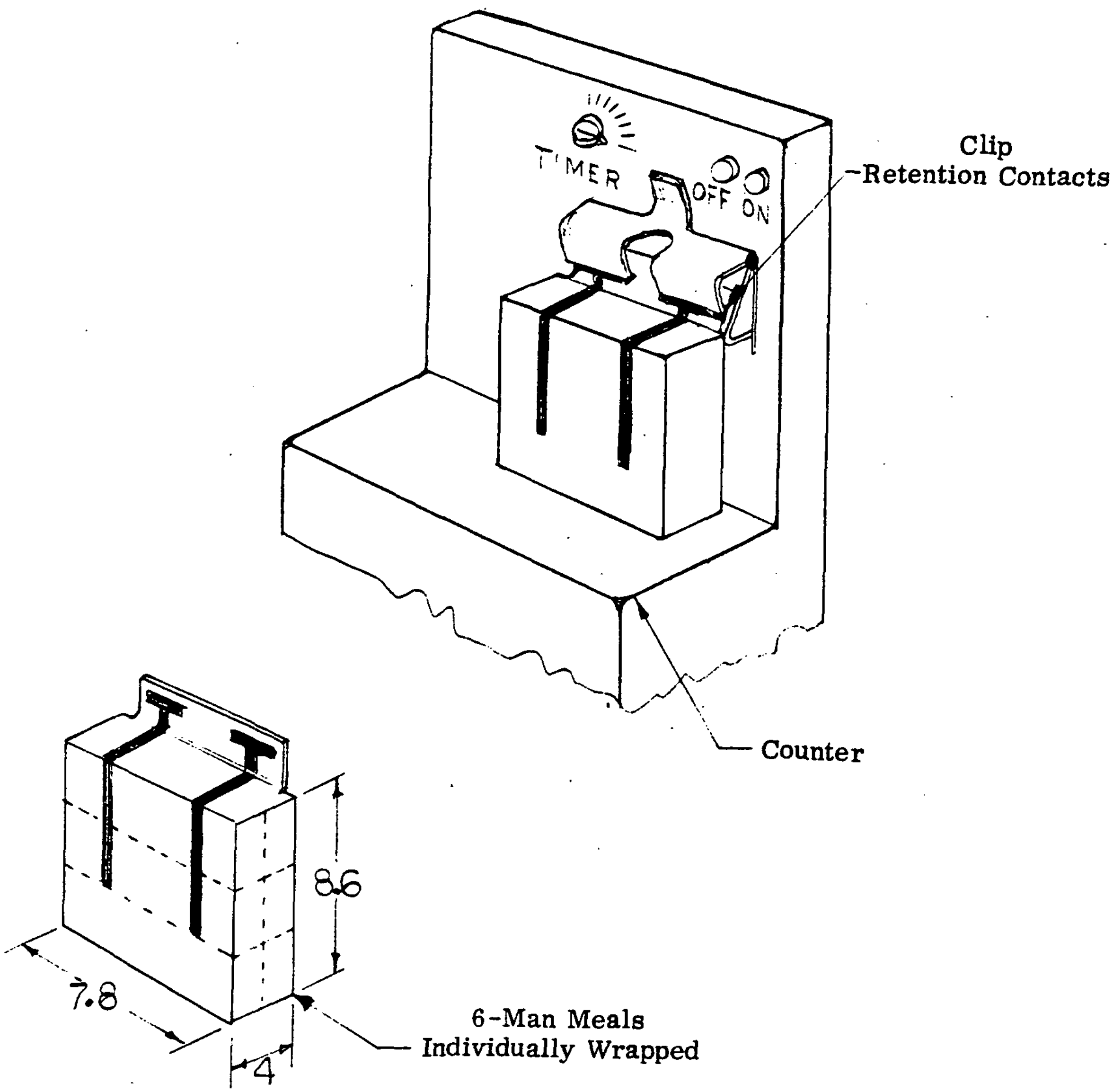
The self-heating package concept is compatible with generally all container shapes and materials. This concept requires a minimum amount of development effort.

D— 3.2.6 A

(Sheet 1 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Self-Heating Food Package



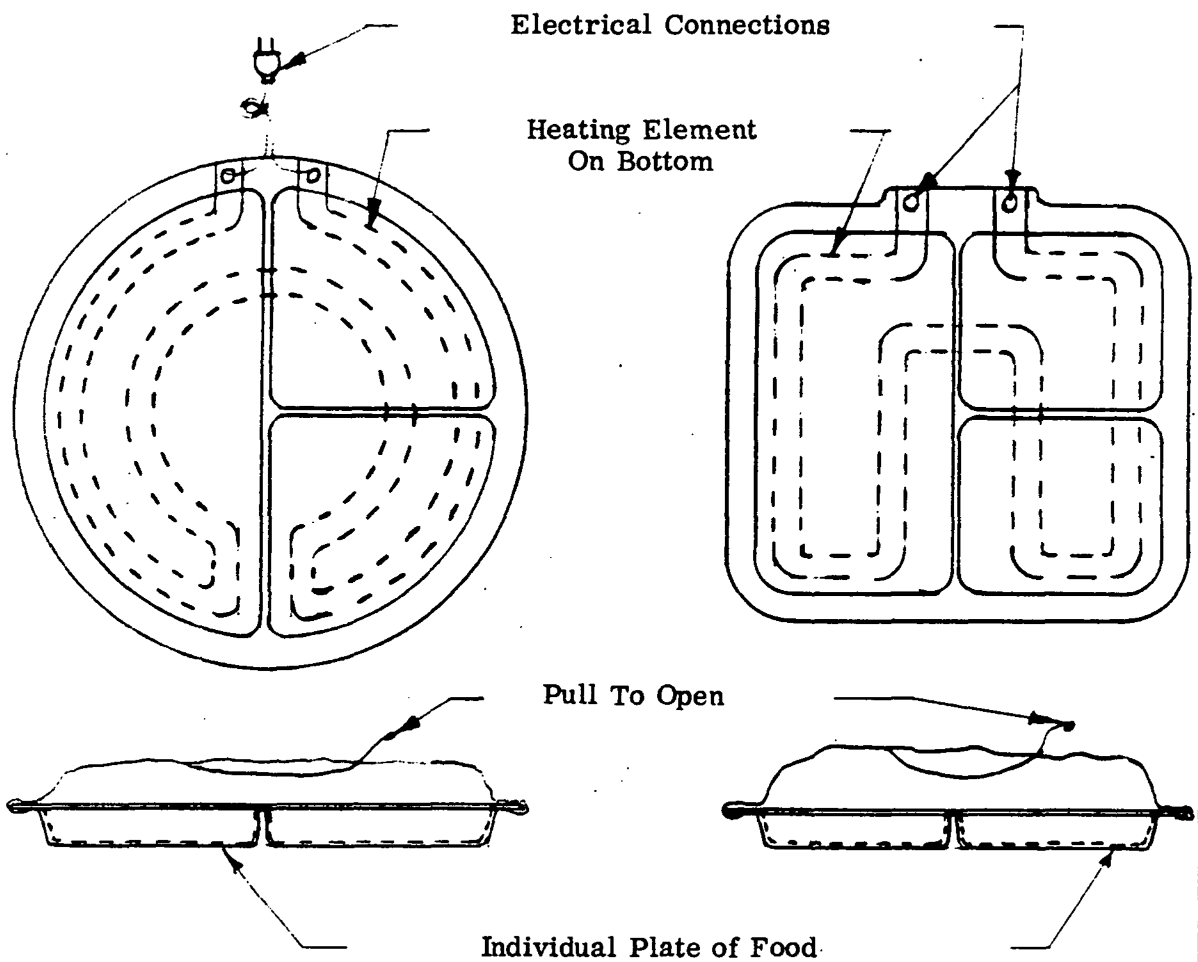
This concept illustrates a clipboard type of retention clamps which can retain and heat the food packages on a vertical or horizontal surface. The clamps provide electrical power as well as zero-g retention.

D— 3.2.6 A

(Sheet 2 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Self-Heating Food Package



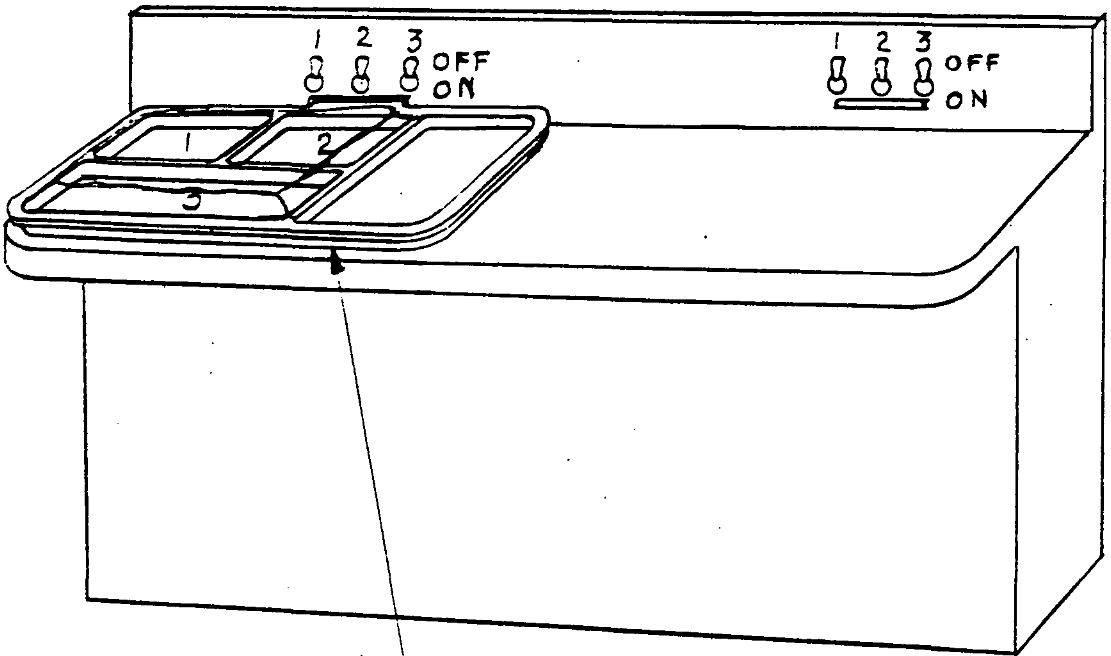
These concepts depict a modification of the self-heating individual food package techniques. Two disposable type plates, either round or square, are sectored to contain a complete prepackaged heatable meal. An integral heating element within the plate can utilize either a plug-in or socket-type electrical connector for initiating the heating cycle.

D— 3.2.6 B

(Sheet 1 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Self-Heating Food Package



Plug-In Tray
With Heated Panels

This tray provides heating elements in three sectors for warming food. The fourth sector is not heated; it provides space for eating utensils, drinking cup, and dessert.

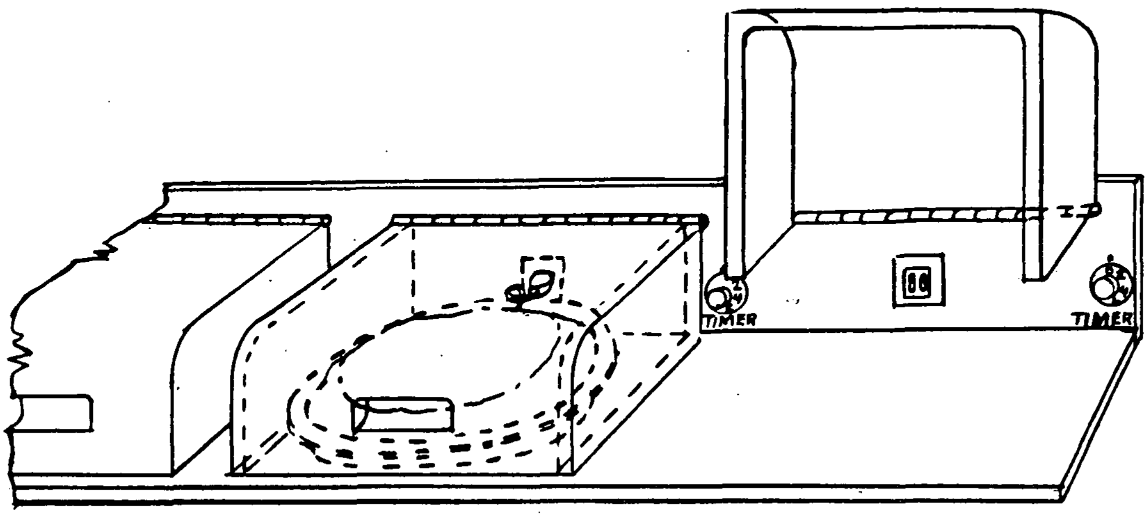
The tray contains a plug that can be connected by pushing the tray into place. Switches are provided for each panel. The system could operate without switches, if so desired, by limiting the heating to a satisfactory warming temperature regardless of the type of food.

D— 3.2.6 B

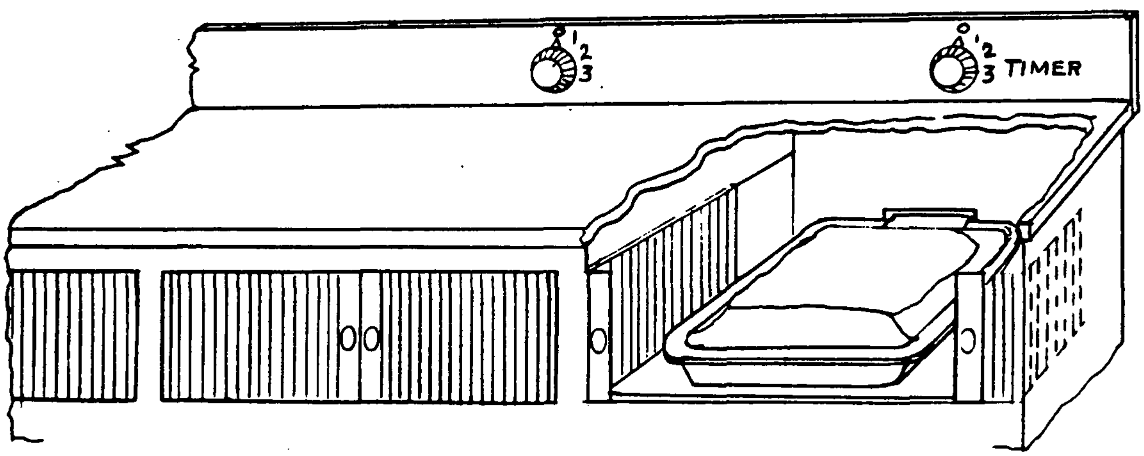
(Sheet 2 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Self-Heating Food Package



Counter Top Insulated Hoods - Plug In



Under Counter Sliding Door - Automatic Receptacle

This sketch illustrates two systems for handling self-warming plates. One is on the counter top with a timer, electrical receptacle, and switch. A hood is provided to retain the heat. The other is under the counter with a sliding door, an electrical receptacle, and timer.

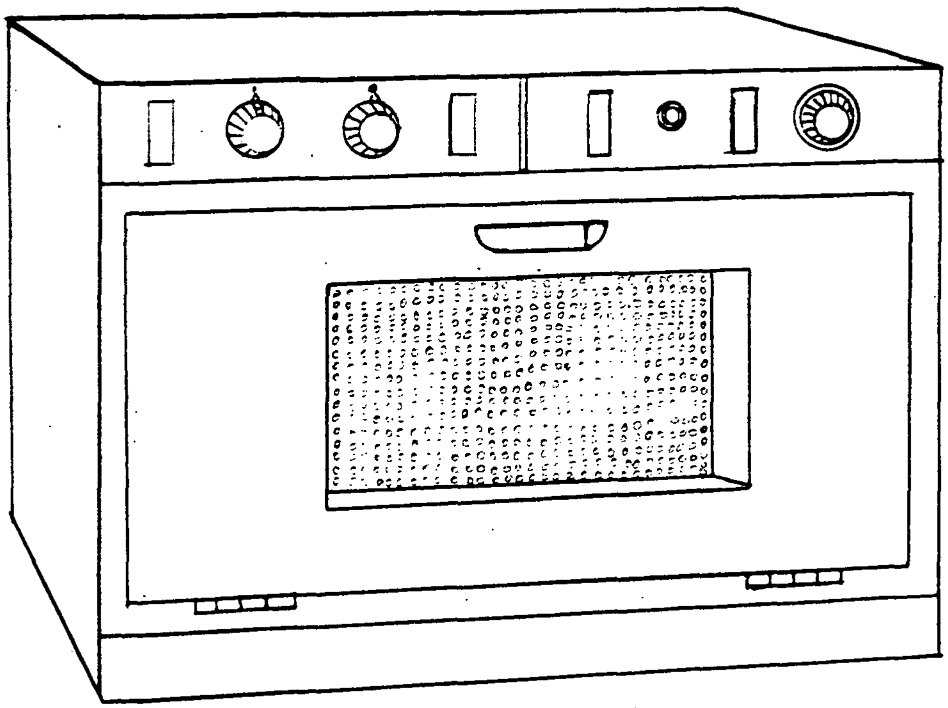
The under counter system leaves the counter free for other uses. The counter top system provides more under counter space.

D— 3.2.6 B

(Sheet 3 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Combination Microwave and Resistance Heating Oven



Oven: 10 x 24 x 14 (inches)

Overall: 20 x 28 x 20 (inches)

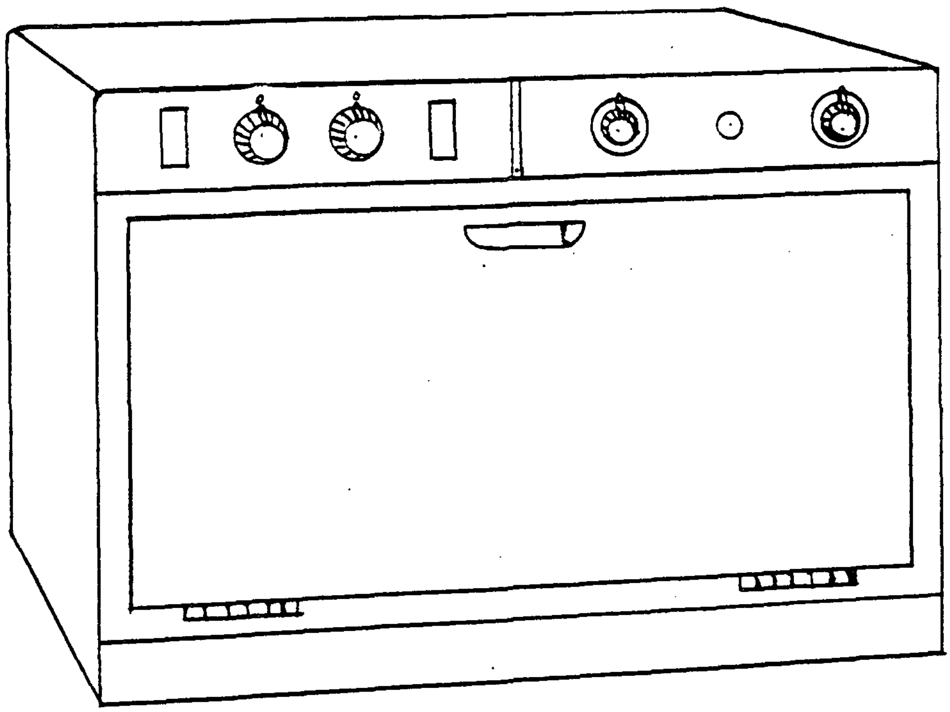
This combination of heating concepts utilizes the microwave function for food thawing and heating in conjunction with the radiant function for a food browning capability.

This combination of heating concepts increases the crew acceptability of the microwave function with a very small increase in weight.

D— 3.2.13

FOOD SYSTEM STUDY SKETCH

Title: Combination Hot Air Convection and Resistance Heating Oven



Oven: 10 x 24 x 14 (inches)

Overall: 20 x 28 x 20 (inches)

This combination of heating concepts utilizes the hot air convection function for food thawing and heating in conjunction with the radiant function for a food browning capability.

This combination of heating concepts increases the crew acceptability of the hot air convection function with a very small increase in weight.

D— 3.2.14

3.3 Candidate Powered Support Equipment Techniques

a. Concept: Hot Plate (3.3.1)

Concept Description: This concept will provide a low-heating or temperature holding capability for foods, sauces and beverages retained in bowls, reconstitution devices, dispensing mugs, etc. The hot plate will be fitted with convenient zero-g means to retain the food containers.

Technical Analysis: Development time for this concept is low; the concept provides a convenience to the food preparation tasks.

b. Concept: Reconstitution Machine (3.3.2)

Concept Description: This concept will provide a mechanized assist to large scale reconstitution requirements. Suitable means will be provided for filling the machine with both water and dry powder. Stirring and dispensing functions will be provided. A suitable heating element will provide for warmed beverages, soups, etc.

Technical Analysis: The development time is moderate; safety, crew acceptance, and convenience are rated good.

c. Concept: Chilled Display Cabinet (3.3.3)

Concept Description: This concept provides an intermediate storage capability for chilled desserts, salads, and perishable items. The refrigerated cabinet will be capable of displaying its contents to facilitate retrieval tasks.

Technical Analysis: Development risk is considered moderate; safety, acceptance, and convenience are considered good.

d. Concept: Thawing Device (3.3.4)

Concept Description: This device would provide a means to thaw frozen food packages quickly using a heating and convection means.

Technical Analysis: This concept was discarded because thawing will be a predesigned function of the food warming oven concept. Accordingly, refrigerated foods such as dairy and wet packed products will be thawed at 40°F in the refrigerator concept.

e. Concept: Hot Beverage Maker (3.3.5)

Concept Description: This device will be capable of heating hot beverages and soups in large quantities using a suitable heating means.

Technical Analysis: This concept was discarded because the heating of beverages and soups will be performed by Concept 3.3.2, the reconstitution machine.

f. Concept: Food Blender (3.3.6)

Concept Description: This concept will provide a mechanized assist to large-scale blending requirements.

Technical Analysis: This concept was discarded because the blending of foods will be accomplished by Concept 3.3.2, the reconstitution machine.

g. Concept: Can/Package Opener (3.3.7)

Concept Description: This concept will provide a mechanism assist to opening food packages and cans.

Technical Analysis: This concept was discarded because the design of convenience-opening techniques will be incorporated into the food packaging concepts.

h. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-8 below. Rating numbers are derived from the detailed Selection Rationale Sheets in the Data Book - Book III.

TABLE III-8

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 3.3 TITLE: Powered Support Equipment		INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.3.1	Hot Plate	*		X	-		X
3.3.2	Reconstitution Machine	*		X	-		X
3.3.3	Chilled (Display) Cabinet	*		X	-		X
3.3.4	Thawing Devices	*		X	-	X	
3.3.5	Hot Beverage Maker	*		X	-	X	
3.3.6	Food Blender	*		X	-	X	
	*Rating considered "not applicable" since all concepts were studied in the Interim phase.						

For each of the concepts selected for detailed study, technical data is referred to below.

1) Technical Data - Food Warming Plate (Concept 3.3.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.3.1.1 through 3.3.1.3 in Data Book - Book I.

2) Technical Data - Reconstitution Machine (Concept 3.3.2). Detailed data for this concept are presented on Element Concept Data Sheets 3.3.2.1 through 3.3.2.3 and 3.3.2.5 through 3.3.2.7 in Data Book - Book I.

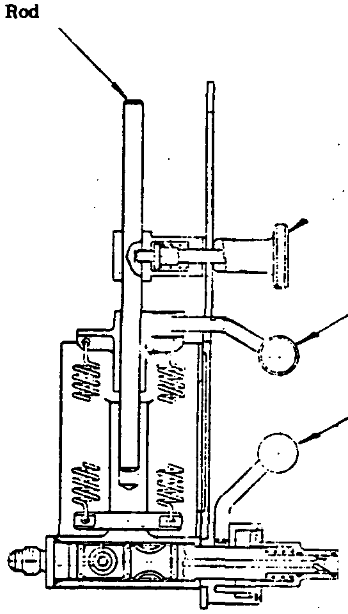
3) Technical Data - Chilled Display Cabinet (Concept 3.3.3). Detailed data for this concept are presented on Element Concept Data Sheet 3.3.3.1 in Data Book - Book I.

i. Applicable Sketches

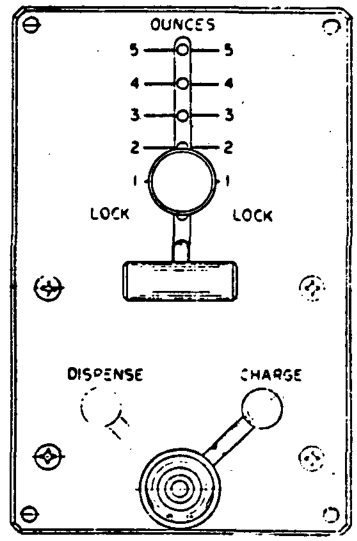
The following sketches depict equipment concepts for the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Hot and Cold Water Transfer Device



Side View



Face Plate

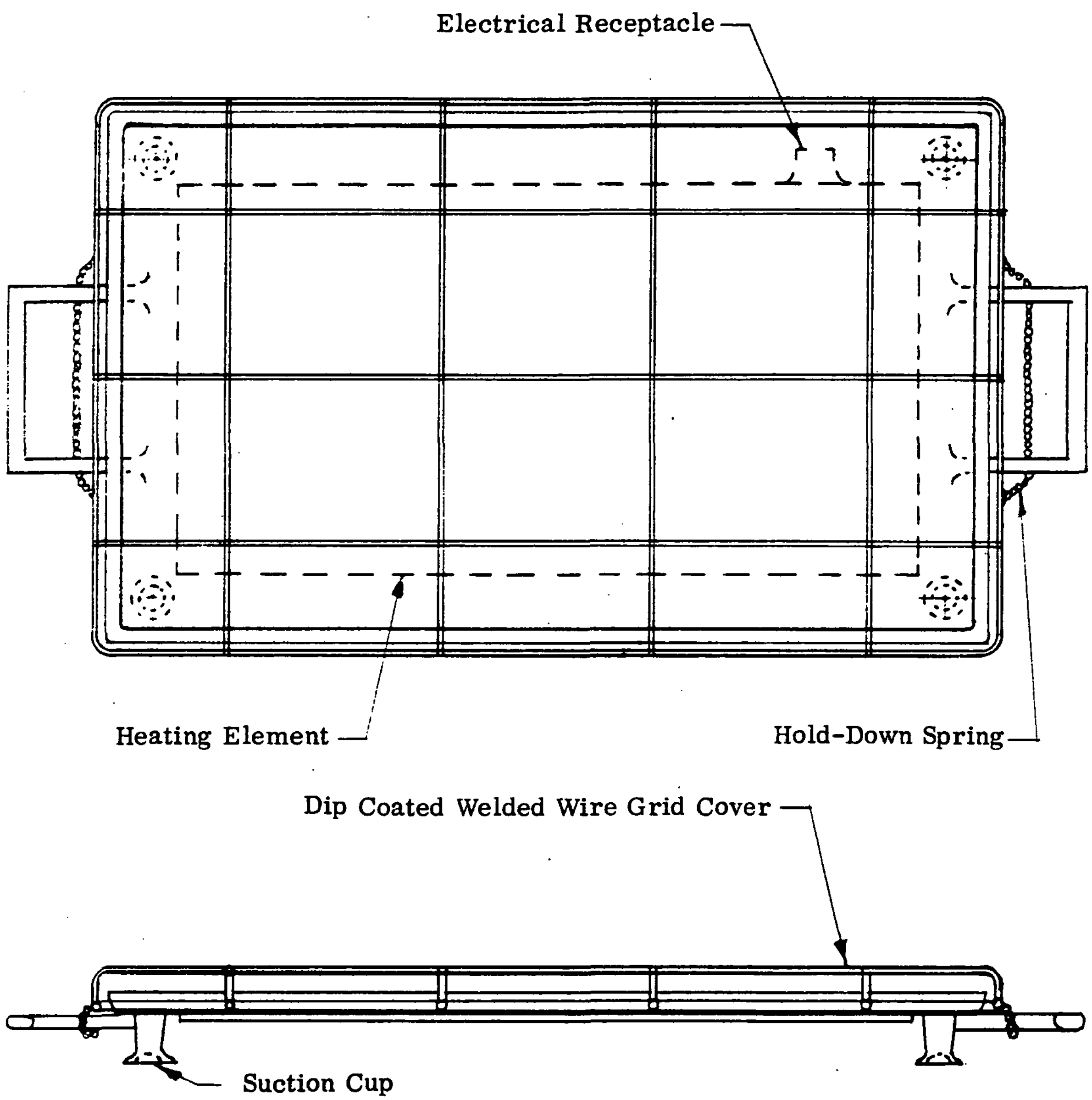
The hot or cold water transfer device is a wall-mounted, metering sub-assembly which interfaces with pressurized hot or cold water supply subsystems. The unit consists of ON/OFF controls, volume cylinders, pistons, and valves to facilitate discharging of preselected quantities of potable water from one to five ounces. Transfer of water into the food or beverage container is accomplished by pushing the container inlet valve against the discharge port of the spring-loaded transfer device.

This is basically for zero-g application, but is equally usable in partial-to one-g environment.

D— 3.3

FOOD SYSTEM STUDY SKETCH

Title: Hot Plate



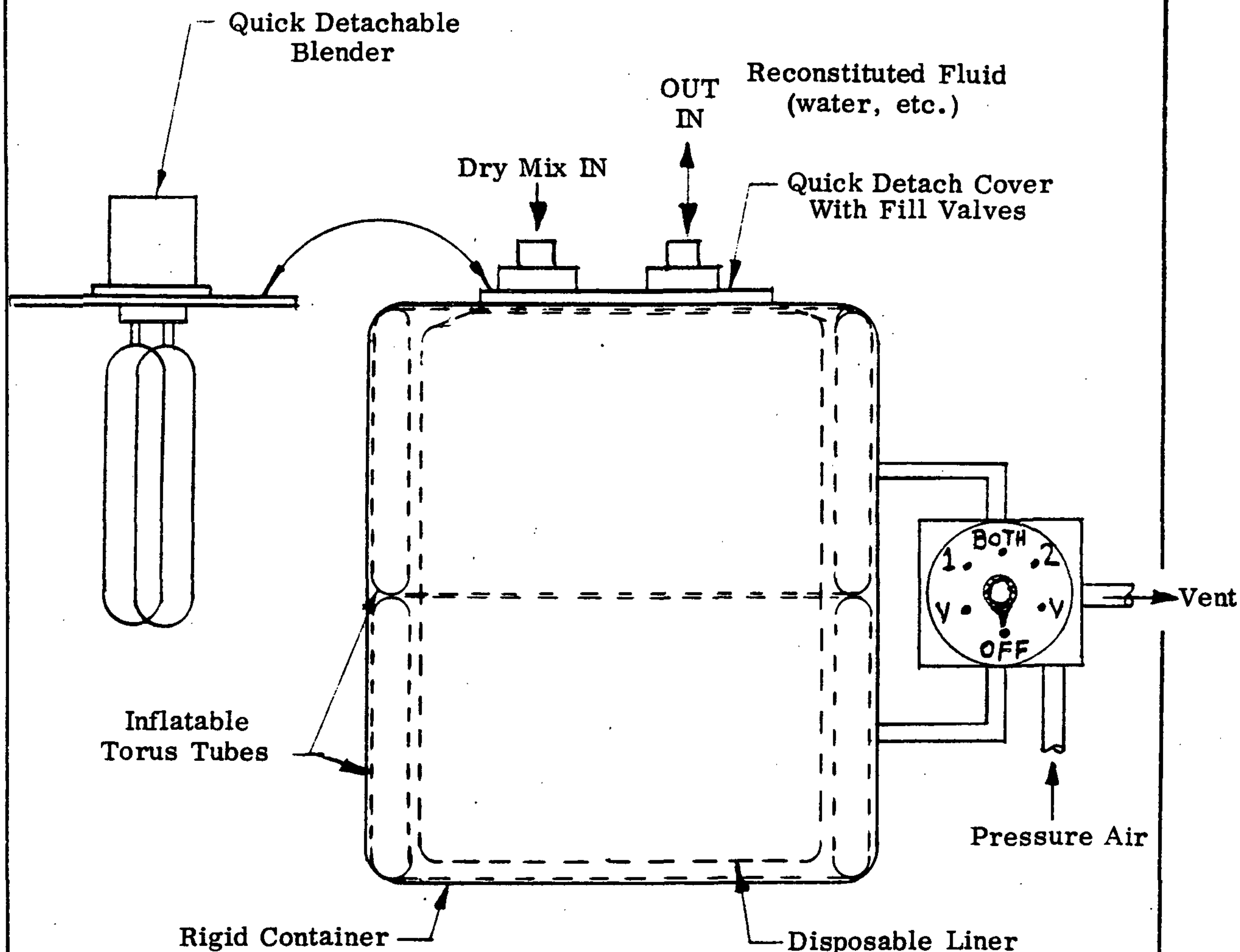
This is a ceramic tray with an embedded heating element. It is capable of water submersion for cleaning. Handles and a grid cover provide transportation restraints. The tray provides the capacity to heat and maintain twelve dishes at 150°F. The grid cover maintains the dishes in intimate contact with the warming surface.

This concept is applicable to zero-g and one-g usage.

D— 3.3.1

FOOD SYSTEM STUDY SKETCH

Title: Reconstitution Machine



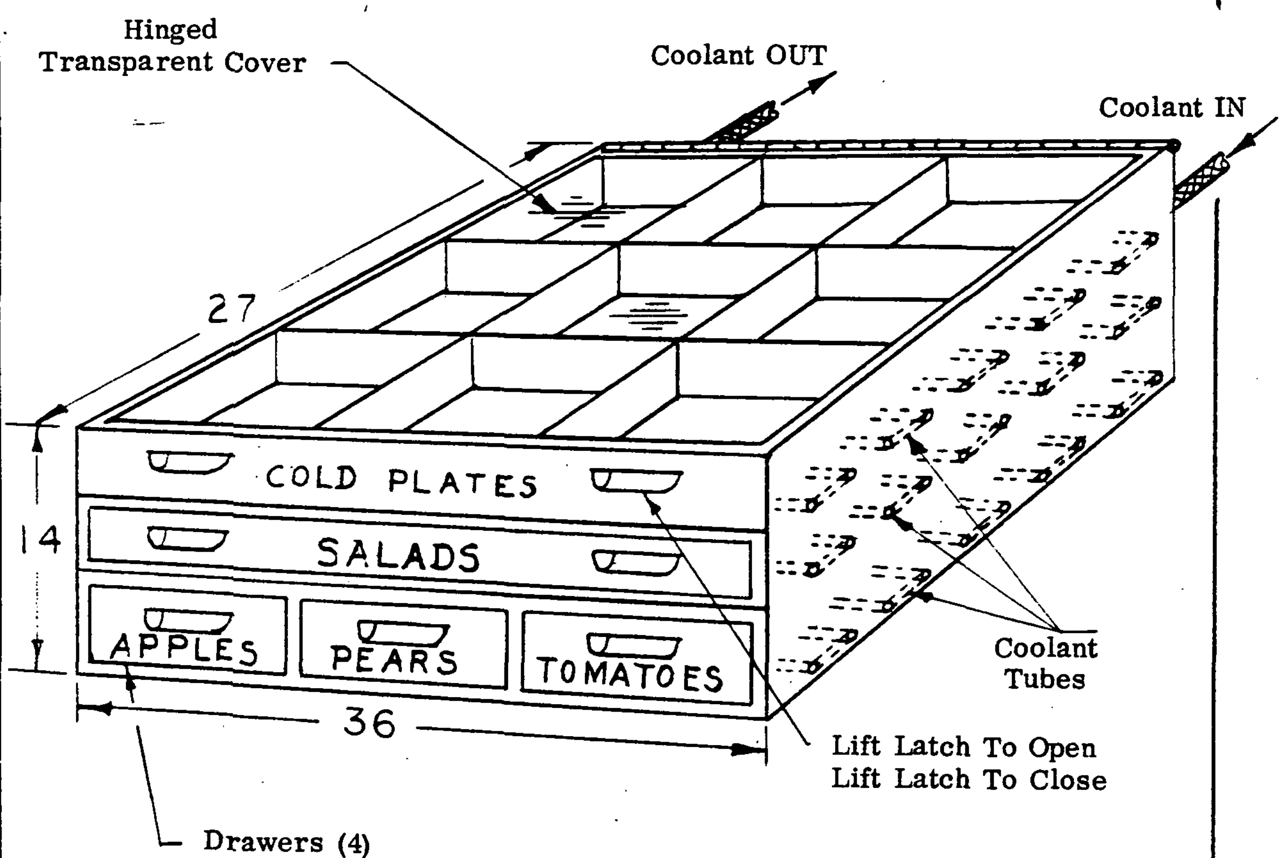
This machine consists of a rigid container, a disposable bag, two inflatable tubes, and a control box. A source of air pressure is required. Electrical power is required to operate the blender when it is installed, or when automatic sequencing controls are used.

To Operate: The required amounts of dry mix and fluids (80% liquid, 20% fluid) are pumped into the mixer. The shut-off valves are closed. The control is used to inflate each tube alternately, forcing the contents back and forth with a mixing action. The reconstituted mix is forced out of the container by inflating both tubes. The blender can be installed when blending is required. The operations can be sequenced manually or automatically.

D— 3.3.2

FOOD SYSTEM STUDY SKETCH

Title: Chilled Display Cabinet



This concept for a chilled display cabinet contains a hinged see-through cover and four independent drawers for storage of perishables.

The cabinet is maintained at 38°F by means of a heat exchanger in the environmental control system. Positive mechanical latches prevent cover and drawers from inadvertent opening.

The upper level has a hinged cover for access to baked goods, etc.; middle level has a full width drawer for access to partially prepared foods; lower level has three equally sized drawers for fruit storage.

D— 3.3.3

3.4 Candidate Preparation Counters

a. Concept: Wall Mounted Preparation Counter (3.4.1)

Concept Description: This would be a wall mounted unit providing a work surface containing an integral cutting or chopping block and plasticized counter top. The unit would be fabricated of a honeycomb type material and provide for preparation utensil storage in special drawers. The unit can be either permanently wall mounted in a fixed position or can be designed to snap-in on a grid pattern so that a range of locations would be possible for various configurations. The counter top would contain either magnetized inserts or mechanical snaps, detents or lock tabs for restraining equipment during zero-gravity preparation tasks.

Technical Analysis: A galley concept will require the use of preparation counters for performing the necessary assembly tasks in setting up a meal tray for service to the dining area. The work surface should be easily cleanable, but must contain zero-gravity retention devices for all anticipated equipment usage in conjunction with the unit. For those items of equipment most often used, integral storage provisions are required to minimize crew time expenditure in obtaining or returning these items. The counter is required for all configurations of galley/dining room arrangements rather than crew size limitations.

b. Concept: Counter With Electrical Power Source (3.4.2)

Concept Description: This concept is similar to Concept 3.4.1 above, with the exception of an electrical source addition for operating powered preparation equipment devices. The electrical outlet can be either a continuous strip outlet for extension type cords or could be female receptacles for direct equipment plug-in. The cabinet portion of the unit would contain provisions for storage of utensils and preparation devices.

Technical Analysis: This modification to the basic preparation counter is related to crew size and the degree of automation designed into the galley. As the number and type of powered preparation devices increase, the need for quick plug-in adapters becomes mandatory to achieve maximum efficiency in utilizing these devices resulting in crew time savings.

5

c. Concept: Fold-Away Preparation Counter (3.4.3)

Concept Description: A fold-away counter provides an auxiliary work surface to either supplement a large galley or support a small galley area. Consequently, this concept provides for a plug-in unit that can be stowed flush to a wall and hinged to an open position when needed. The unit would be spring-loaded in both the stowed and opened position by an over-center spring and mechanically latched in either position to prevent inadvertent release. The counter top should be of a plasticized-formica type material for ease of cleaning and sanitation purposes.

Technical Analysis: This counter would be a usable device for any galley or crew size. By designing it as a plug-in type unit, the counter can either be installed in a folded position or stowed for use as required. If the galley walls contain multiple plug receptacles, the counter can be moved to various locations to suit crew size changes or galley configuration options.

d. Concept: Serving Cart Counter Top (3.4.4)

Concept Description: A serving cart used primarily to transport prepared meals to the dining area can also be used as a preparation counter to assemble meal trays. The serving cart counter top would provide a work area that would restrain trays, utensils, and dishes by the use of either magnetized or mechanical zero-gravity devices.

Technical Analysis: The serving cart concept is limited to either intermediate to large size crews (12 men and up) or relatively spacious galley/dining areas that can accommodate the cart volume and guide system. For these applications, use of the cart top as a preparation and work counter is an efficient utilization of that device.

e. Concept: Combination Preparation/Serving Counter (3.4.5)

Concept Description: This is a compact single station concept for meal preparation and consumption. A fixed individually sized counter top or work surface would become a centralized point for the crewman to prepare his food, assemble the meal, and consume it in place. This concept, therefore, must include all provisions for zero-gravity restraints and clean-up after use.

Technical Analysis: This concept is particularly applicable to small to intermediate (3-12 man) crew sizes and to potential combined galley/dining areas that may be considered in smaller space station configurations. The crewman can stand or sit in position while performing his tasks thereby avoiding traffic flow pattern problems in confined areas. Equipment placement would require critical analysis to ensure proper utilization sequences in terms of crewman tasks.

f. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-9 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-9

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 3.4	SUB-FUNCTION TITLE: Preparation Counters	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.4.1	Wall Mounted Preparation Counter	11.6		X	-		X
3.4.2	Counter With Built-In Electrical Power Source For Operating Preparation Devices	10.6		X	-		X
3.4.3	Fold Away Preparation Counter	11.8		X	-		X
3.4.4	Serving Cart Counter Top	9.2		X	-		X
3.4.5	Combination Preparation and Serving Counter	11.0		X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Wall Mounted Preparation Counter (Concept 3.4.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.4.1.1 through 3.4.1.3 in Data Book - Book I.

2) Technical Data - Counter With Electrical Power Source (Concept 3.4.2). Detailed data for this concept are presented on Element Concept Data Sheets 3.4.2.1 through 3.4.2.3 in Data Book - Book I.

3) Technical Data - Fold-Away Preparation Counter (Concept 3.4.3). Detailed data for this concept are presented on Element Concept Data Sheets 3.4.3.1 through 3.4.3.3 in Data Book - Book I.

4) Technical Data - Serving Cart Counter Top (Concept 3.4.4). Detailed data for this concept are presented on Element Concept Data Sheets 3.4.4.1 and 3.4.4.2 in Data Book - Book I.

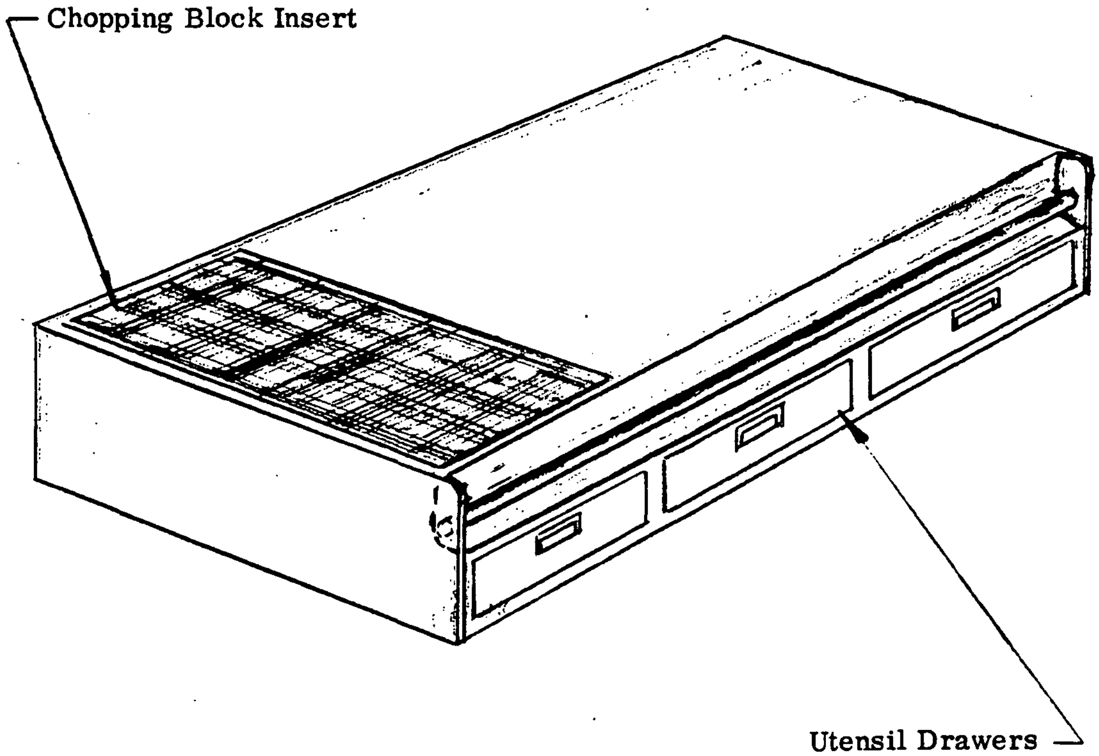
5) Technical Data - Combination Preparation/Serving Counter (Concept 3.4.5). Detailed data for this concept are presented on Element Concept Data Sheet 3.4.5.1 in Data Book - Book I.

g. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Preparation Counter



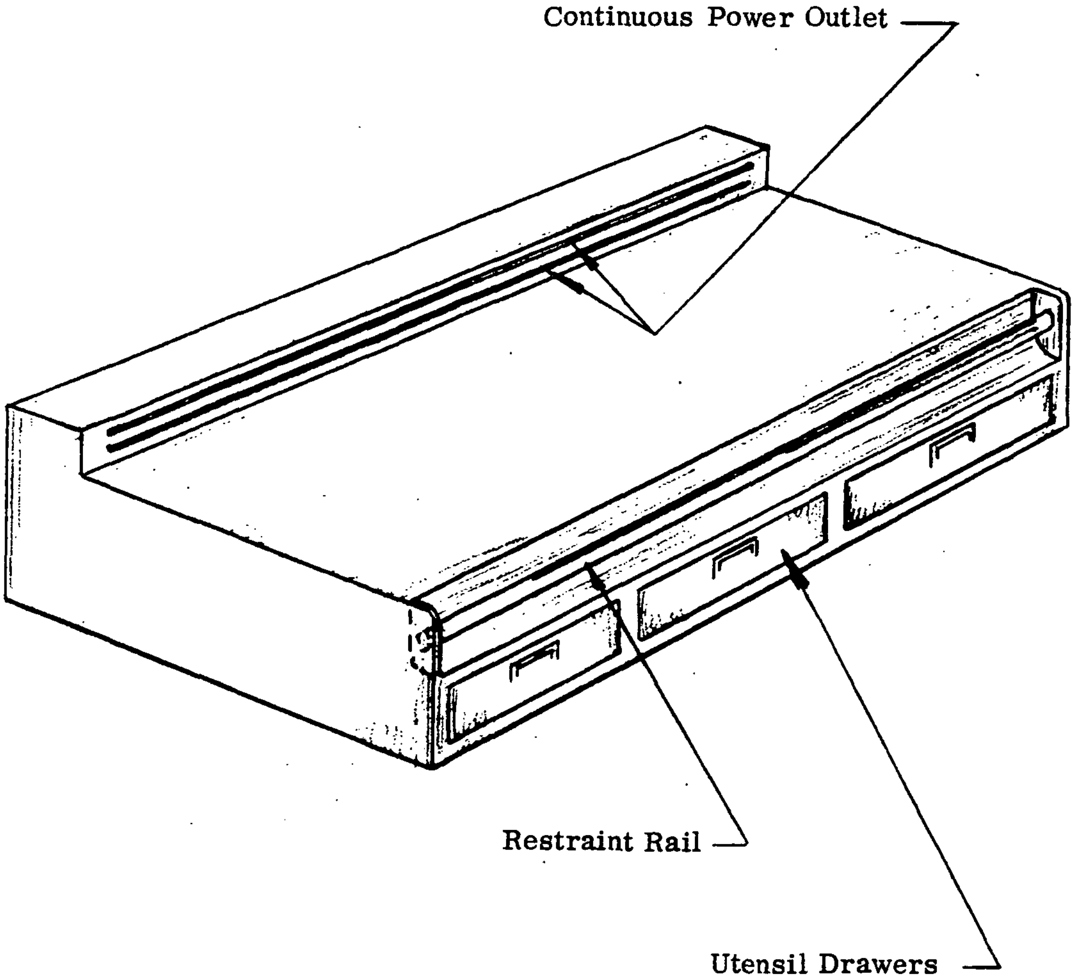
This is a wall-mounted preparation surface which has a built-in chopping block surface in one area. There are utensil storage drawers below this area for quick access. A built-in body restraint rail across the front of the unit will allow the crewman to be fully restrained while working.

It is applicable during both zero-g and one-g operation.

D— 3.4.1

FOOD SYSTEM STUDY SKETCH

Title: Counter With Electrical Power



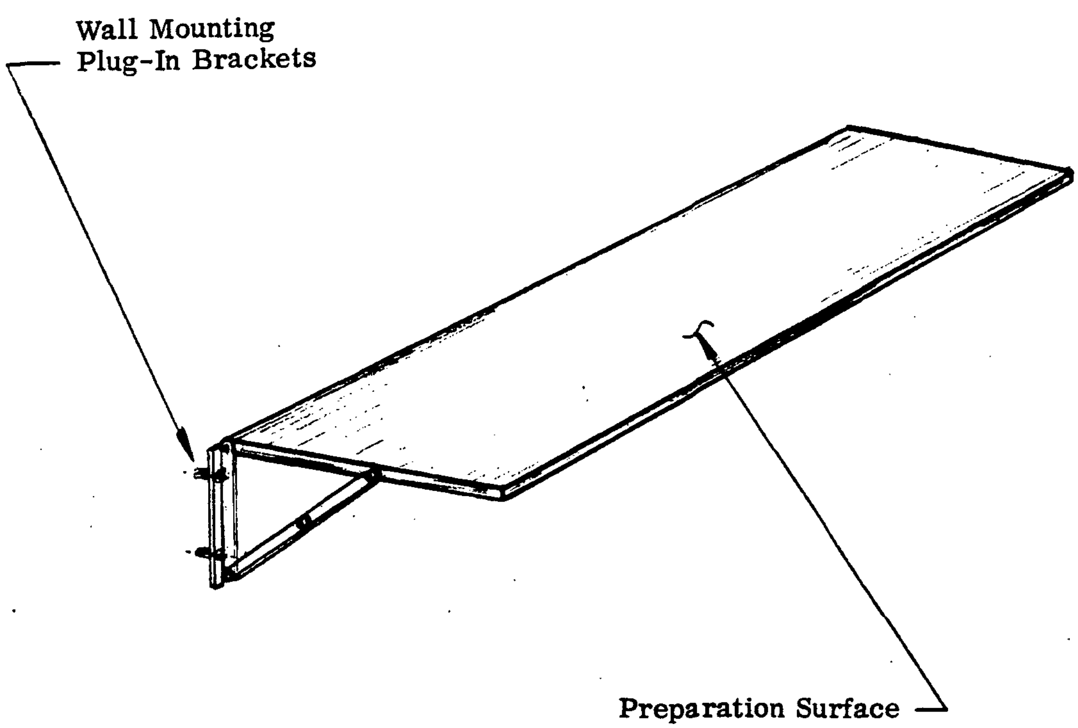
This is a wall-mounted preparation surface which has a built-in continuous electrical power outlet to which powered preparation devices may be attached. Top surfaces will consist of impervious coatings for ease of clean-up. It has storage drawers below and a body restraint rail across the front for zero-g restraint.

This design is similar to present equipment and will require a minimum of design.

D— 3.4.2

FOOD SYSTEM STUDY SKETCH

Title: Fold-Away Preparation Counter



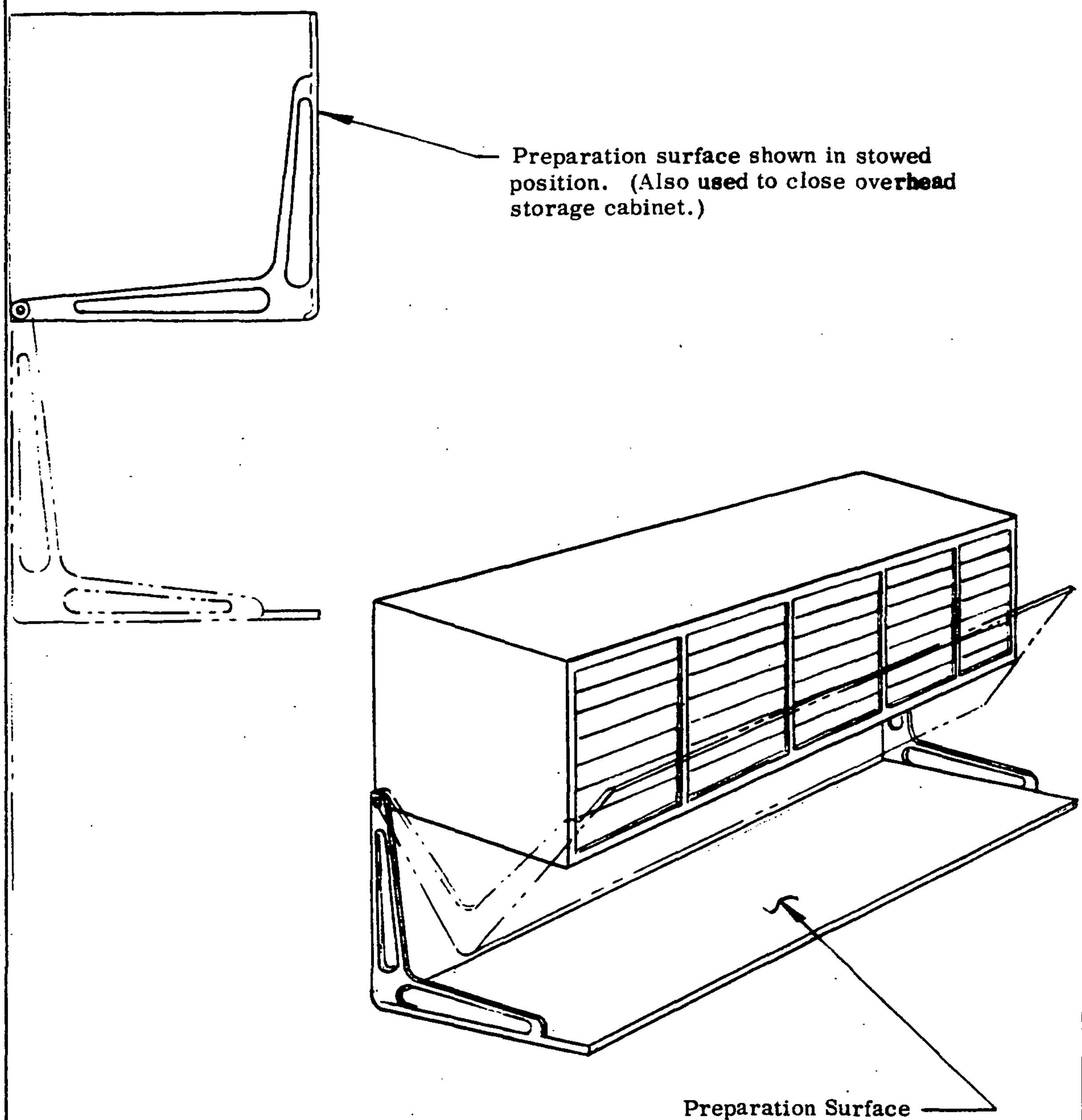
This preparation surface serves two purposes. It is both a preparation surface and an overhead cabinet closure. The overhead cabinet may hold preparation devices and food packages. By releasing the preparation counter, the overhead cabinet and preparation counter are ready for use.

This dual usage will reduce weight and quantities of equipment.

D— 3.4.3 A

FOOD SYSTEM STUDY SKETCH

Title: Fold-Away Preparation Counter



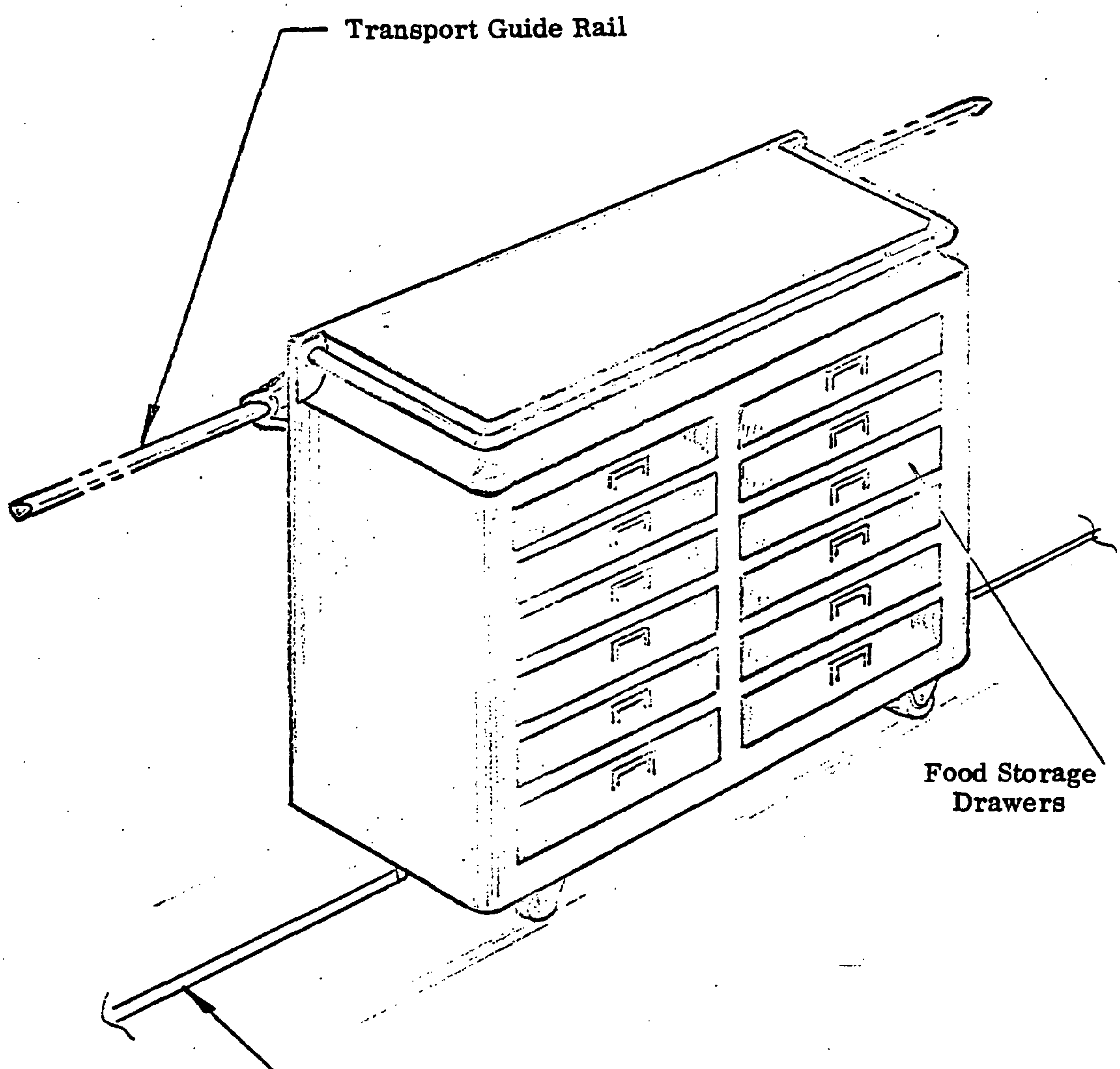
This preparation surface serves two purposes. It is both a preparation surface and an overhead cabinet closure. The overhead cabinet may hold preparation devices and food packages. By releasing the preparation counter, the overhead cabinet and preparation counter are ready for use.

This dual usage will reduce weight and quantities of equipment.

D— 3.4.3 B

FOOD SYSTEM STUDY SKETCH

Title: Serving Cart Counter Top



This cart is designed to perform diverse tasks such as (1) transfer food from storage to the preparation area in the galley, and (2) to use the top surface as a preparation counter top. The cart will have casters for stability in zero-g and to propel it in one-g conditions.

A recessed floor track will guide it to its destination. Due to the possibility of contaminants collecting in this track, it may be advisable to use a wall-mounted guide rail.

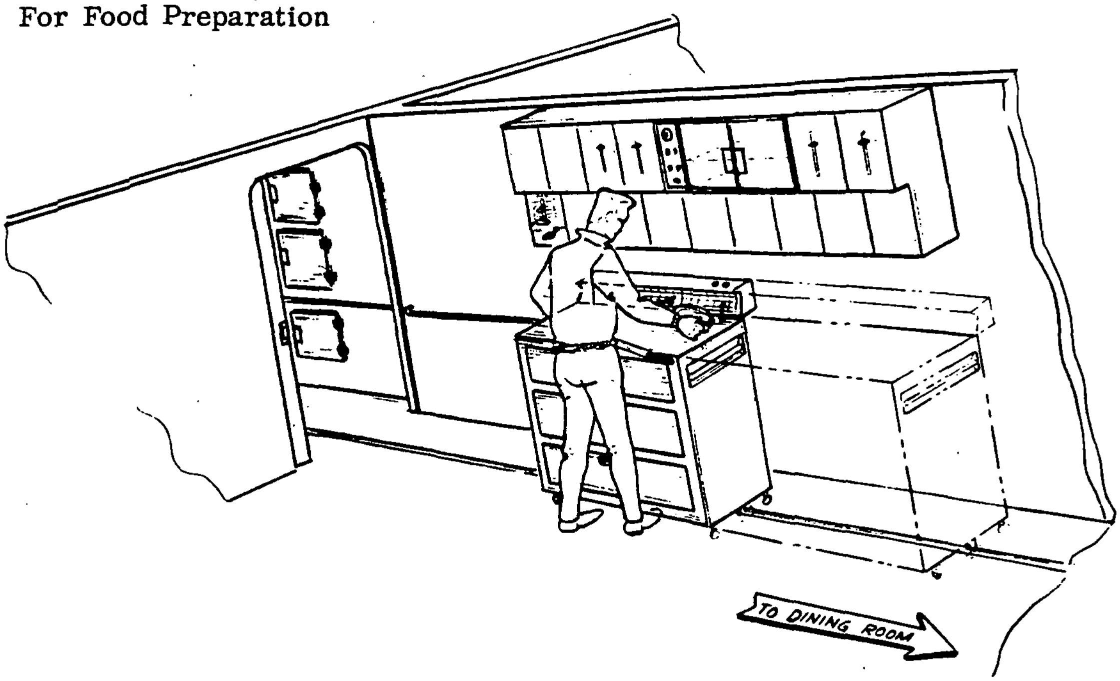
D— 3.4.4

(Sheet 1 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Serving Cart Counter Top

Recessed Track
Guided Cart.
Cart Counter Top Used
For Food Preparation

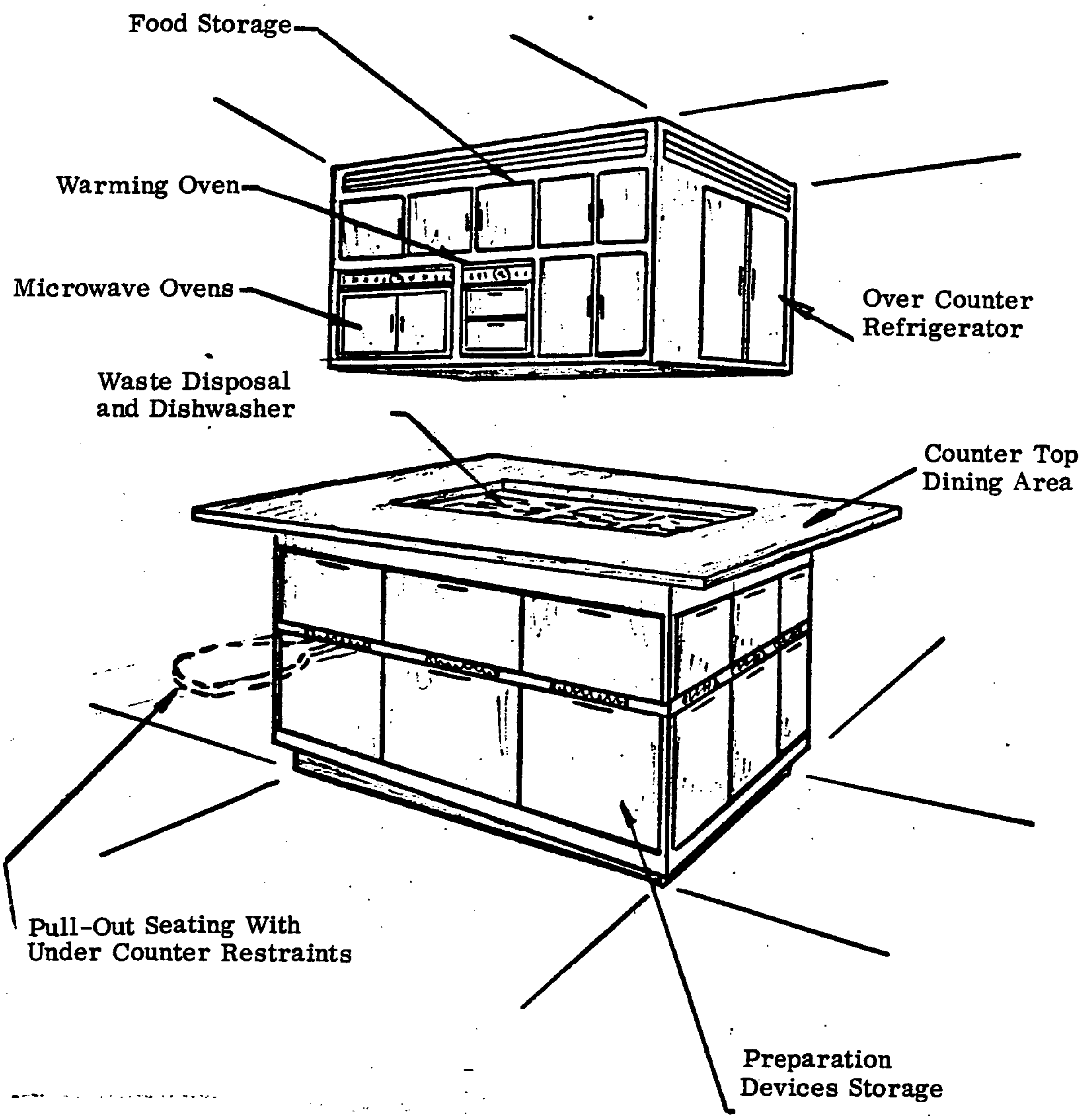


D— 3.4.4

(Sheet 2 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Combination Preparation and Serving Counter



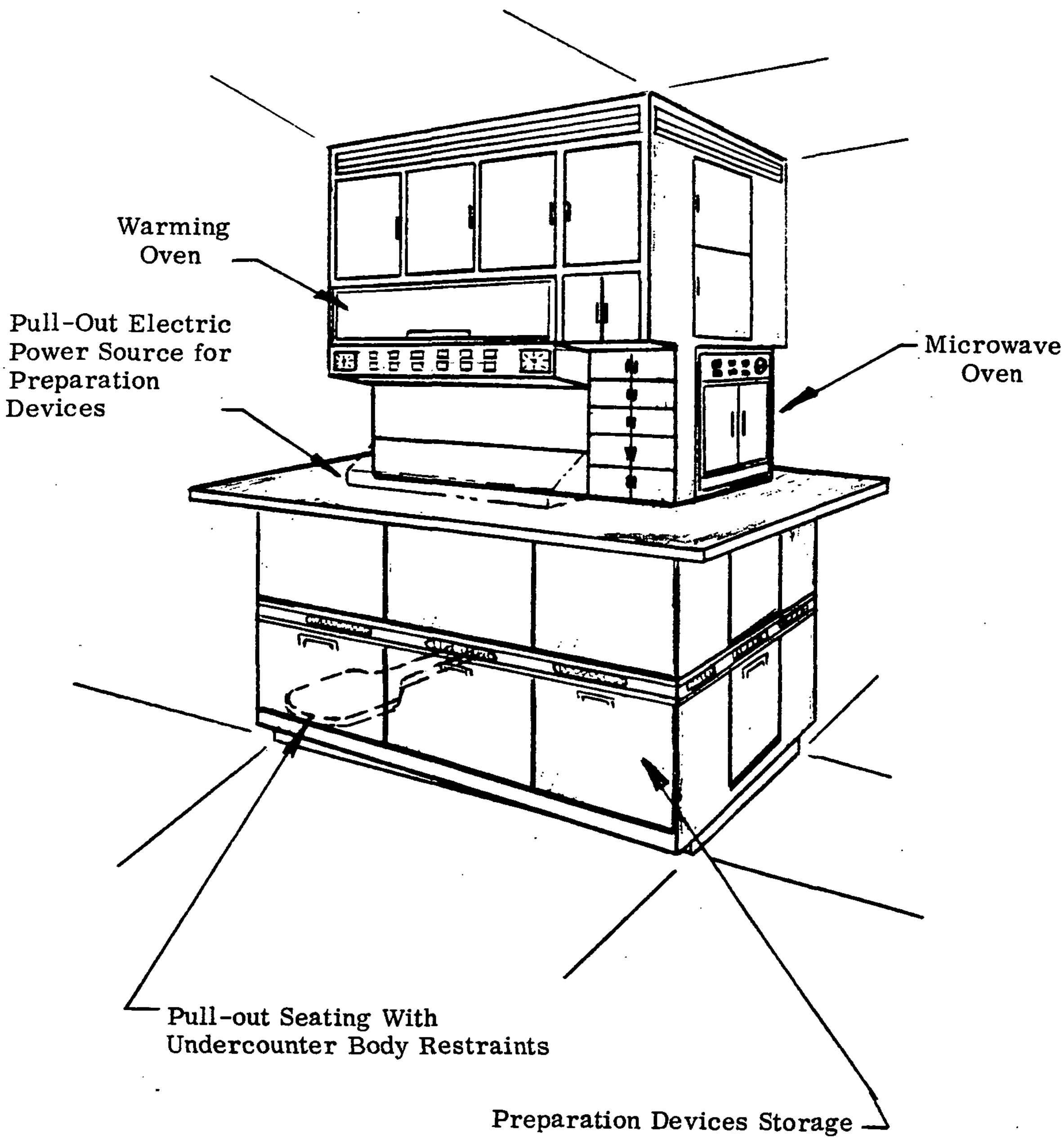
This concept is a four-sided grouping of preparation, dining, and clean-up devices. Overhead preparation and storage equipment allows for cross-talk when eating and full access to disposal and washing equipment. Pull-out seats with restraints will enable up to twelve men to eat at one time.

A minimum amount of further development is needed for this concept; applicable for both zero- and partial-g.

D— 3.4.5A

FOOD SYSTEM STUDY SKETCH

Title: Combination Preparation and Serving Counter



This concept is a four-sided grouping of preparation devices with built-in counters on four sides and preparation devices and storage above and below. Pull-out seats with undercounter body restraints will enable up to twelve men to eat at one time.

By incorporating preparation and eating into an "island" type module, galley and dining area sizing will be greatly reduced. This concept is applicable for both zero- and partial-g usage.

D— 3.4.5B

3.5 Candidate Snack Dispensers

a. Concept: Snack Bar (3.5.1)

Concept Description: This device provides hot snack type foods from a "vending machine" dispenser. The unit would contain an integral heating capability utilizing either microwave or radiant energy. The crewman could have an option of selecting pre-prepared frozen hamburgers, frankfurters, or hot sandwiches. Once the selection is made, the food item is positioned in a holding chamber where it is heated to a preset temperature prior to delivery to the crewman. The unit would also maintain the snack items in a frozen condition during storage.

Technical Analysis: This device appears to have most applicability to larger crew sizes where a variety of feeding techniques can be used to supplement the basic food system. This device requires development to perform in zero-gravity conditions, but then could be used as a basic hot food dispenser for short duration missions. With the addition of beverages and desserts, a small crew (2-4 men) on a shuttle resupply or module experiment mission could utilize this device and pre-packaged mixes as the primary feeding system.

b. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-10 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-10

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 3.5	SUB-FUNCTION TITLE: Snack Dispensers	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.5.1	Snack Bar	9.8		X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

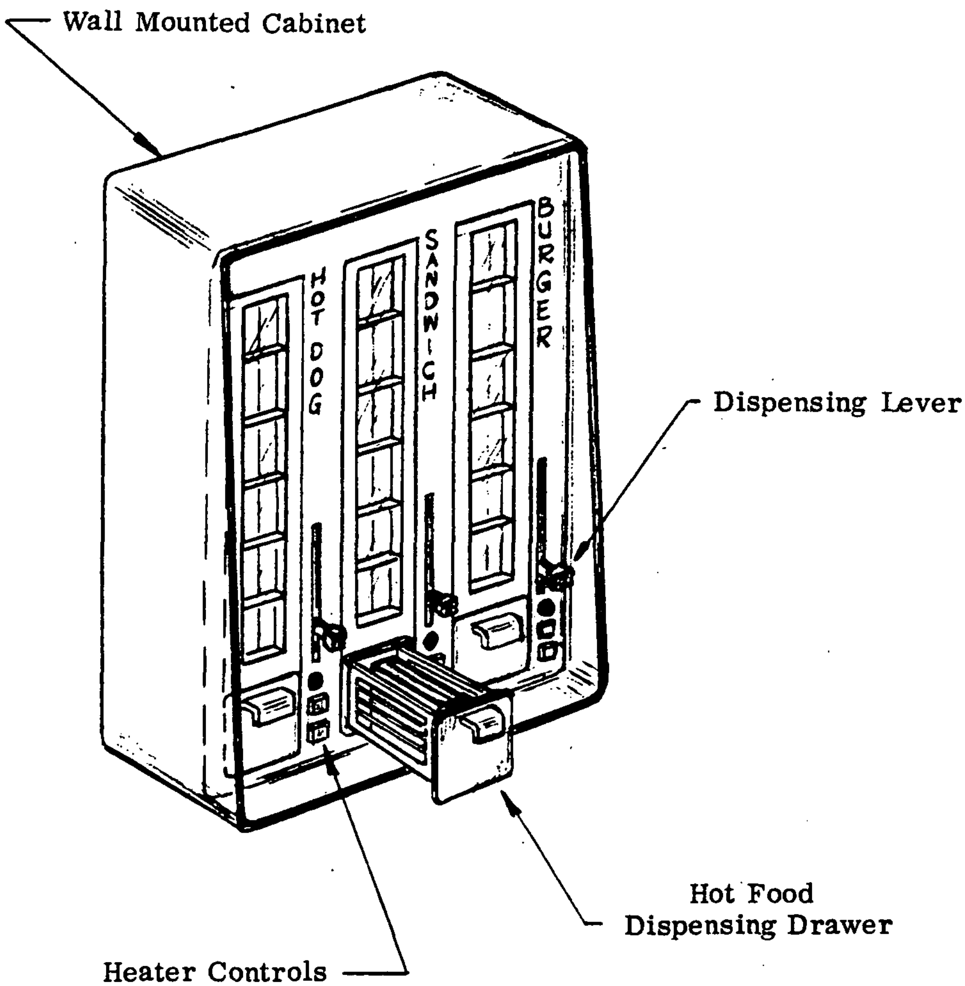
1) Technical Data - Snack Bar (Concept 3.5.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.5.1.1 and 3.5.1.2 in Data Book - Book I.

c. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Snack Bar



This is a lightweight structure which houses a vending-type machine to dispense preprepared hot sandwiches, hamburgers, and hot dogs. The unit contains its own heating provisions to allow a crewman to eat a quick snack type meal with a minimum preparation.

Further development is needed to convert currently available earth-type equipment for zero-g usage.

D— 3.5.1

3.6 Candidate Food Cabinets

a. Concept: Food Dispenser Cabinet (3.6.1)

Concept Description: The dispenser cabinet is designed to accept dishes or trays containing prepared meals and serve as a centralized dispenser station for either steward or self-service. The cabinet would consist of storage racks with accessibility from both sides. Food trays would be placed into the cabinet from the galley side and withdrawn from the opposite dining area side in a manner similar to "automat" service. The cabinet would also serve as a stacking center for used trays, dishes, and utensils upon meal completion. The used items would then be withdrawn on the galley side for cleansing. Zero-gravity restraints are required for the equipment items and to ensure food containment within the dishes or trays. The cabinet should be fabricated to permit ease of cleaning and maintenance.

Technical Analysis: This concept is usable with either steward or self-service if crew sizes are in the 6-12 man range. For smaller crews using self-service, it would be less desirable. The primary advantage is the creation of a temporary holding station of a prepared meal while the next meal is being assembled. This frees the steward or kitchen staff personnel from being restricted by the prepared food tray until a crewman can relieve him of it. Use of the dispenser cabinet permits all meals to be assembled on a continuing basis with a minimum of crew time.

b. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-11 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III- 11

CONCEPT EVALUATION SUMMARY

FUNCTIONAL NO.: 3.6	SUBSYSTEM SUB-FUNCTION TITLE: Food Cabinets	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.6.1	Food Dispenser Cabinet	12.7		X			X

For each of the concepts selected for detailed study, technical data are presented below.

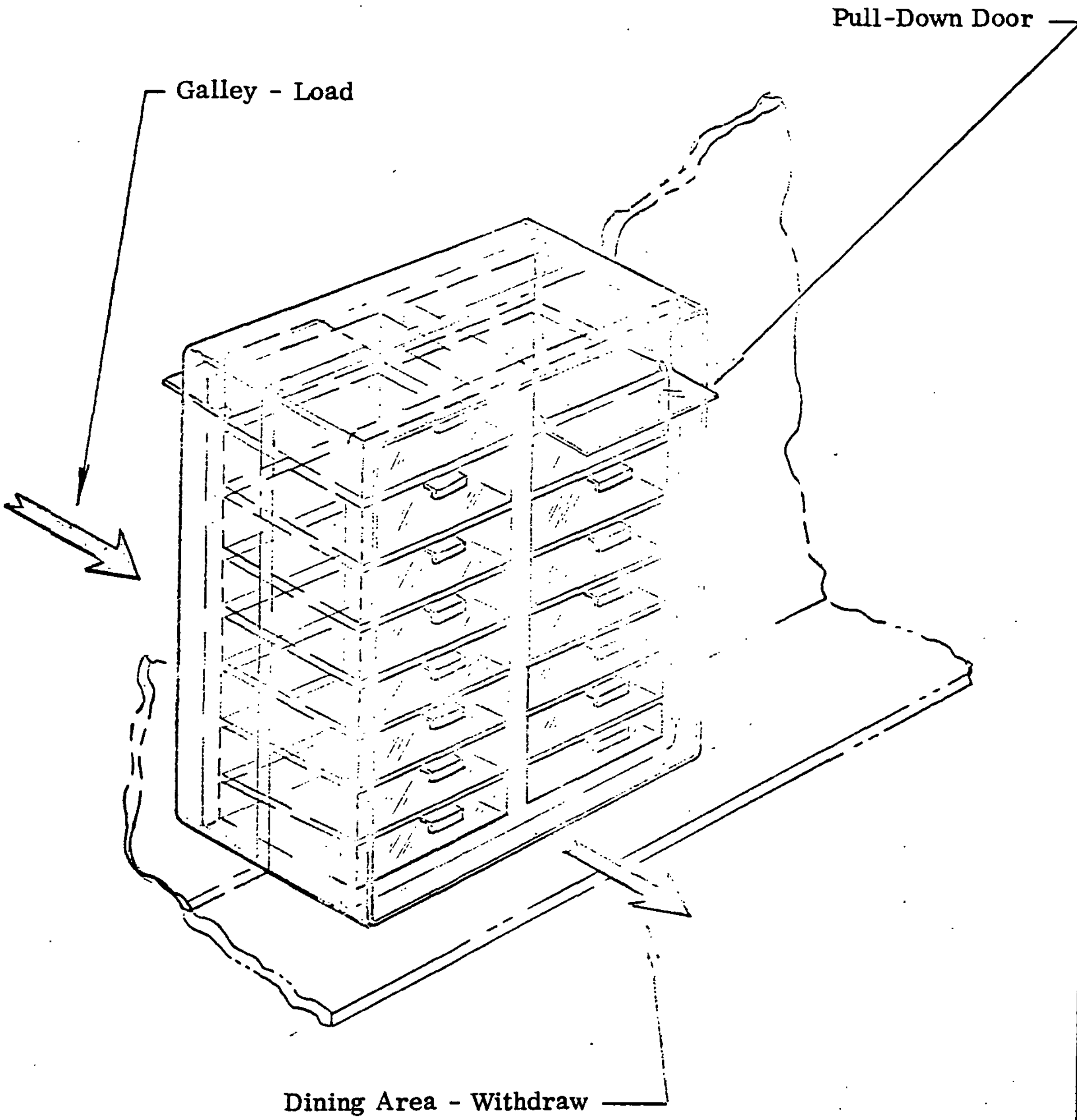
1) Technical Data - Food Dispenser Cabinet (Concept 3.6.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.6.1.1 through 3.6.1.3 in Data Book - Book I.

c. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Food Dispensing Cabinet



This dispensing cabinet will be mounted on either a counter top or built into a wall dividing the galley from the dining area. It will be compartmentized with pull-down, see-through doors at both the dining and galley sides.

A steward may remove food to serve to a crewman or the crewman himself may take it for self-service. The interior will be designed to restrain the contents so that this unit may be used in either zero- or one-g. The concept is similar to the "automat" food system.

D— 3.6.1

3.7 Candidate Food Storage Cabinets

a. Concept: Food Storage Cabinets (3.7.1)

Concept Description: This concept utilizes a stacked cartridge-type food package that is loaded into a housing containing a negator spring that maintains a constant force on the package. Each food package is individually obtained by depressing a lever that extracts the desired package. The negator spring advances the stack, positioning it for the next withdrawal. The concept is contingent on the type of packaging selected for the food. Either complete heatable meal portions per crewman or by food type would be acceptable with this technique. A basic wafer type square or cylindrical stack would be most compatible for minimum volume storage.

Technical Analysis: This is a common and simple technique for storing and withdrawing food packages. Only one-handed operation is required and no moving parts or powered devices are necessary. The spring-loaded stack is automatically positioned in zero-gravity and held in place for the next use, thereby minimizing crew operations. Packaging techniques are compatible with standard procedures and potential configurations for any station or crew size.

b. Concept: Self-Storing Food Containers (3.7.2)

Concept Description: When food items are containerized either individually or in bulk, the containers themselves can be designed to mate with and stack with each other for storage. In this concept, food items of a similar type would be packaged in rigid or semi-rigid containers that could nest with a clip-on to the next container. Each container would be designed to withstand environmental loads during launch and mission requirements, thereby eliminating the need for external or overwrap protective packaging.

Technical Analysis: This concept reduces storage volume requirements by making each food package container structurally self-sufficient. Containers could be added or withdrawn without affecting the integrity of the stack. No separate storage facilities would be required other than the food containers themselves. A probable penalty in weight would occur with this approach. An alternate solution would be to provide a food container housing that is designed to carry primary loads once the actual food containers are stacked, thereby limiting the food container requirements to environmental constraints rather than structural.

c. Concept: Automated Food Storage Cabinets (3.7.3)

Concept Description: This concept interfaces the preparation device and storage cabinets to eliminate handling requirements to effect package opening and transfer to the reprocessing chamber. Each food package consists of either individual or bulk heatable portions of the meal prepackaged for warming. A package opening lever strips the wrapping and a dispenser automatically inserts the meal into the preparation oven which is aligned with the cabinet by means of a guide and power source. The preparation device is closed and the meal is then heated. The preparation device can then be utilized as a server to deliver the heated meal. The storage cabinet would also contain beverage mixes or other food types requiring reconstitution. Different types of preparation devices can be used such as one which would accept water and blend the mixture ready for dispensing. Storage for each of the various types of preparation devices is provided within the cabinet.

Technical Analysis: This concept of a highly automated system is applicable to larger station/crew sizes where significant quantities of food must be prepared and savings in crew time can be substantial. Development is required to establish the feasibility of the design and achieve high reliability. The minimization of handling requirements, however, is a desirable objective for all crew sizes.

d. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-12 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III- 12

CONCEPT EVALUATION SUMMARY

FUNCTIONAL NO.: 3.7	SUBSYSTEM SUB-FUNCTION TITLE: Food Storage Cabinets	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.7.1	Food Storage Cabinets	12.8		X	-		X
3.7.2	Self-Storing Food Containers	12.5		X	-		X
3.7.3	Automated Food Storage Cabinets	11.9		X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Food Storage Cabinets (Concept 3.7.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.7.1.1 through 3.7.1.3 in Data Book - Book I.

2) Technical Data - Self-Storing Food Containers (Concept 3.7.2). Detailed data for this concept are presented on Element Concept Data Sheets 3.7.2.1 through 3.7.2.3 in Data Book - Book I.

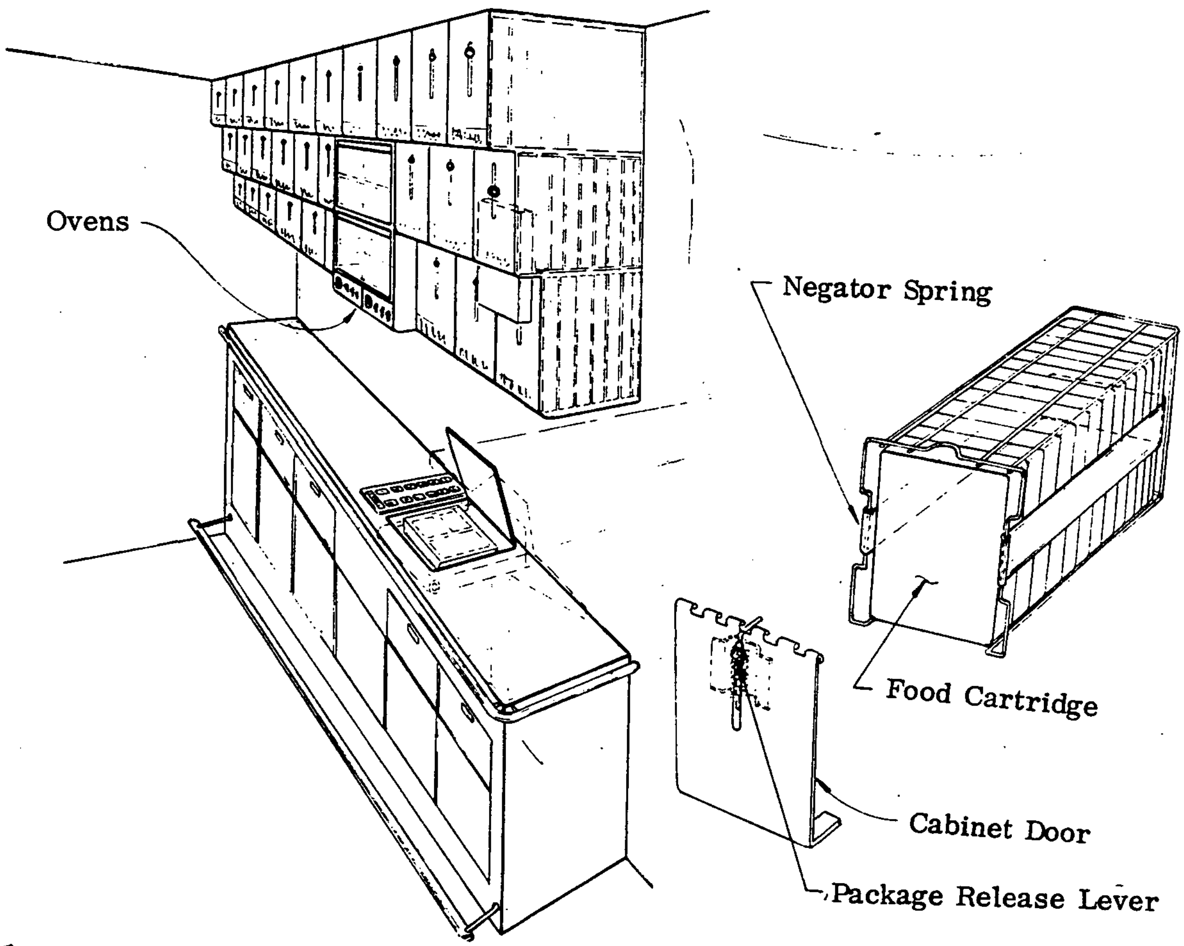
3) Technical Data - Automatic Food Storage Cabinets (Concept 3.7.3). Detailed data for this concept are presented on Element Concept Data Sheets 3.7.3.1 through 3.7.3.3 in Data Book - Book I.

e. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Food Storage Cabinet



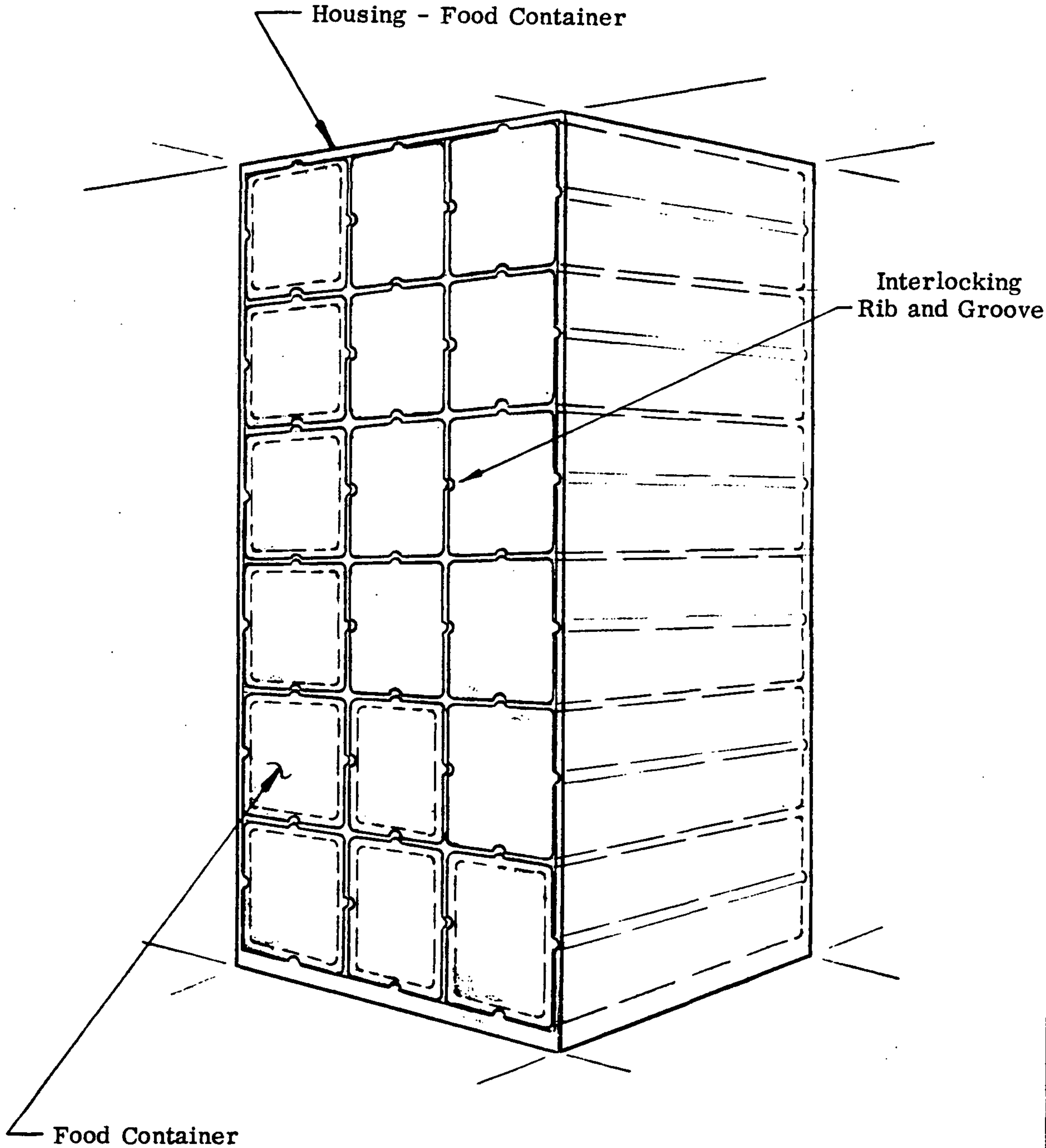
This concept is an over-counter food storage or holding cabinet, constructed of aluminum, using the latest manufacturing techniques available. It will be so designed to accept a wire form type of food cartridge which comes from ambient storage.

This cabinet and food cartridge module will allow a crewman to extract food using only one hand. This concept is basically for zero-g operation, but may also be used for partial- to one-g usage.

D— 3.7.1

FOOD SYSTEM STUDY SKETCH

Title: Self-Storing Food Containers

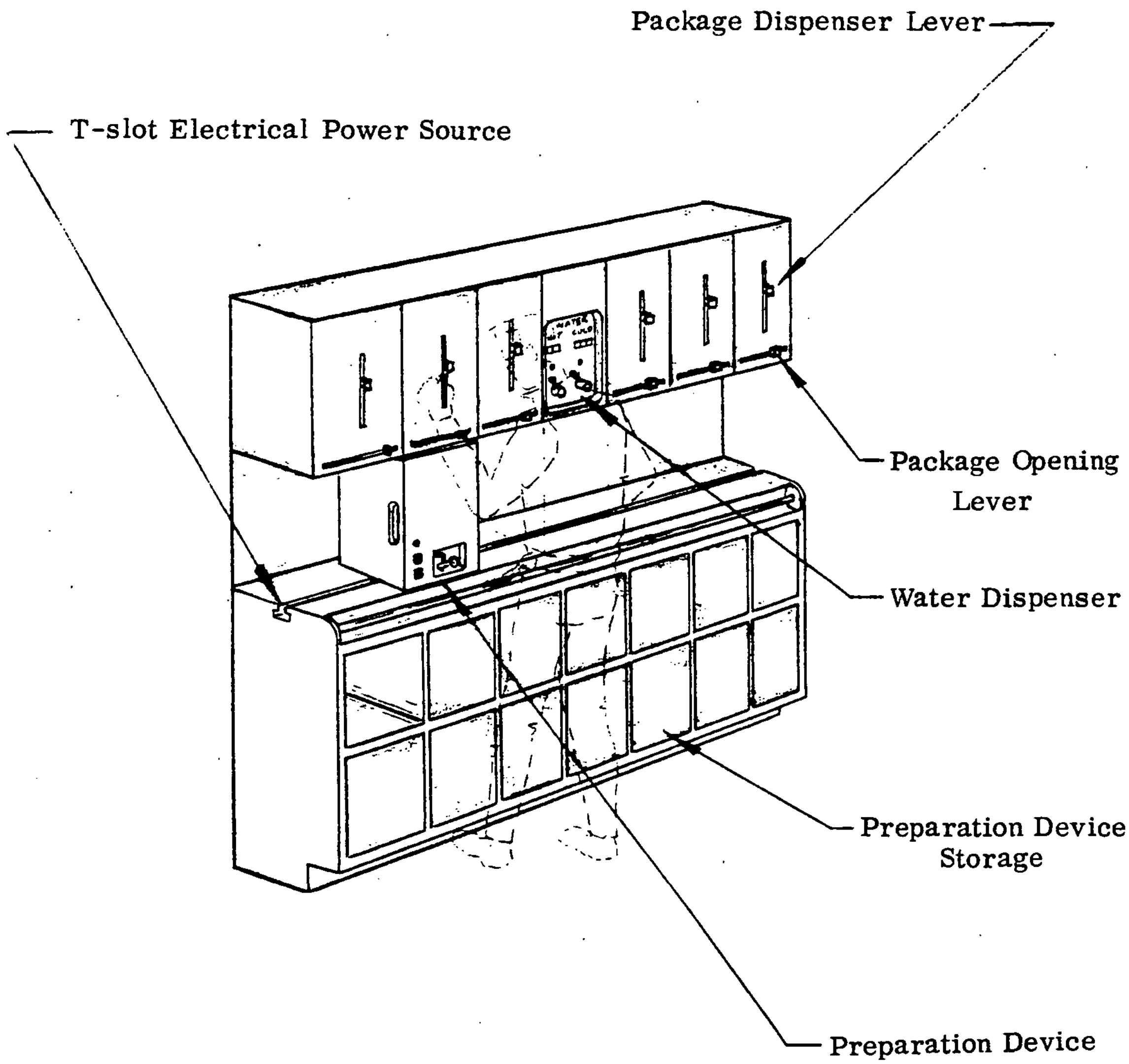


This can be a metal or non-metallic container that has interlocking ribs and grooves to allow mating of one to the other and to mate with and into a special housing. When the housing is completely filled, any container may be removed without disturbing the other containers. Doors or covers give access to its contents. These containers will be stored in the ambient storage locker.

D— 3.7.2

FOOD SYSTEM STUDY SKETCH

Title: Automatic Food Storage Cabinet



This is a system where the method of injecting food into preparation devices is done by merely depressing a lever. A T-slot retains the preparation device and contains an electrical power source.

The advantage of an automatic device is that it prevents spillage during preparation and minimizes crew time and personnel requirements. Further development is needed to perfect this system.

D— 3.7.3

3.8 Candidate Food Preparation Utensils

a. Concept: Kneader-Mechanical (3.8.1)

Concept Description: This is a lever-actuated mechanical kneader that blends or mixes dry foods or powders and liquids directly in the food package to create a homogenous mixture. The kneader consists of two sections hinged together. One half contains a set of movable rollers that can be either hand operated or power driven. The other half of the device contains fixed rollers upon which the food package is placed. When the movable rollers are actuated, they roll over the food bag kneading the contents between them and the stationary rollers. The device can be sized for either individual or multiple food packages.

Technical Analysis: A percentage of the onboard food will require reconstitution directly in its package for direct consumption by the crew-member. For small size crews (up to 6 men) and short resupply missions, the amount and type of food packages will be significant. For larger crews and longer resupply missions, the amount of snack items and beverages requiring reconstitution will also be substantial, but the variety or food types will be less due to the advantages of bulk packaging. The mechanical kneader, therefore, fits a need for reducing preparation times for a variety of mission options in that the device could be utilized as galley equipment on large stations or as an individual assist for small crews.

b. Concept: Kneader-Hand Operation (3.8.2)

Concept Description: This is a technique oriented concept requiring crewman hand kneading of the individual food package once liquid is added to the mixture. The technique is limited to food types or beverages that are amenable to hand reconstitution as on Apollo food supplies. The quality of the final mixture is dependent on the amount of mixing performed by the crewman.

Technical Analysis: This is a limited application concept that would be too time consuming and impractical as a means of providing primary food entrees for large crews. It should be considered as a supplementary technique for large crews (12 or more men), providing snacks, desserts, beverages, or special meals. For smaller crews and short resupply missions, hand kneading may be an acceptable alternative for main meal and supplementary food items.

c. Concept: Hot Food Handling Tongs (3.8.3)

Concept Description: The handling tongs are used to assist the galley personnel or crewman in preparing meals in ovens or other heating devices. Dishes or trays containing the heatable portion of a meal may be inserted into the pre-heated ovens and upon completion of the warming cycle, the heated dish will be with-drawn for serving. The tongs would clamp the edge of a dish or tray and be locked in place by a locking lever to prevent inadvertent release.

Technical Analysis: The use of ovens or similar heating devices implies that either food packages, dishes, casseroles, or trays will require handling after heating and prior to consumption. A positive insulated device should permit the crewman to manipulate the heated item without direct hand contact. For any of the missions or systems utilizing this type of food preparation equipment, supporting utensils are required.

d. Concept: Clamshell Handling Device (3.8.4)

Concept Description: This can be a multipurpose device used in transferring portion sized food items to or from a preparation device. It can also be utilized directly as a consumption utensil. An upper clamshell half is pivoted by a thumb-operated link. The food is retained in the lower spoon-shaped receptacle and on release of the link, a light torsion spring returns the upper clamshell to a closed position, encapsulating the food.

Technical Analysis: Preparation, transfer, and dining techniques in zero-gravity should be assisted with simple devices and utensils that minimize crew operational tasks. Transporting food in open utensils requires extreme care as any sudden movement can dislodge the food. The adhesive/cohesive characteristics would also impact the possibility of escape unless a retention device was employed.

e. Concept: Mixing Bowls (3.8.5)

Concept Description: Onboard preparation of certain food items, bakery products, desserts, and beverages require mixing of ingredients. A set of mixing bowls similar to those used in the home except covered to prevent escape of food particles would be required. Access through the cover for a mixing spoon would permit blending of the bowl contents.

Technical Analysis: This concept was discarded for further study on the basis of poor adaptability to zero-gravity usage, excessive crew time for operation, and cleansing problems.

f. Concept: Spoon - Conventional (3.8.6)

Concept Description: To support the tasks of dispensing or transferring food between dishes, trays, dispensing devices, or preparation devices, a conventional spoon can be used. Foods will also require distribution from bulk packages to individual portions in trays or dishes. A spoon can serve as a transport device as well as a measuring and serving utensil.

Technical Analysis: An open spoon has poor acceptability in zero-gravity due to the care that must be exercised during use. As a preparation aid, the conventional spoon was discarded for further study since it has limited use as a transport utensil and cannot serve as an accurate measuring device, thereby negating its function in preparation. For the serving or dining functions, the conventional spoon was considered as a candidate eating utensil.

g. Concept: Scoop - Ice Cream Type (3.8.7)

Concept Description: For separation and distribution from bulk to portion sizes of cohesive type soft foods, a scoop can be utilized in the galley. The scoop would be designed with a hydrophilic coated metal or plastic to minimize transfer problems and as an assist in retaining food within the scoop. A lever-actuated wiper would separate the food from the scoop and dispense it into the desired receptacle with a positive and directional displacement.

Technical Analysis: This device may have wide use as it appears to be highly diverse in application. It is retained for further study since it may be adaptable to a larger variety of foods than originally anticipated. The scoop configuration can be modified to a conical section rather than a cup shape to improve zero-gravity retention characteristics. This would permit use with both cohesive and non-cohesive type foods resulting in a valuable preparation aid for any size crew or resupply mission.

h. Concept: Egg Slicer (3.8.8)

Concept Description: This piece of equipment is similar to a commercial hard boiled egg slicer. The device would be modified so that a hinged cover would follow the cutting wires to encapsulate the sliced egg after cutting, thereby preventing separation in zero-gravity.

Technical Analysis: This concept was discarded for further study as it was considered an unnecessary device. Eggs can be presliced and frozen and then stored in the freezer for any of the resupply mission periods considered. An overwrap of foil would be required for storage. The alternative of storing hard boiled eggs in their shells unfrozen is less desirable due to a more limited storage life (approximately six weeks) and the problems involved in shelling and slicing in zero-gravity.

i. Concept: Kitchen Utility Shears (3.8.9)

Concept Description: This is basically an off-the-shelf pair of safety shears to be used in opening plastic food packages and as a general utility shear. The shears will have magnets imbedded on both sides for retention in zero-gravity. The points will be rounded into ball ends to prevent inadvertent punctures or accidents.

Technical Analysis: The shears are required for opening food packages as well as for light duty shearing purposes. The need is not limited by mission and is, therefore, recommended as an across-the-board requirement and as a multi-purpose utensil.

j. Concept: Hand-Operated Mixer/Blender (3.8.10)

Concept Description: This device provides a convenient method for mixing or blending ingredients for beverages, desserts, and certain soft foods. A container of dry mix, either pre-filled or filled as required, is mated to the water reconstitution device which meters a prescribed amount of fluid. The container is then inserted into a cylindrical housing and fitted onto an actuating mechanism. A trigger on the housing translates an oscillating rotary motion to the container resulting in agitation of the contents. After mixing, the container is withdrawn and an integral mouthpiece used for direct consumption.

Technical Analysis: For small to intermediate crew sizes (up to 12 men), this device could be used as the primary method for providing beverages and soft desserts. For larger crews, it could supplement bulk preparation as a means of providing individual drinks or snack items on demand. Each container could be capable of being refilled for longer mission requirements or can be designed as a plastic throw-away for short missions. The mixer/blender provides positive mechanical mixing by its oscillating rotary motion and minimizes hand operations involved in manual mixing. Overall safety with respect to possible leakage or breakage of packages is improved with this device.

k. Concept: <u>Rubber Spatula</u> (3.8.11)

Concept Description: This utensil is utilized as a galley aid in preparation, mixing, stirring, or scraping. It would be fabricated of a molded hard rubber or teflon with hydrophobic surfaces. The edges would be rounded to avoid inadvertent puncture or damage to food packages.

Technical Analysis: Soft foods of high cohesive properties such as mashed potatoes, creamed vegetables, and desserts can be mixed, stirred, dispensed, separated, or cleansed from dishes, trays, or preparation devices with a simple spatula. The utensil, due to its hydrophobic characteristics, will, when used with these cohesive food types, permit the galley steward or crewman to use the utensil as a multipurpose device. A wipe can be used to cleanse the spatula.

l. Concept: <u>Food Chopper</u> (3.8.12)

Concept Description: The chopper consists of an enclosed container which has a spring-loaded, hand-actuated chopping mechanism for breaking bulk bars or blocks of food into distributable portions. It would also reduce reconstitution time by reducing the bulk mass into smaller volumes. The housing is separable and locked in position by a detent stop. The plunger to which are affixed the teflon coated cutting blades is hand operated and spring returned to the open position. A vertical up and down actuation operates the cutter.

Technical Analysis: The primary purpose of this device is to reduce crew time in handling frozen bulk food items prior to preparation. It enables the crewman to reduce a bulk package into smaller units so that food can be distributed into individual meal size portions. It would be adaptable to larger crew sizes where bulk packaging results in appreciable volume and weight savings.

m. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-13 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-13

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 3.8	TITLE: Food Preparation Utensils	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.8.1	Kneaders - Mechanical	10.7		X	-		X
3.8.2	Kneader - Hand Operation	10.0		X	-		X
3.8.3	Hot Food Handling Tongs	16.9		X	-		X
3.8.4	Clam Shell Handling Device	14.4		X	-		X
3.8.5	Mixing Bowl	8.8	X				
3.8.6	Spoon - Conventional	8.5	X				
3.8.7	Scoop - Ice Cream Type	11.6		X	-		X
3.8.8	Egg Slicer	8.1	X				
3.8.9	Kitchen Utility Shears	12.0		X	-		X
3.8.10	Hand-Operated Mixer/Blender	11.5		X	-		X
3.8.11	Rubber Spatula	14.1		X	-		X
3.8.12	Food Chopper	10.0		X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Mechanical Kneader (Concept 3.8.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.1.1 and 3.8.1.2 in Data Book - Book I.

2) Technical Data - Hand Operated Kneader (Concept 3.8.2). Detailed data for this concept are presented on Element Concept Data Sheet 3.8.2.1 in Data Book - Book I.

3) Technical Data - Hot Food Handling Tongs (Concept 3.8.3). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.3.1 and 3.8.3.2 in Data Book - Book I.

4) Technical Data - Clam Shell Handling Device (Concept 3.8.4). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.4.1 and 3.8.4.2 in Data Book - Book I.

5) Technical Data - Food Scoop (Ice Cream Type) (Concept 3.8.7). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.7.1 through 3.8.7.3 in Data Book - Book I.

6) Technical Data - Utility Shears (Concept 3.8.9). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.9.1 and 3.8.9.2 in Data Book - Book I.

7) Technical Data - Hand Operated Mixer/Blender (Concept 3.8.10). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.10.1 through 3.8.10.3 in Data Book - Book I.

8) Technical Data - Spatula (Concept 3.8.11). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.11.1 through 3.8.11.3 in Data Book - Book I.

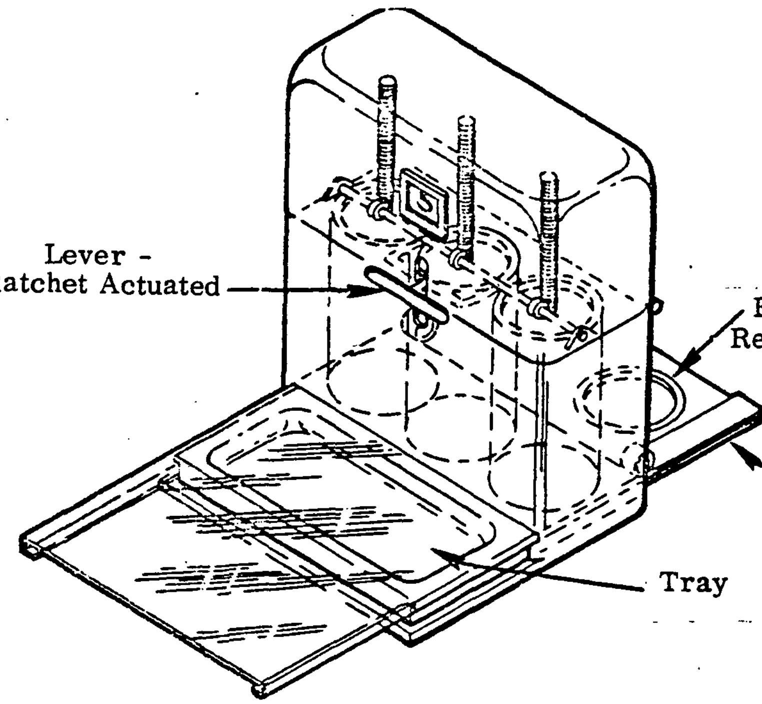
9) Technical Data - Food Chopper (Concept 3.8.12). Detailed data for this concept are presented on Element Concept Data Sheets 3.8.12.1 through 3.8.12.3 in Data Book - Book I.

n. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Preparation Equipment - Food Dispenser



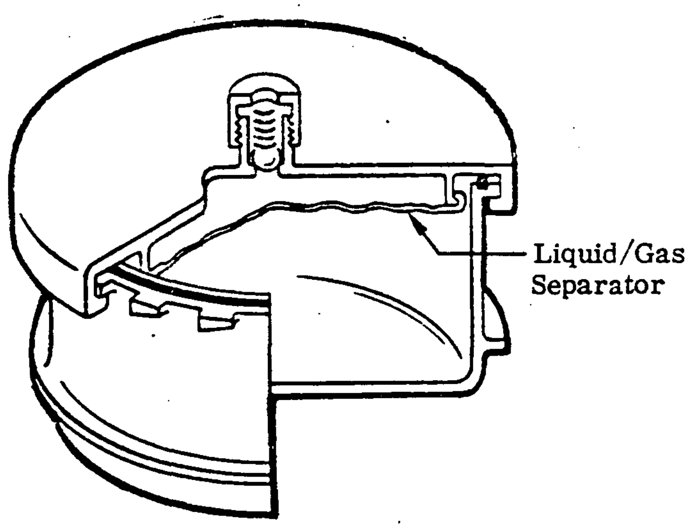
Bulk-to-Individual Food Portion Dispenser consists of three food cavities matched to the bulk packaged food containers with a ratchet-actuated dispensing mechanism. The lower section incorporates a spring-loaded dispenser cover with a cavity to accept the food package end cap. The food package (hot or cold) is inserted into the food cavities and the ratchet-actuated piston is engaged to the upper food package cap. A tray is inserted into the tray port and this action slides the spring-loaded dispenser cover, containing the lower food cap, to the rear. Actuation of the piston deposits a metered food quantity into the positioned tray. Withdrawal of the tray results in shearing the food portion and closing the lower dispenser cover.

This dispenser can be used for both zero- and one-g applications.

D— 3.8 A

FOOD SYSTEM STUDY SKETCH

Title: Preparation Equipment - Zero-G Pressure Cooker

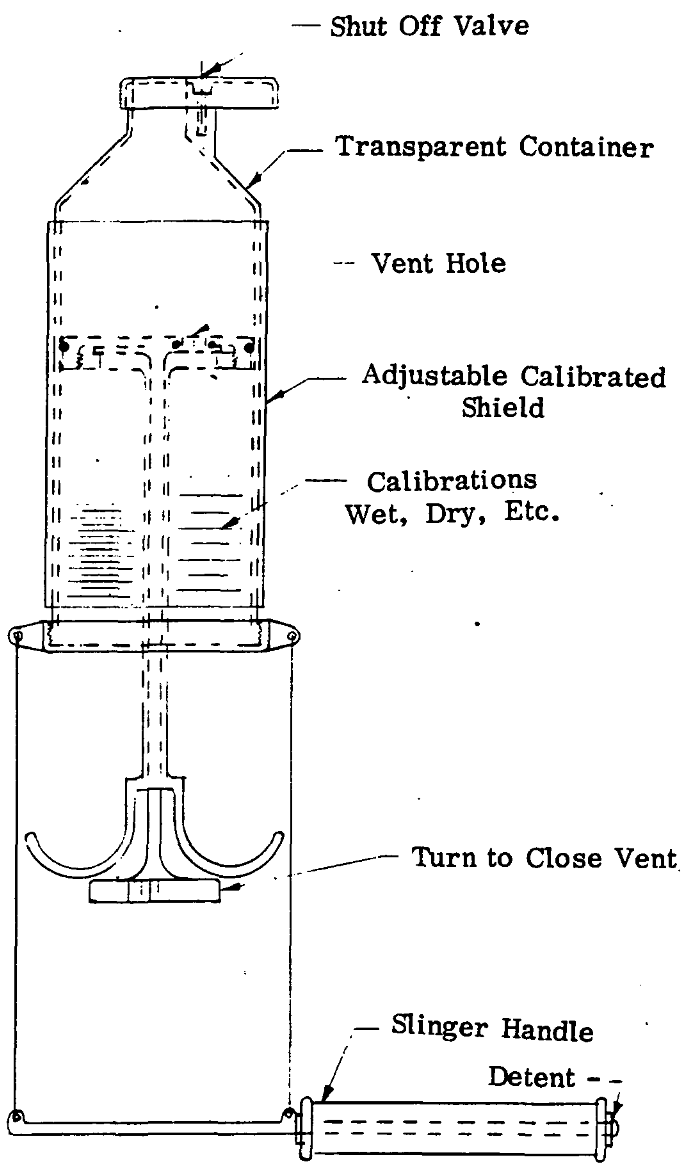


Zero-G Pressure Cooker consists of a pressure vessel with a partial turn, cam-lock cover. Hydrophobic/hydrophilic surface will be incorporated selectively on the interior surfaces to control fluid position for liquid-gas separation. A liquid-gas separator membrane, a relief valve, and associated safety pressure relief feature will be incorporated into the cover. The pressure vessel will be equipped with electrical resistance heating elements and associated time and temperature controls.

D— 3.8 B

FOOD SYSTEM STUDY SKETCH

Title: Food Preparation Utensils - Measuring Device

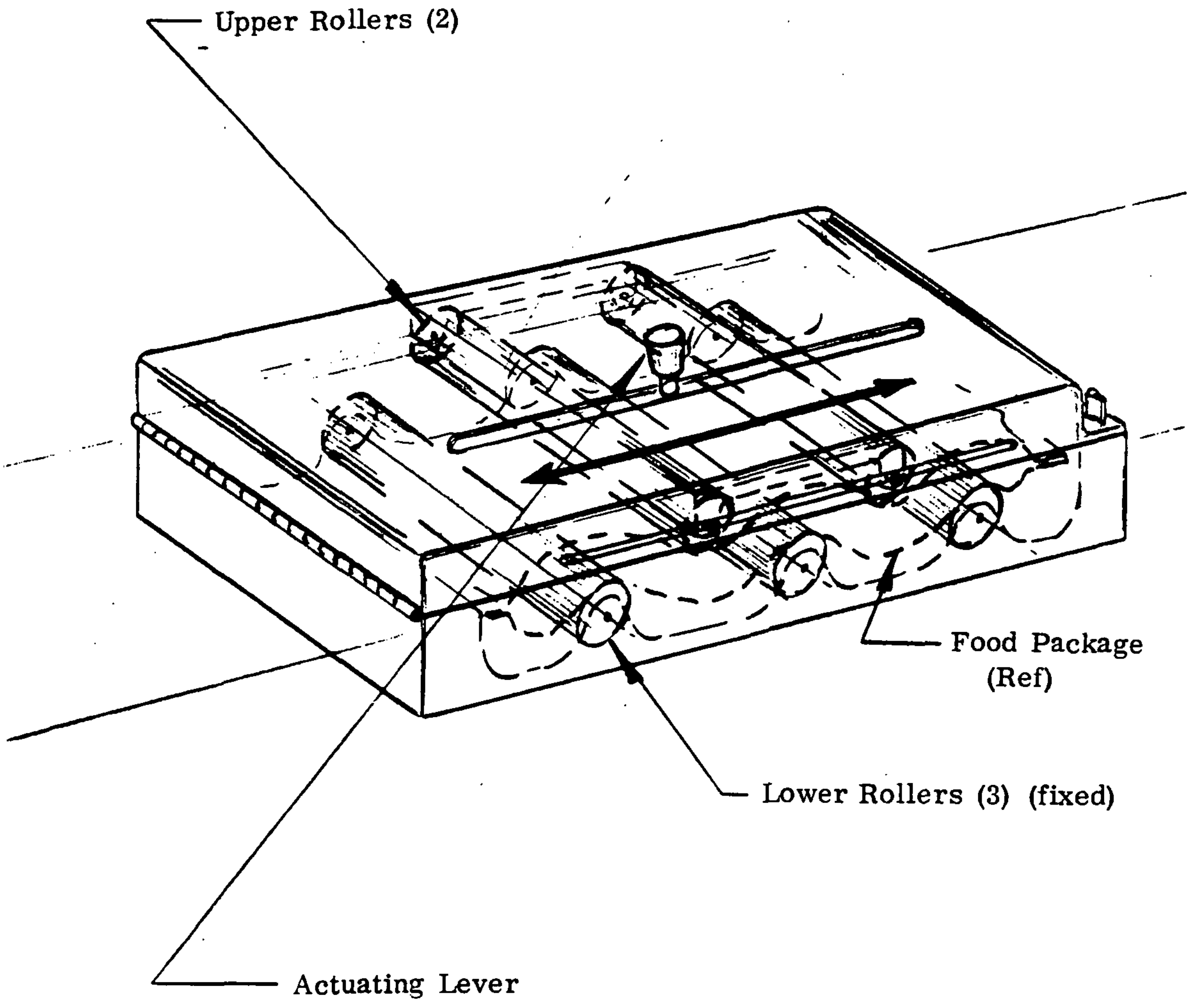


The device consists of a cylinder with a shut-off valve, a piston with a vent valve, and a manual slinger. To operate, connect to or insert into a container. Pull back on the piston handle. Either the liquid or powder to be measured will enter the cylinder with some air. Close the shut-off valve. Vent the piston. Spin the measuring device about the slinger handle. The fluid or powder is forced to one end and the air exits out the piston vent. Close the vent. Rotate the calibrated sleeve to the desired scale. Slide the scale along the tube until zero coincides with the liquid or powder line. Open the shut-off valve. Push the plunger until the desired amount has been dispensed according to the scaled calibrations. Close shut-off valve.

D— 3.8 C

FOOD SYSTEM STUDY SKETCH

Title: Kneader - Mechanical



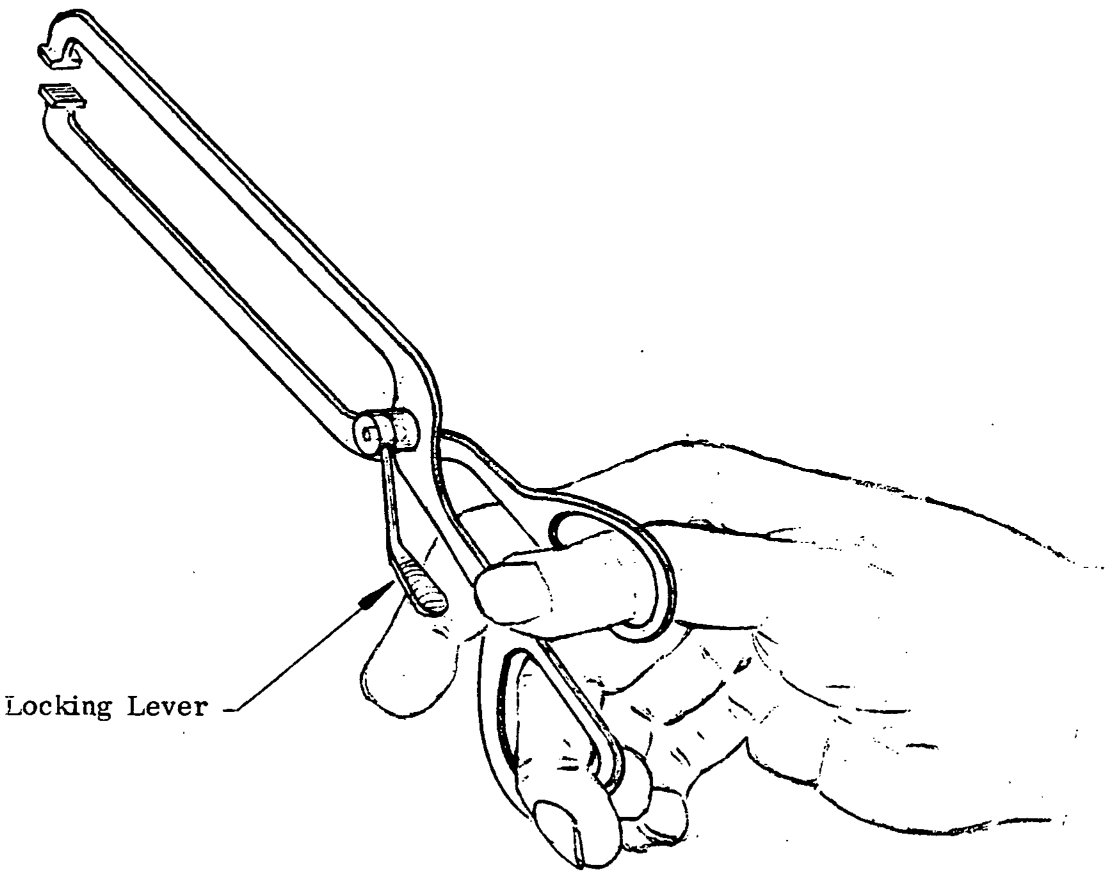
This mechanism is hand-actuated. By moving the actuating lever back and forth, two rollers bracketed to the actuating lever will roll over a plastic-type food package containing dry food and water. This action over stationary rollers will tend to knead the food back and forth.

This device would reduce meal preparation time and could be used either by the galley staff or individual crew members. Some development is anticipated to ensure compatibility with the food package design.

D— 3.8.1

FOOD SYSTEM STUDY SKETCH

Title: Hot Food Handling Tongs

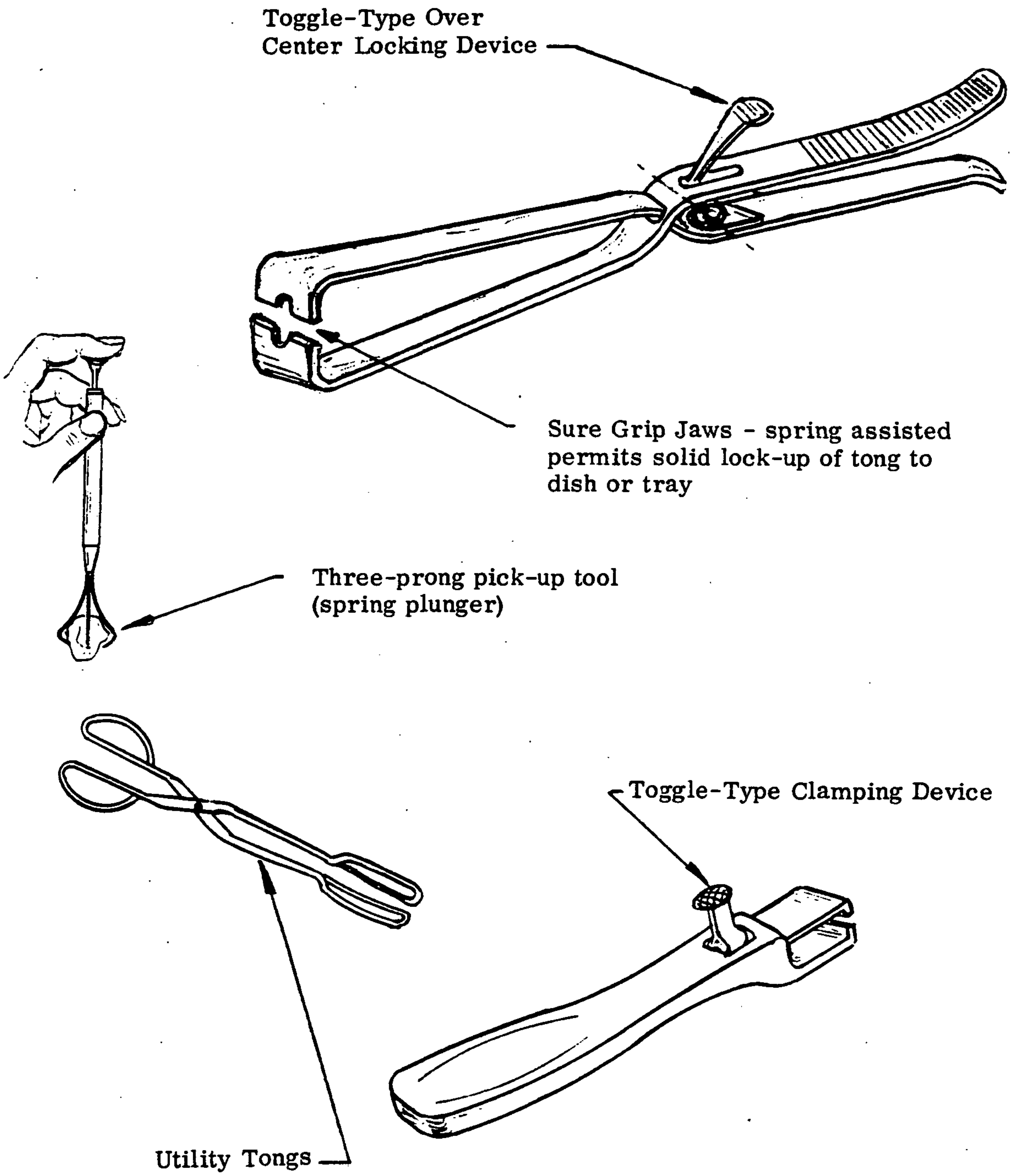


These tongs are held and operated by hand. The locking lever is used to lock the tongs in position on a food tray or dishes. It may be preferable to use two tongs to ensure proper handling. This item is an adaptation of an off-the-shelf design and would require a minimum of development. It is applicable for either zero- or one-g operation.

D— 3.8.3A

FOOD SYSTEM STUDY SKETCH

Title: Tong-Type Devices

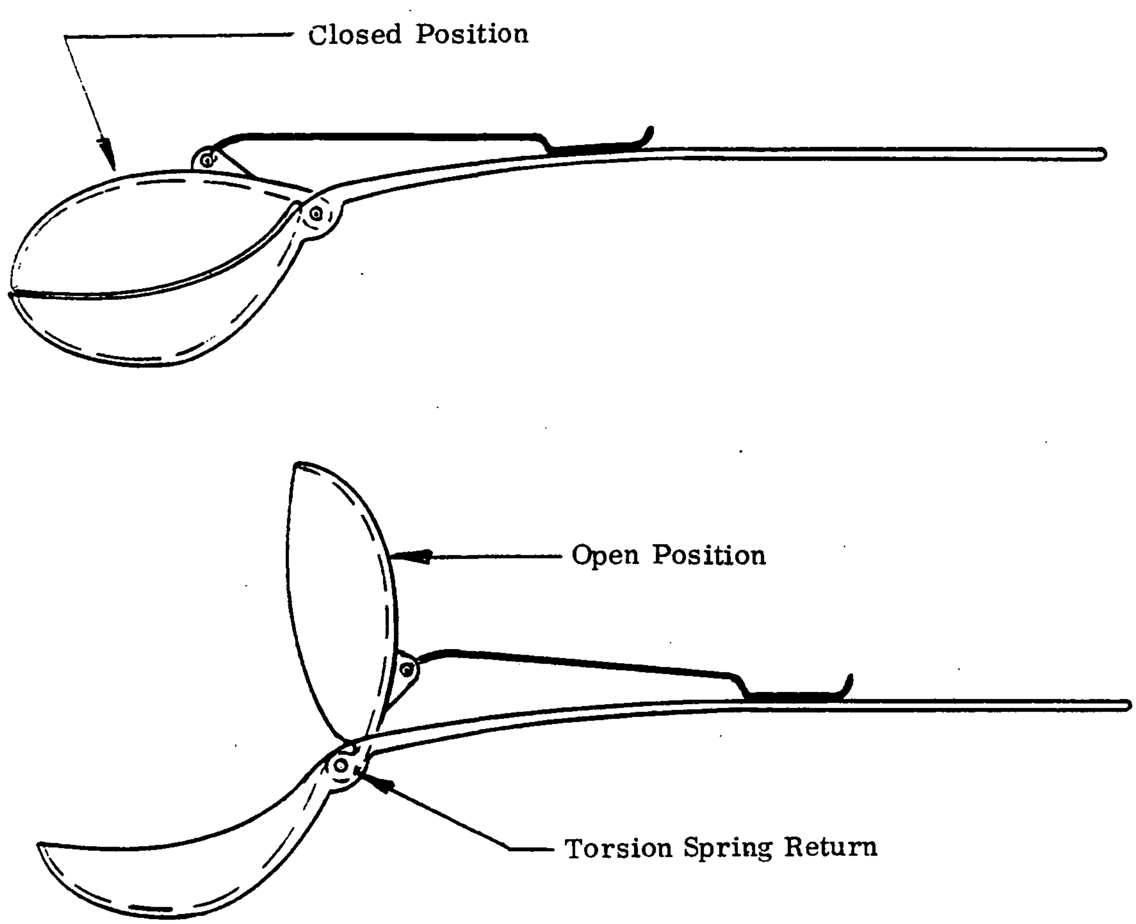


These are various concepts of tong-type devices for picking up food items, for handling hot food dishes or trays, or for transferring food or equipment in the galley. These implements may be used for both zero-g and one-g usage.

D— 3.8.3 B

FOOD SYSTEM STUDY SKETCH

Title: Clamshell Type Handling Device



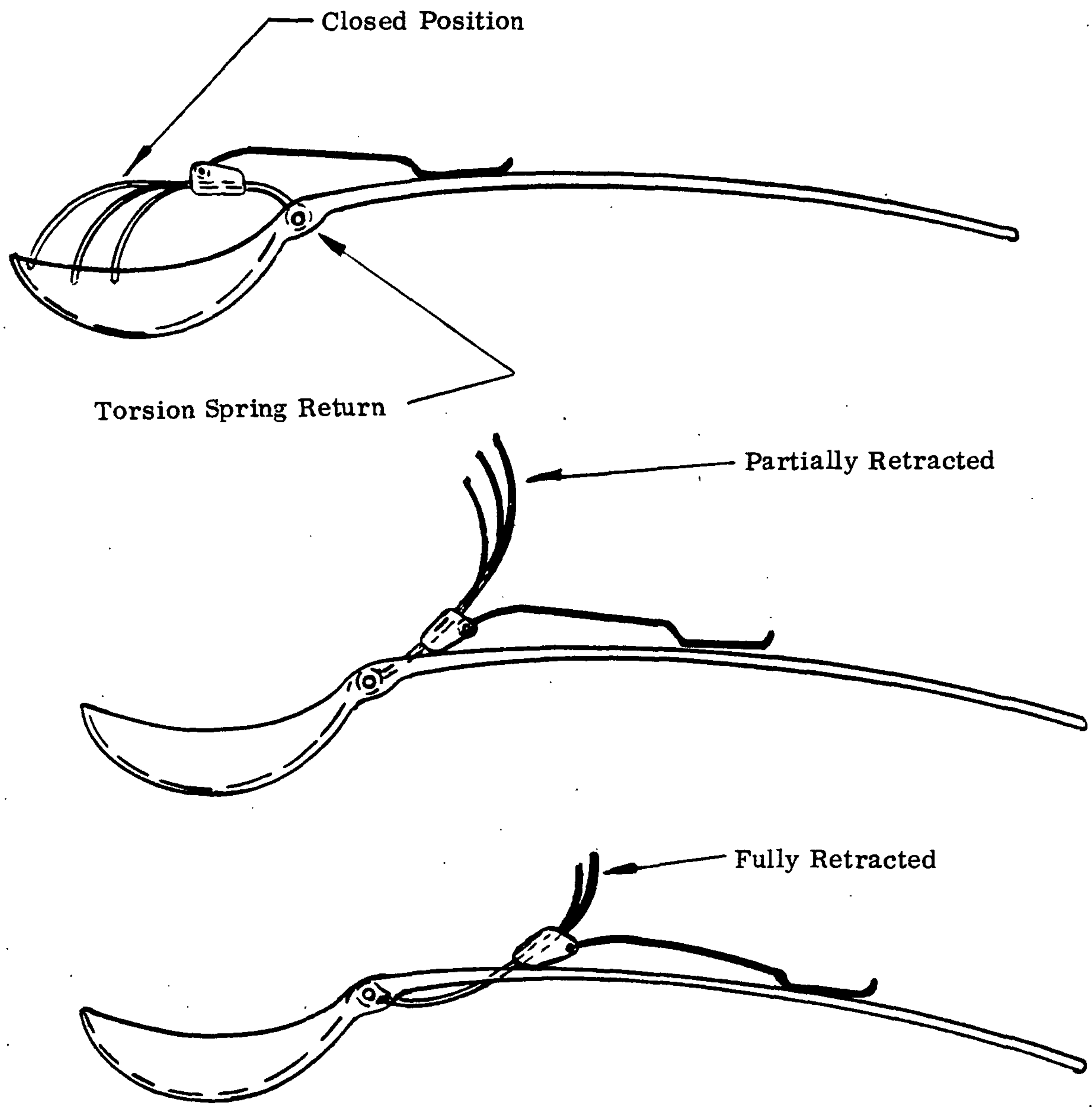
This device would be used to transfer food items which, if held in an open utensil, may tend to escape or be dislodged by sudden movements of the hand. The upper clamshell half will pivot back to remove contents. When released, a spring mechanism will return it to the closed position.

This utensil is primarily for zero-g use.

D— 3.8.4 A

FOOD SYSTEM STUDY SKETCH

Title: Clamshell Type Handling Device



This device would be used to transfer solid or semi-solid food items from preparation devices to food trays.

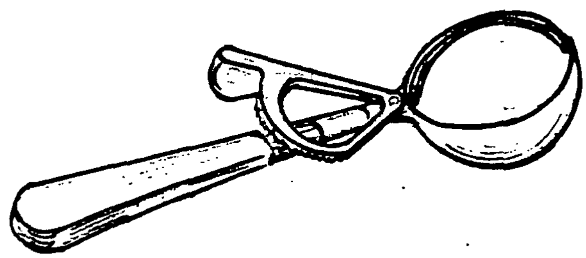
The upper half is made of spring-type wire in the form of fingers or tines. By pulling back on the lever, the fingers are pulled back out of the way. A spring will automatically return them to the closed position when the lever is released.

This utensil is primarily for zero-g use.

D— 3.8.4 B

FOOD SYSTEM STUDY SKETCH

Title: Scoop - Ice Cream Type



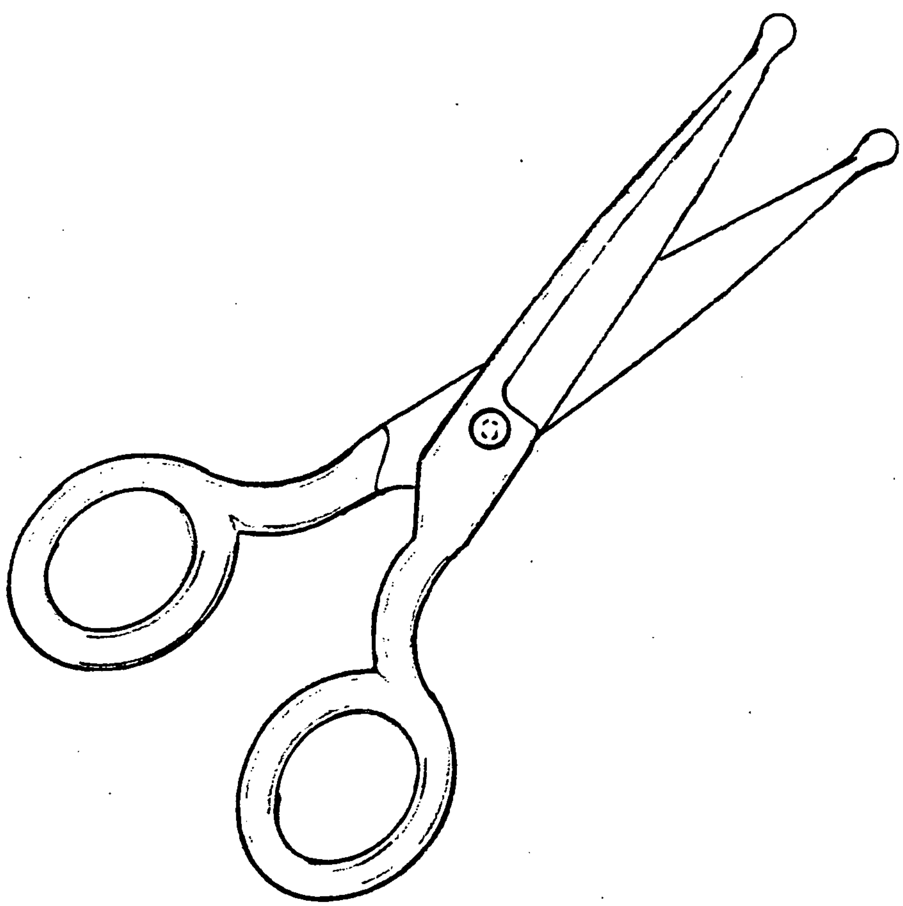
This is an off-the-shelf item made to simulate a conventional ice cream scoop. It would be made of a lightweight, stain resistant coated metal for ease of cleaning. It would be used to transfer cohesive type food items from bulk containment to individual dishes or trays.

Its application would be best suited for partial-g operation, but with training and care can be used in zero-g.

D— 3.8.7

FOOD SYSTEM STUDY SKETCH

Title: Kitchen Utility Shears

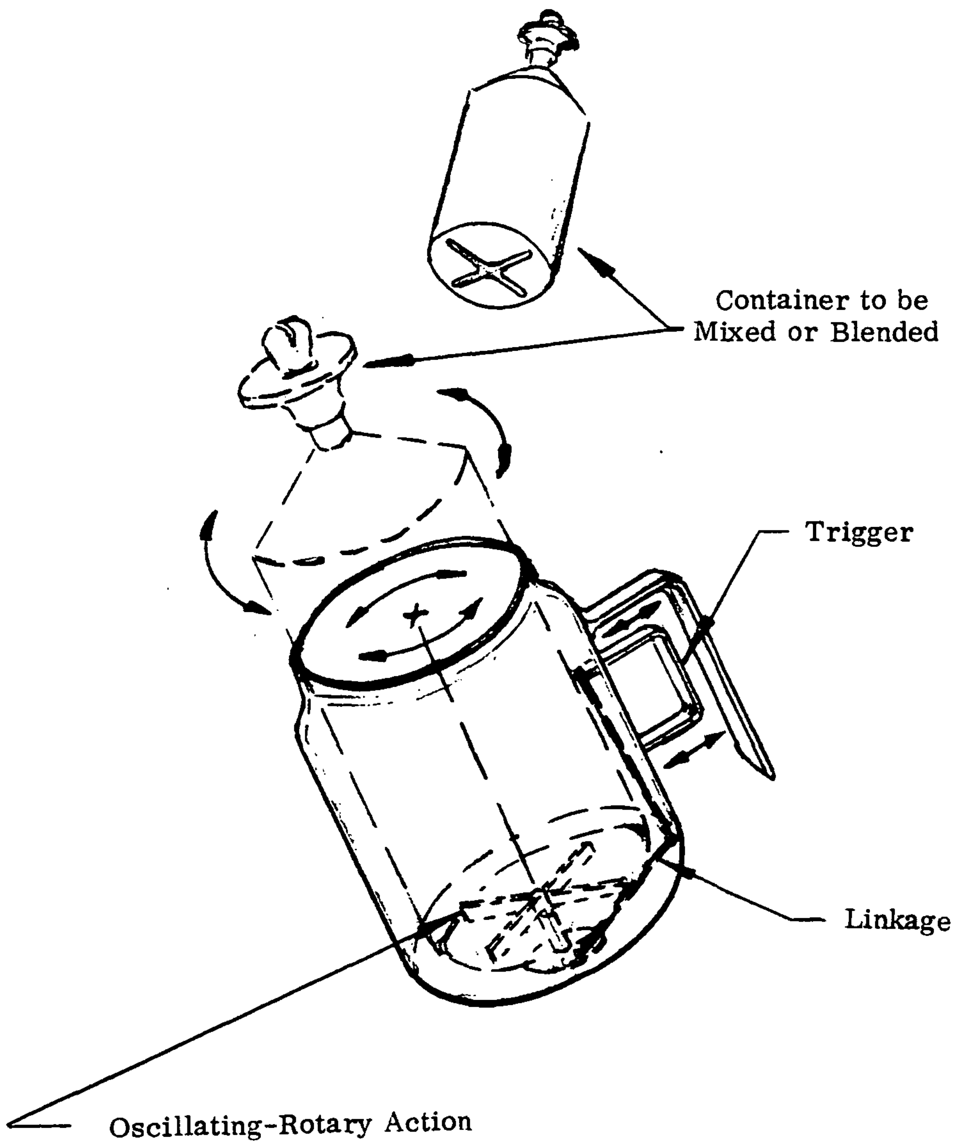


These safety shears are off-the-shelf equipment and may be used in the galley, dining area, or by the crew for various other light duty shearing purposes. They may be magnetized for restraint holding.

D— 3.8.9

FOOD SYSTEM STUDY SKETCH

Title: Hand-Operated Mixer/Blender



This is a device for mixing or blending food or liquid. A container is placed in the cylindrical housing onto the "X" shaped actuating mechanism which, upon operating the trigger, produces an oscillating rotary action.

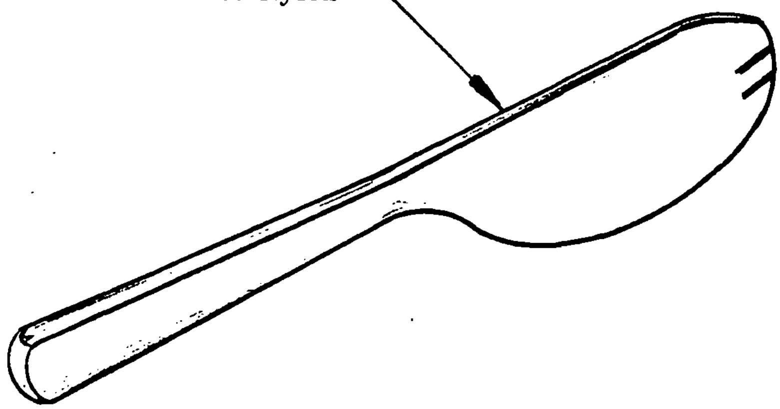
This lightweight, simple mechanism may be used for crews of 12 or less or when a minimum amount of mixing/blending operations are needed.

Similar mechanical mechanisms are commercially available. The design can be used in both zero- and one-g.

D— 3.8.10

FOOD SYSTEM STUDY SKETCH

Title: Spatula



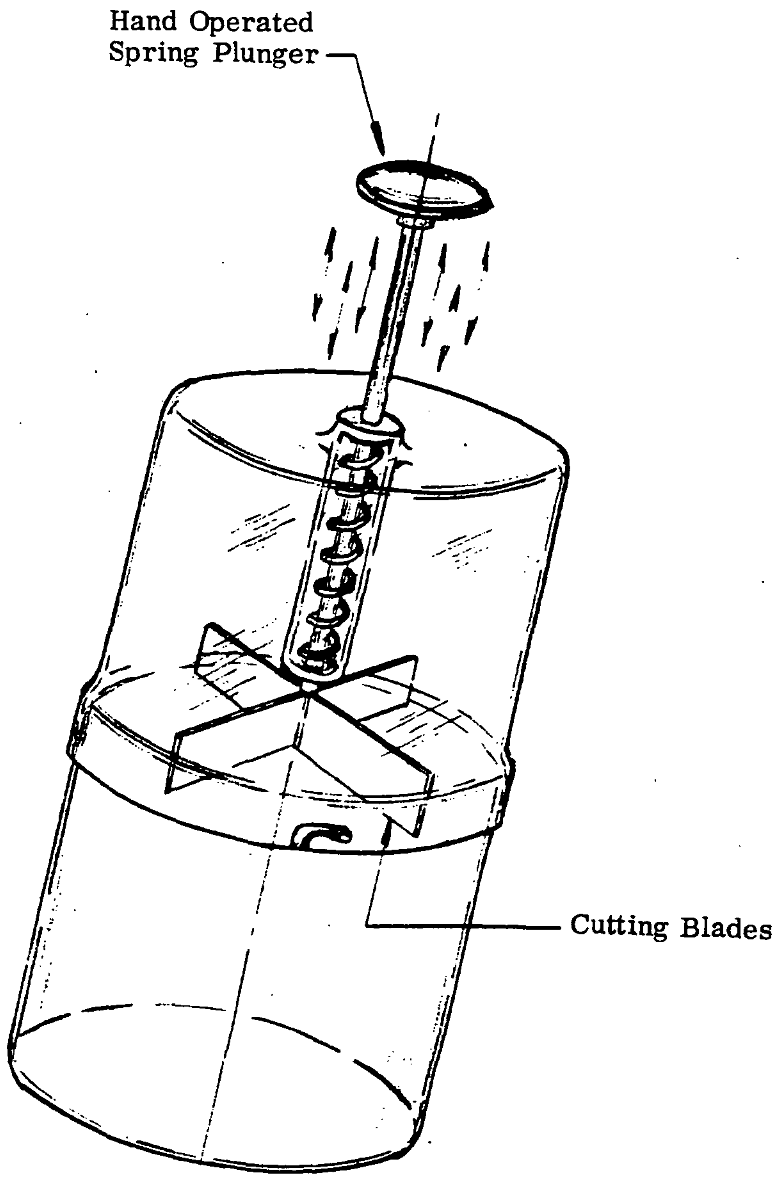
The spatula is made of either a hard rubber type material with a metal or non-metallic hand moulded in place or of a one-piece nylon construction. The spatula will be used for mixing foods in containers or scraping food out of containers.

This is an off-the-shelf item and can be used for either zero- or one-g applications.

D— 3.8.11

FOOD SYSTEM STUDY SKETCH

Title: Food Chopper



This is a totally enclosed container which has a spring-actuated chopping mechanism housed within a transparent non-metallic cover. A vertical up and down actuation operates the cutter.

It may be used to chop or break up frozen or solid foods. No development is required as it is an off-the-shelf item and may be used in both zero- and one-g.

D— 3.8.12

3.9 Candidate Debris Entrainment Devices

a. Concept: Controlled Spillage Device (3.9.1)

Concept Description: A controlled spillage module would be utilized in the preparation area as part of the work surfaces and counters. The module could be an integral unit with the preparation counter or a snap-on separate movable unit. It would contain its own air mover and controls, requiring only an interface with a power source to drive the blower. The blower induces a directional airflow that ingests food particles, waste, and debris through a series of orifices in the module. Within the module, a plenum chamber would be teflon lined to facilitate cleaning. The hydrophobic surfaces minimize adherence of food particles to the walls. The collection air is moved through bacterial and odor control filters prior to being returned to the cabin by the blower exhaust. An additional capability can be provided by the incorporation of iris-type openings in the module through which debris larger than the orifice sizes, such as wipes or disposable utensils, can be manually inserted by the galley steward or crewman.

Technical Analysis: Inadvertent spillage or escapement of foods and beverages is almost inevitable in the zero-gravity environment. Preparation tasks for multi-size crews will result in diverse food handling techniques for a greater variety and amount of food, thereby compounding the problems of food wastes and debris. The controlled spillage concept minimizes cleansing and particle retrieval tasks by capturing these wastes and moving them in a preferential direction by the use of induced airflow. The module is adaptable to not only food preparation areas, but to dining areas as well. It would also serve as a useful device in almost all work areas of a space station.

For larger space station concepts, the module can be ducted to a "trap" where wastes would be bagged and ultimately disposed of by either onboard systems or packaged for shuttle return. For modular space station concepts and crew sizes up to 12 men, individual self-contained units may be more practical. This concept is strongly recommended for future development.

b. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-14 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III- 14

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 3.9	SUB-FUNCTION TITLE: Debris Entrainment	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.9.1	Controlled Spillage Device	10.9		X	-		X

For each of the concepts selected for detailed study, technical data are presented below:

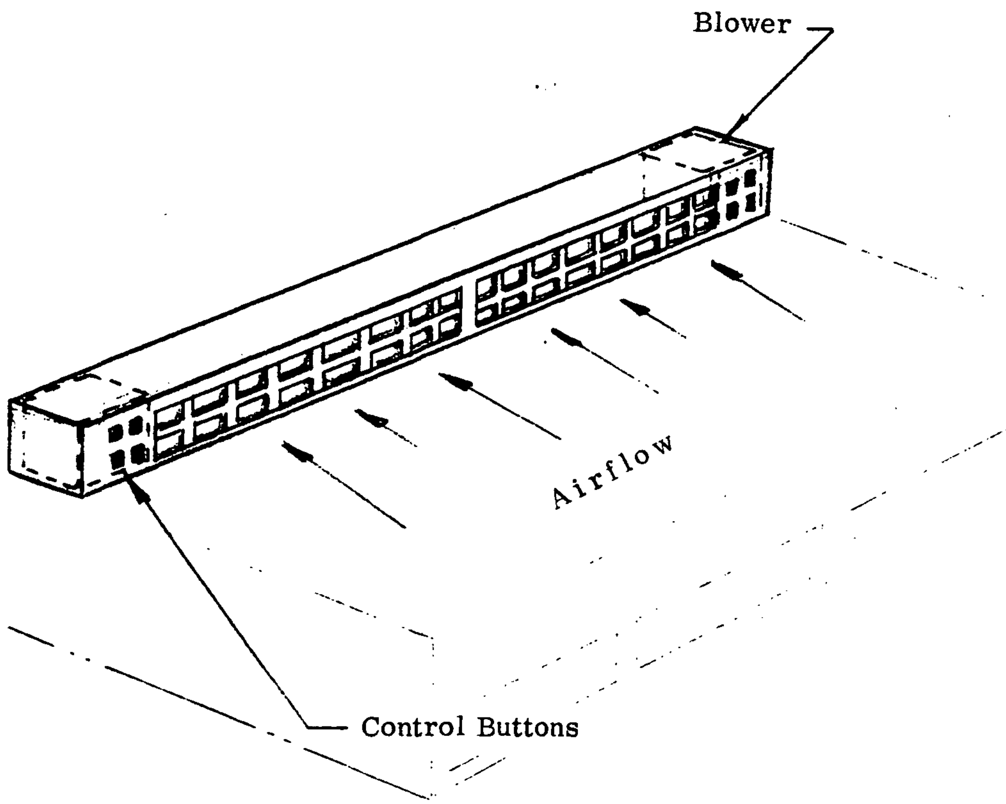
1) Technical Data - Controlled Spillage Module (Concept 3.9.1). Detailed data for this concept are presented on Element Concept Data Sheets 3.9.1.1 through 3.9.1.3 in Data Book - Book I.

c. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Controlled Spillage Module



This controlled spillage module has a plenum chamber duct which uses a low velocity induced directional airflow to ingest spilled food particles through a series of orifices located across the front of the unit. ON-OFF control buttons will allow this unit to be used when preparing food.

Development will be needed to verify optimum opening sizes, airflow requirements, and cleaning operations. Possible zero-g testing should be performed in a KC-135 aircraft. This technique is recommended for further study and prototype development.

D— 3.9.1

3.10 Candidate Zero-Gravity Restraints

a. Concept: No Man Restraint (3.10.1)

Concept Description: In this concept, no physical restraints are employed by the crewman in performance of his preparation tasks. It is assumed that the galley is compactly sized and the crewman can support himself by either bracing against equipment or holding existing handles, knobs, and rails.

Technical Analysis: Since no equipment or restraining devices are required in this concept, ratings for development, operability, system compatibility, and crew size acceptability are high. The more absolute criteria of safety, crew acceptability, crew time, and poor zero-gravity adaptation resulted in an overriding decision to discard this concept even though it scored a rating of 9.8.

b. Concept: Chair With Waist Restraint (3.10.2)

Concept Description: To restrain the crewman or galley steward while preparing food trays or meals in a zero-gravity environment, a movable chair or stool affixed to a guide rail can be considered. A waist restraint belt or clamp maintains the crewman's position on the chair. The seating device would be stowable when not in use either by folding flush to the walls or by a telescoping tube. The seat would provide accessibility to all parts of the galley by sliding along a guide rail and rotating 360 degrees.

Technical Analysis: A chair limits both galley design options and accessibility to overhead and floor level storage areas. Crew performance limitations, crew time penalties, acceptability, and poor system compatibility resulted in a discard decision for this concept.

c. Concept: Waist and Foot Restraint (3.10.3)

Concept Description: In order to provide full accessibility to all parts of the preparation area, a waist or hip belt with ball-type swivel units and a restraint guide rail attaching arm is worn by the crewman. The belt swivel unit socket could also be fabricated directly into a constant wear garment, thereby eliminating the need for a special belt. The attaching arms are designed as telescoping booms with guide rail hook-on slide fittings at the end. The design can be such that the attaching restraint arms are disconnected at either the guide rail fitting or the swivel socket, leaving the attaching arm on the guide rail or the crewman, at his option. The restraint guide rail would be at counter top level and extend around the galley area. Additional guide rail sections can be placed throughout the galley to permit attachment and access at different locations and orientation within the galley. In zero-gravity, it may be more convenient to float at an angle to the floor to obtain food or equipment from storage locations than perform conventional stretching or bending maneuvers. Foot restraint would also be provided by the use of a continuous recessed cabinet design at floor level permitting "toe-holds" at any location.

Technical Analysis: For maximum accessibility and minimum interference with crew operations, the waist and foot restraint concept is recommended. A primary objection to a fixed attaching arm between either a belt or suit hip socket and guide rail is the restriction on turning. The telescoping boom attaching arms permit limited turning by compressing one arm and extending the other. An alternative would be to disconnect one side or have the belt loose enough so that the crewman could turn within the belt. A toe-hold foot restraint design has been proven to be adequate when used in conjunction with another positive restraint.

The concept is adaptable to any galley design and is not crew size limited.

d. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-15 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-15

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 3.10	SUB-FUNCTION TITLE: Zero "G" Restraints	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.10.1	No Man Restraint	(9.8)	X				
3.10.2	Chair With Waist Restraint	7.1	X				
3.10.3	Waist and Foot Restraint	11.5		X	-		X

For each of the concepts selected for detailed study, technical data are presented below:

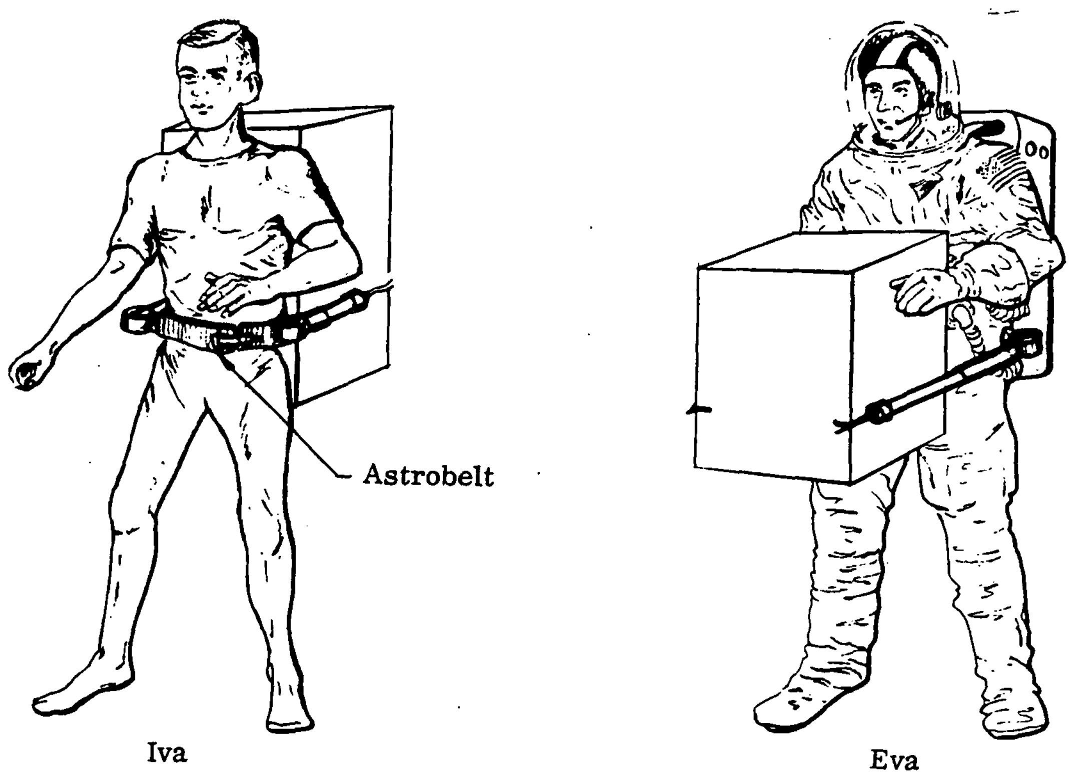
1) Technical Data - Waist and Foot Restraint (Concept 3.10.3). Detailed data for this concept are presented on Element Concept Data Sheets 3.10.3.1 through 3.10.3.3 in Data Book - Book I.

e. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Waist Restraint

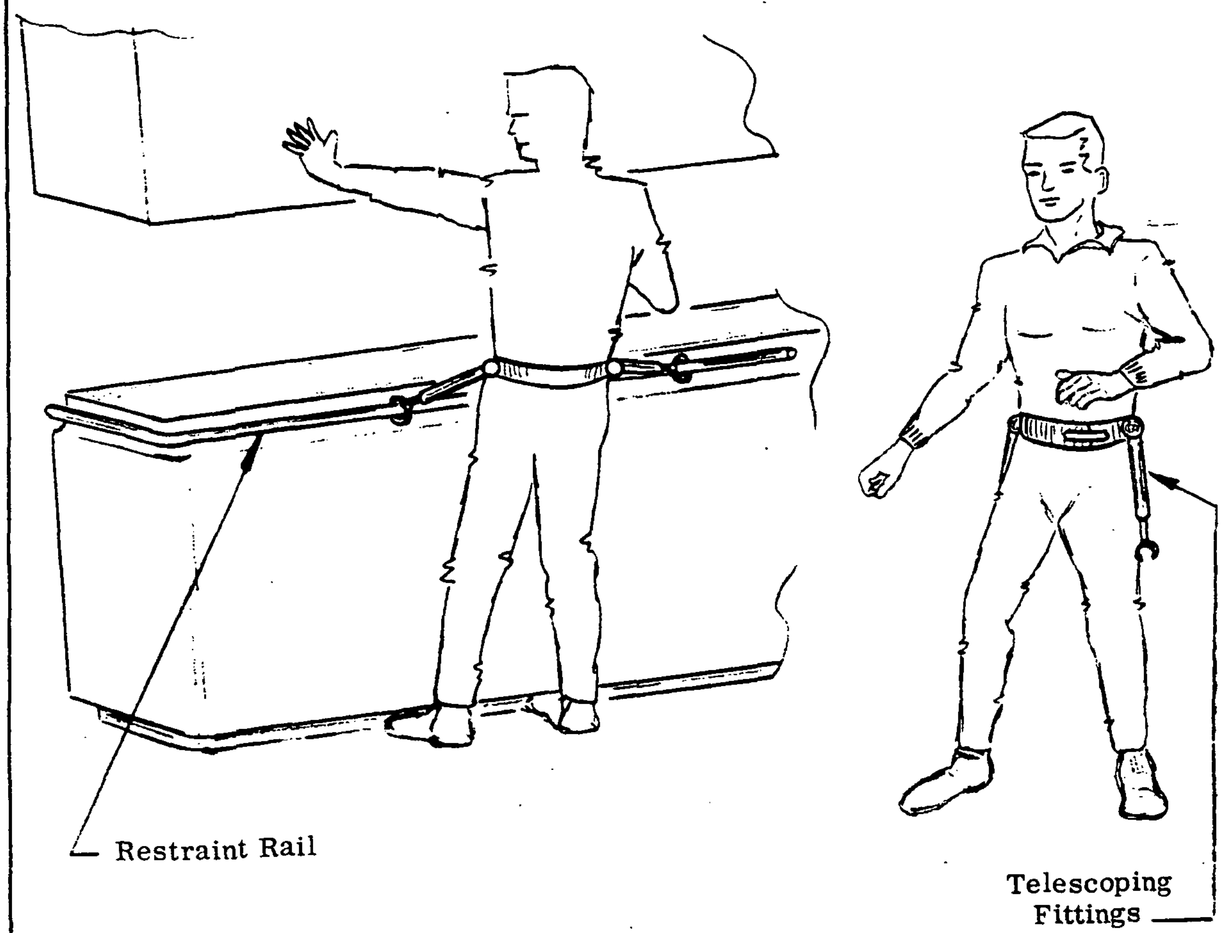


This concept envisages the use of the FH/RAD Astronaut Restraint Unit (Astrobelt) as an aid in food container handling in intra-or extra-vehicular activity. The ARU consists of a belt assembly which is worn by the astronaut over the Constant Wear Garment (for IVA) and is adaptable to the EVA space suit by providing dual snaplock thru-fittings on each side of the suit for belt and boom attachment. Attached to this belt is a laterally opposed pair of telescoping booms which can be locked to any length within their extension capability, and which are capable of a conical motion envelope thru 250° of rotation in the horizontal plane. Each of these booms can be fitted at its outer extremity with a variety of grippers which can be used to retain containers in any attitude suited to the nature of the task at hand, leaving the crewman's hands free to perform other tasks.

D— 3.10 A

FOOD SYSTEM STUDY SKETCH

Title: Waist Restraint



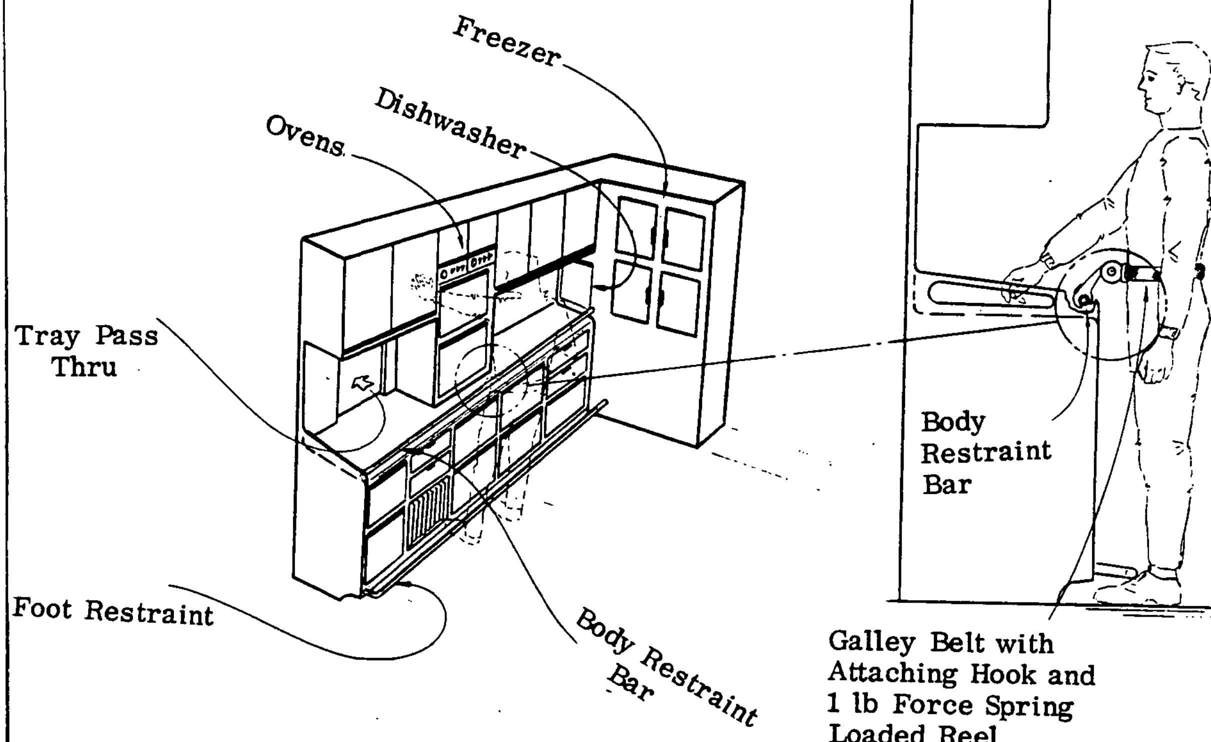
The restraint is a cloth-type webbed belt worn around the midsection of the body. There are hip mounted ball type swivel units to which telescoping booms and fittings are attached. This restraint will secure the man in any position and leave his hands free to perform required tasks.

Minor development work will be needed to verify loads, locking design alternatives, and accessibility and comfort requirements. This unit will be used primarily in zero-g.

D— 3.10 B

FOOD SYSTEM STUDY SKETCH

Title: Waist and Foot Restraint



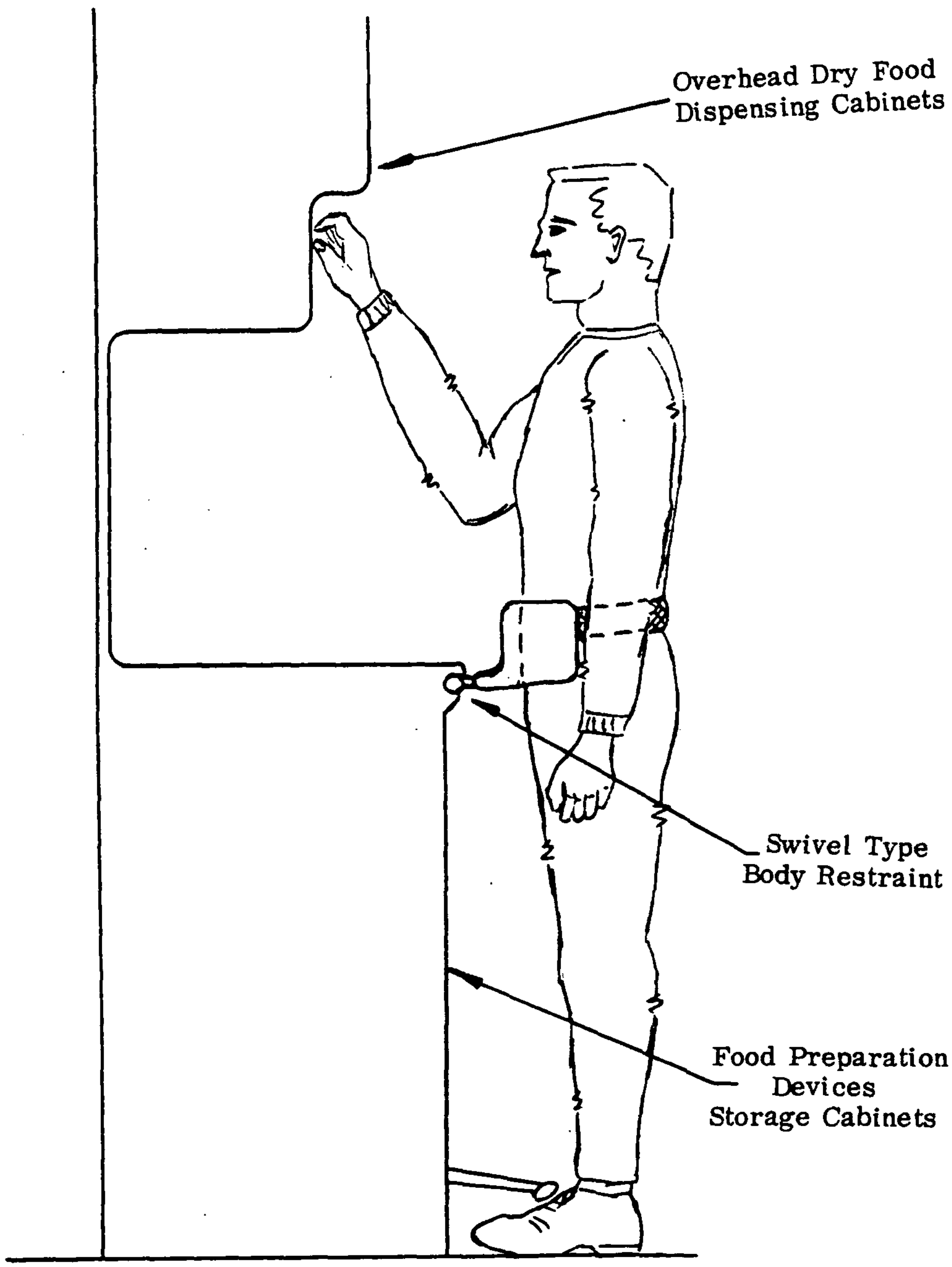
This is a waist attached, web-type cloth belt which has a hook-type latching fitting for attaching to a cabinet mounted restraint bar. The hook is attached to a cable that is contained within a light spring-loaded reel. This allows for freedom of movement such as bending to open doors or drawers, etc.

This is basically a galley work belt for zero-g applications, but may also be applicable for other activities.

D— 3.10.3 A

FOOD SYSTEM STUDY SKETCH

Title: Waist and Foot Restraint



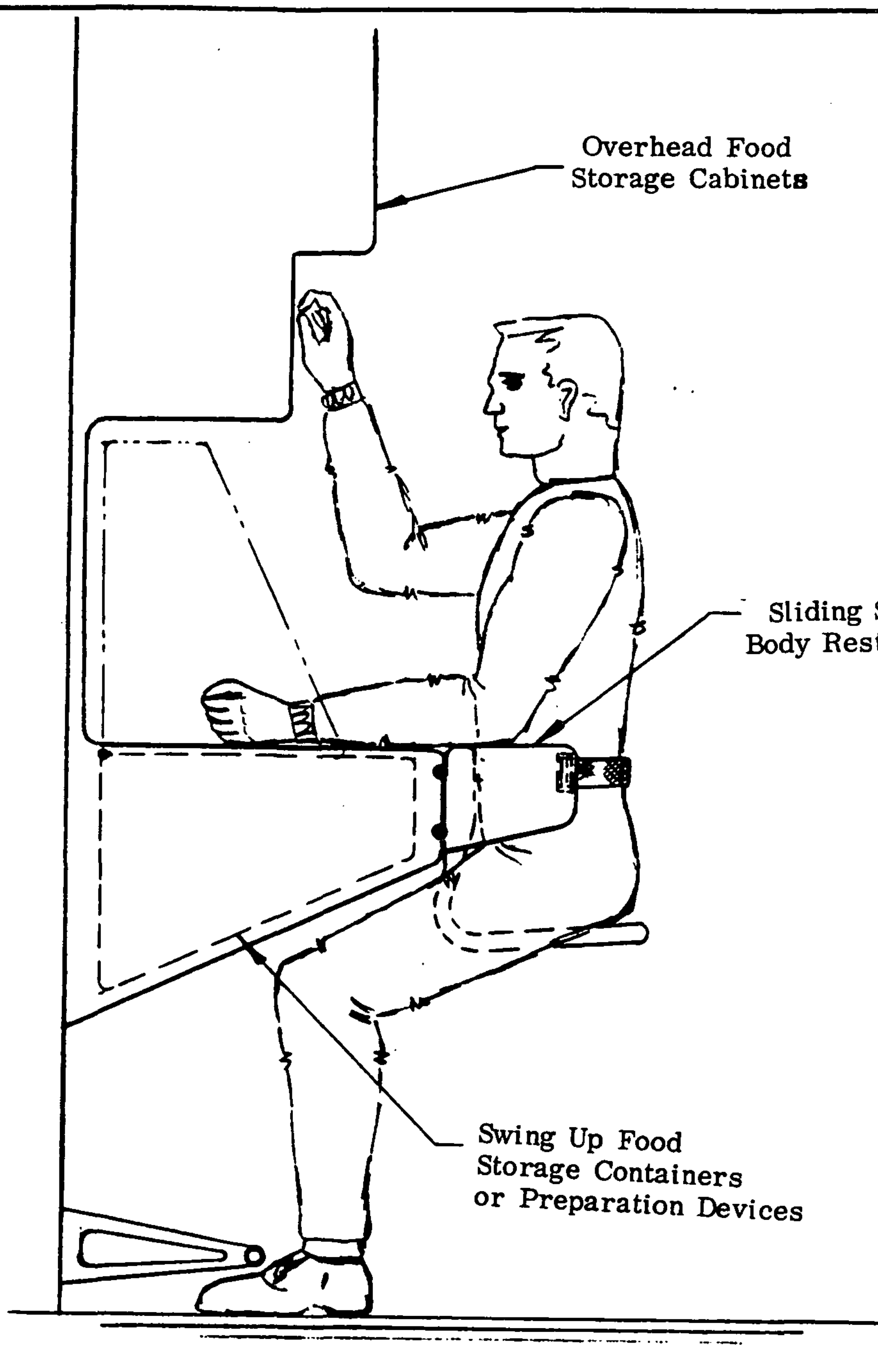
This concept is a preparation cabinet mounted body restraint. The upper restraint is attached to the cabinet and contains a waist attachment and belt. A swivel fitting allows the crewman some degree of movement. The lower restraint is a rail which allows the crewman to hook his feet beneath.

A minimum amount of further development is envisioned for this concept.

D— 3.10.3 B

FOOD SYSTEM STUDY SKETCH

Title: Waist and Foot Restraint



This concept is similar to Concept 3.10.3A except that the crewman is sitting and the waist attachment is part of the seat. The seat is mounted to the cabinet in a "monorail" fashion which allows the crewman to move to any area of the cabinet. A foot rail will restrain his feet.

This concept is primarily for use in a zero-g condition, but may also be used in one-g.

D— 3.10.3 C

3.11 Candidate Food Transport Devices

a. Concept: Conveyor Belt (3.11.1)

Concept Description: In order to transport food from primary stores which may be remotely located from the galley preparation area, an automated conveyor belt may be used. The conveyor would be a continuous belt or chain that is motor driven and travels through the access hatches between decks of the space station to the galley. Large food packages could be transported by attaching them to the belt and delivering them on the galley deck.

Technical Analysis: This concept has limited acceptability to large crew size, multi-deck space stations where resupply missions may be 90 days or more. For this application, the concept has validity since bulk food packages will be stored remote to the galley area. The conveyor belt may also be used as the primary crew transfer device between decks as well as an equipment mover.

b. Concept: Magnetic Conveyor System (3.11.2)

Concept Description: This is a modification of Concept 3.11.1, consisting of a totally enclosed magnetic cable contained in a non-metallic tubing. Food packages containing embedded magnetic inserts are placed in contact with the conveyor and transferred between decks. This concept is also adaptable to delivery of food trays from the preparation area to the dining stations.

Technical Analysis: Similar limitations as in Concept 3.11.1 are applicable here as well as the alternate uses of the conveyor. By enclosing the moving cable, potential safety hazards are reduced and possible mechanism contamination is eliminated.

c. Concept: Mechanical Rail Transport System (3.11.3)

Concept Description: This concept is for use in transporting food packages, trays, meals, and equipment either between decks or to various locations on a deck. Fixed guide rails would provide a track system for delivery of bulk packages or trays that mate with the rail. "Sidings" can be incorporated within the track system to permit passing or temporary holding of the transported item. The guide rails would extend through the deck hatches for inter-deck transfer of packages, men, or equipment. For transfer of food trays from the preparation area to the dining station, a guide rail can be used along which the crewman would slide a mated tray, eliminating the need for hand carrying in zero-gravity. The rail would also provide restraint for the crewman or steward during food delivery and return to galley.

Technical Analysis: It is likely that restraint or guide rails will be incorporated in a large zero-gravity space station as a transport assist. This concept provides for multi-purpose rails to be used by both men and equipment. For smaller modules and crew sizes, its use may be limited due to minimization of transfer requirements.

d. Concept: Dolly-Type Guided Container (3.11.4)

Concept Description: This concept supplements Concept 3.11.3 in that a container or cart is guided by the transport rails mounted on the space station walls. The container/cart would be designed to accept various size food packages as well as meal trays. It can be used as an inter-deck transfer container or a server from galley to dining area. The top surface of the container/cart could be utilized as a preparation counter when stored in the galley. An alternative to the rail transport would be to propel the container in a recessed floor guide, although this recess may be subject to accumulations of debris or contaminants. Swivel casters can be added to the cart for stability in zero-gravity and for use in partial-gravity.

Technical Analysis: For large space stations and crews (12 men and up), transfer and transport aids will be required. This multi-purpose device fulfills multiple task functions and significantly reduces crew operating times. For smaller modules and crew sizes, space constraints may limit its usefulness.

e. Concept: Net Type Bag (3.11.5)

Concept Description: Transport of multiple packages of varying sizes can be accomplished with use of a net type "shopping bag". A mesh or netting fully encloses the contents, permitting one-hand transport. A hinged carrying handle is spread to open the bag and snapped together to close.

Technical Analysis: This concept is valid for all crew size/ station sizes, either as a primary transport device or as a transport aid to supplement other techniques. One-hand carrying provides maximum flexibility to the crewman in guiding and restraining himself in zero-gravity.

f. Concept: Hand Carrying of Loose Packages (3.11.6)

Concept Description: As an alternative to any of the transport devices considered, the crewman can carry food packages or equipment by hand from point to point on the space station.

Technical Analysis: The deletion of transport support equipment and aids resulted in a rating factor of 10.1 for this concept due to elimination of development risk and no operability or system compatibility penalties. It was decided, however, that the overriding criteria of safety, acceptability, and crew time should reverse the study selection, resulting in the discarding of this concept.

It should be noted that hand transport of food trays by a steward or self-service is considered a viable concept in functional area 4.0 - Provide For Serving. It is primarily as a transport function from storage to the preparation area that some form of assist is recommended.

g. Concept: Food Handling Tongs (3.11.7)

Concept Description: This concept is a modification of Concept 3.11.5 - Net Type Bag. A food package handling tongs similar to "ice tongs" permit lifting and carrying of various size packages as well as multiple packages in a single transfer. Each of the tong arms are pivoted to allow for pickup and subsequent locking in place over a package. A spring-loaded latch maintains the tong arms in a locked position during transfer, and must be manually released to unlock the tongs.

Technical Analysis: This is a simple lightweight device that permits one-hand transfer and transport of food packages between storage and preparation facilities. It is useful in both zero- and partial-gravity modes of operation.

h. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-16 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-16

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 3.11	TITLE: Food Transport	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
3.11.1	Conveyor Belt	10.8		X	-		X
3.11.2	Magnetic Conveyor System	11.4		X	-		X
3.11.3	Mechanical Rail Transport System	11.7		X	-		X
3.11.4	Dolly Type Guided Container	10.5		X	-		X
3.11.5	Net Type Bag	14.3		X	-		X
3.11.6	Hand Carrying of Loose Packages	(10.1)	X				
3.11.7	Food Handling Tongs	16.1		X	-		X

For each of the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Conveyor Belt (Concept 3.11.1). Detailed data for this concept are presented on Element Concept Data Sheet 3.11.1.1 in Data Book - Book I.

2) Technical Data - Magnetic Conveyor System (Concept 3.11.2). Detailed data for this concept are presented on Element Concept Data Sheet 3.11.2.1 in Data Book - Book I.

3) Technical Data - Mechanical Rail Transport System (Concept 3.11.3). Detailed data for this concept are presented on Element Concept Data Sheets 3.11.3.1 through 3.11.3.3 in Data Book - Book I.

4) Technical Data - Dolly Type Guided Container (Concept 3.11.4). Detailed data for this concept are presented on Element Concept Data Sheets 3.11.4.1 and 3.11.4.2 in Data Book - Book I.

5) Technical Data - Net Type Bag (Concept 3.11.5). Detailed data for this concept are presented on Element Concept Data Sheets 3.11.5.1 through 3.11.5.3 in Data Book - Book I.

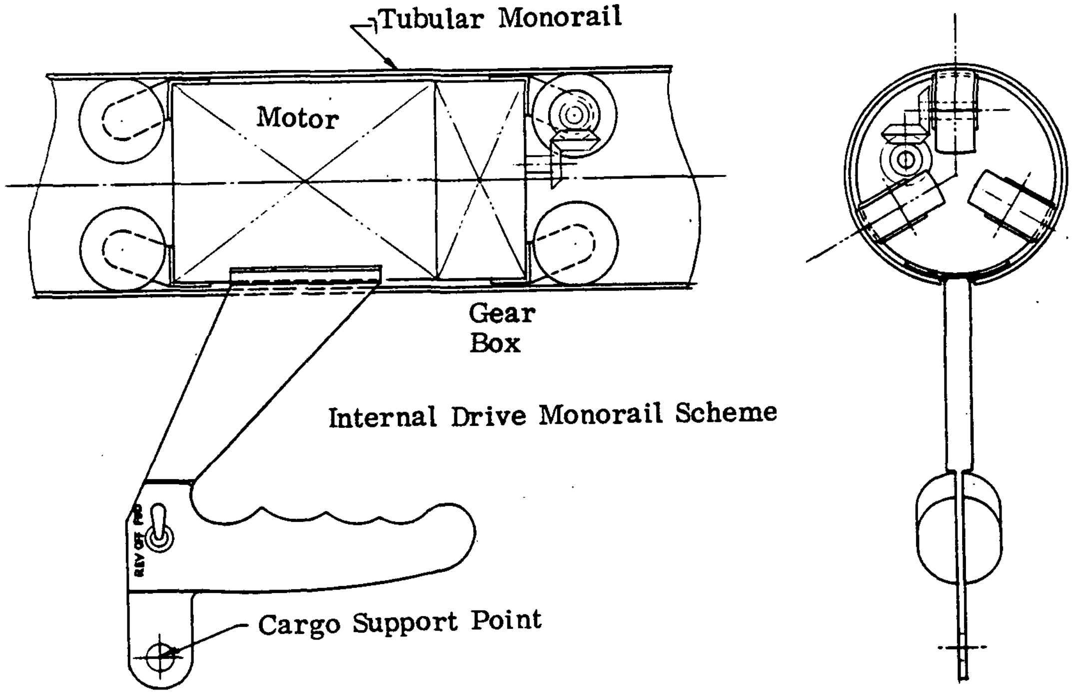
6) Technical Data - Food Handling Tongs (Concept 3.11.7). Detailed data for this concept are presented on Element Concept Data Sheets 3.11.7.1 through 3.11.7.3 in Data Book - Book I.

i. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Food Transport



In this system a small diameter tube serves as the monorail. The tube is split on its underside for its entire length to permit egress of a personnel handgrip and cargo hook which is attached to a trolley riding on the inside of the tube. The trolley is composed of a motor-gearbox combination with three equally-spaced wheels mounted on each end. Driving force is provided by one of the wheels located opposite the slit in the tube.

While this system is intended primarily for the automated transfer of personnel and/or cargo, it can also be used as an unpowered vehicle where the astronaut launches himself from place to place.

D— 3.11A

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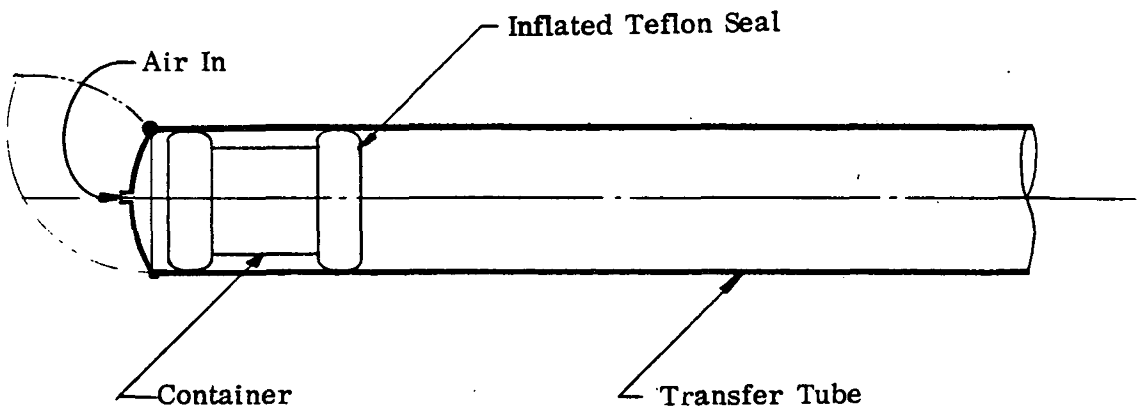
FOOD SYSTEM STUDY SKETCH

Title: Food Transport



This scheme envisons a smooth-bore tubular conduit inside of which a specially designed container is driven by pneumatic pressure.

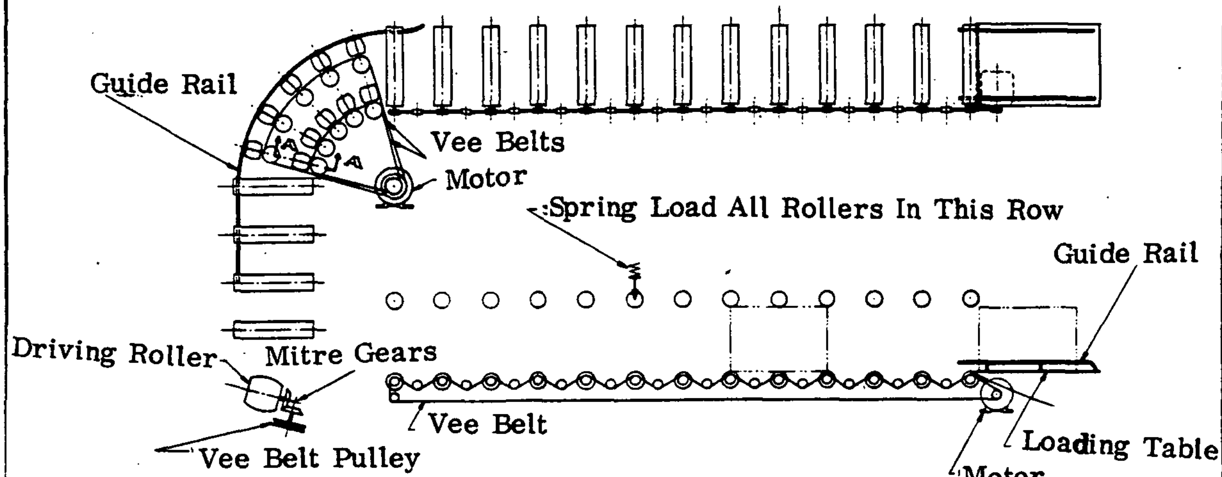
The container, which is cylindrical and of a diameter smaller than that of the conduit bore, incorporates at each of its ends a deformable seal which is made from teflon or a similar material chosen for its low coefficient of friction and space material compatibility.

The advantage of this system lies in its wide adaptability. It can be used to transfer a large variety of materials in conduits of varying diameter. The transfer path can be straight, curved, parallel or perpendicular to decks, and its passage through doors and locks lends itself to simple solutions.

D— 3.11 B

FOOD SYSTEM STUDY SKETCH

Title: Food Transport



Section A-A
Driving Scheme For All Skewed Rollers

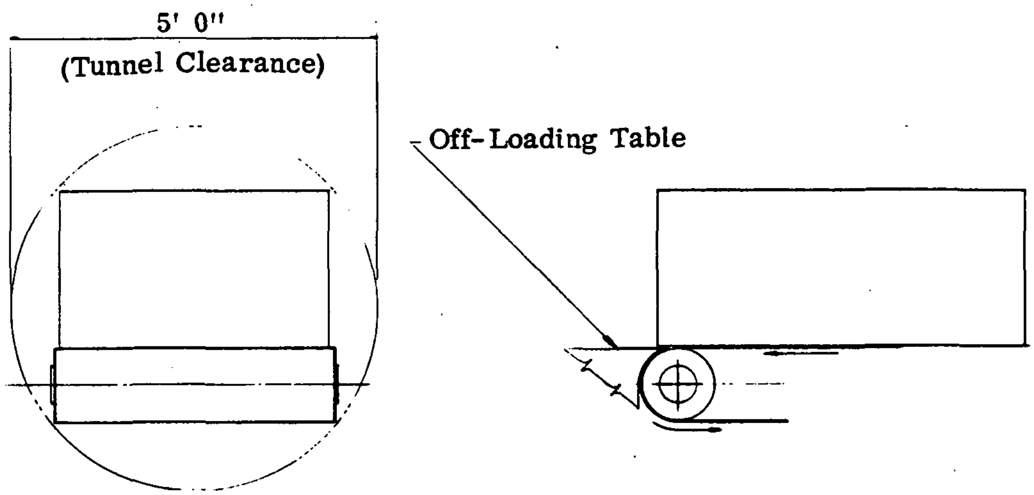
This scheme is similar in operation to an earth-based roller conveyor, except that because of the lack of gravity in most space environments, provision must be made to retain the transported material against the conveying rollers. To this end this system employs an array of idling rollers, each located directly opposite its driving counterpart and each spring-loaded to exert a small squeezing pressure on a standard sized container. This squeeze serves not only to retain the container but also to supply a normal force to provide friction between the container and the driving rollers.

Advantages of this system includes ease of loading and the fact that it is completely automated.

D— 3.11 C

FOOD SYSTEM STUDY SKETCH

Title: Food Transport

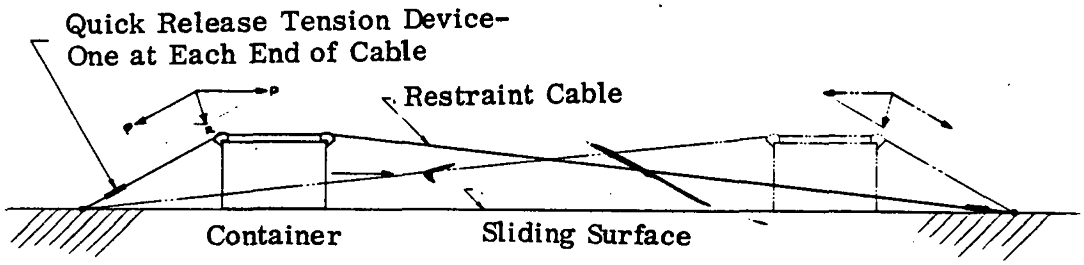


The conveyor belt is one of the more obvious solutions to the problems of material transfer inherent in space activities. Its operation is straightforward except for difficulties presented by the zero-g condition, which requires that the material being moved be prevented from leaving the belt surface by some adhesive force. The required adhesion could be provided by (a) a Velcro belt in conjunction with Velcro strips on the container, (b) a steel mesh belt acted on by permanent magnets imbedded in the container, and (c) a belt made from a metallic fabric acted by electro-adhesive devices incorporated in the container.

D— 3.11 D

FOOD SYSTEM STUDY SKETCH

Title: Food Transport



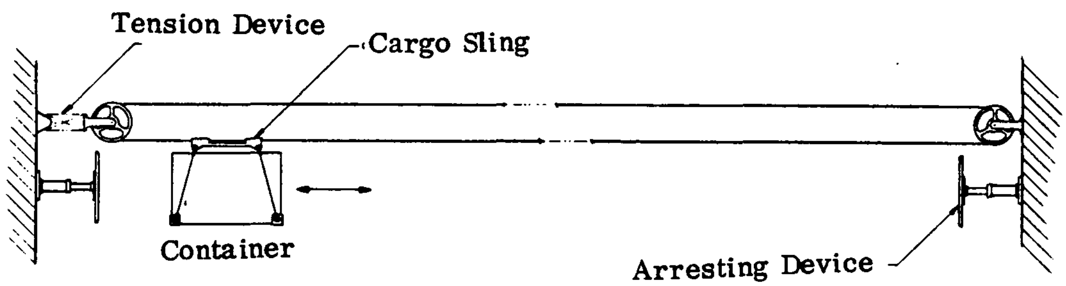
In this system the container is manually slid from place to place. Restraint is provided by a "bowstring" cable, passed over the box and held under sufficient tension so that its downward force component will prevent the container from leaving the surface on which it is sliding.

A salient advantage of this scheme is that there is an inherent decelerating force at the end of the line as shown in the vector diagram in the above sketch. There is a disadvantage in its succeptibility to side forces, which could, however, be met by providing side rails between which the package would move in those situations where side restraint proves necessary.

D— 3.11 E

FOOD SYSTEM STUDY SKETCH

Title: Food Transport



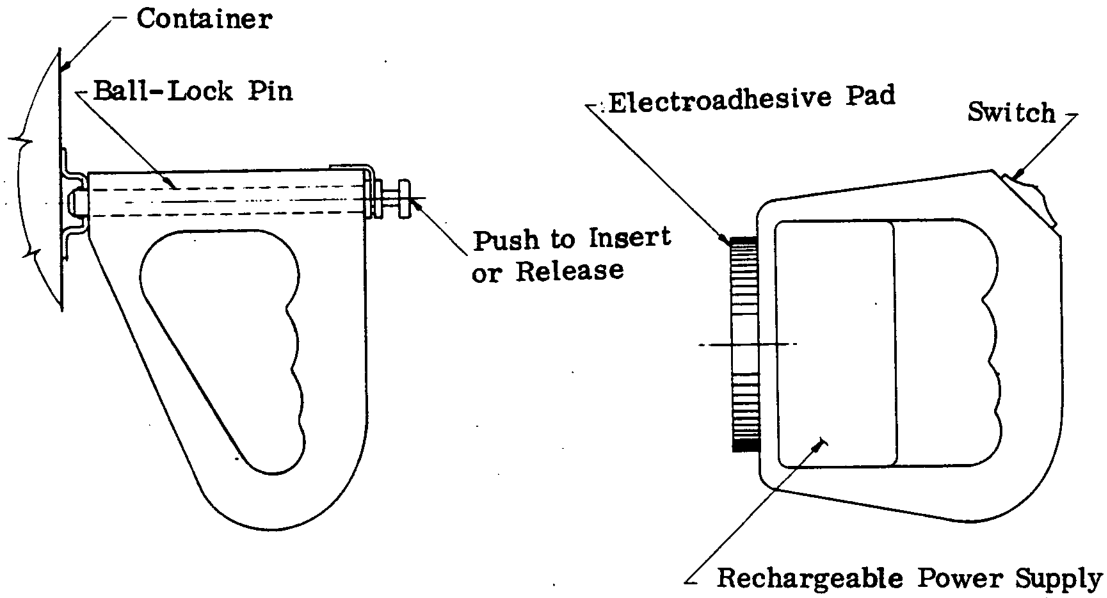
This system is comprised of a continuous cable, rove around two sheaves, to which cargo or food containers are affixed for manual transfer. Each sheave is firmly mounted to fixed structure, and tautness in the system is maintained by a turnbuckle or other tension device attached to one of the sheaves. Deceleration of the moving load is accomplished by a snubbing device mounted to fixed structure at either end of the line.

Among the obvious advantages of this scheme are, a) its extreme simplicity, b) it can easily be adapted to a variety of installation situations, and c) it is equally applicable to gravity or weightless conditions.

D— 3.11 F

FOOD SYSTEM STUDY SKETCH

Title: Food Transport



These devices are intended for use by the astronaut in manhandling food/ containers or other loads within the space station, or on the loading dock.

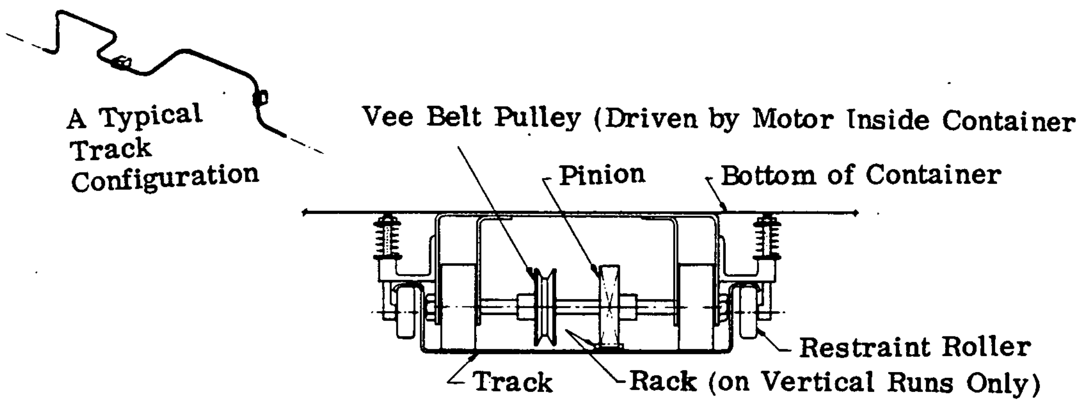
The ball lock device requires the incorporation of a receptacle on the object or container being lifted. The electroadhesive pad will adhere to any conductive surface.

The devices shown or ones similar, designed to perform the function of aiding a space worker in the handling of packages and containers, can be considered to be 'manual assist' transfer tools. Their basic function is to provide the capability of one-handed operation, leaving the worker's other hand free for support, traversing, or performing other tasks.

D— 3.11 G

FOOD SYSTEM STUDY SKETCH

Title: Food Transport



Section Thru Car Showing Drive and Hold-Down Arrangements

This concept proposes a self propelled 4-wheeled cargo car which travels on an inverted hat-section track.

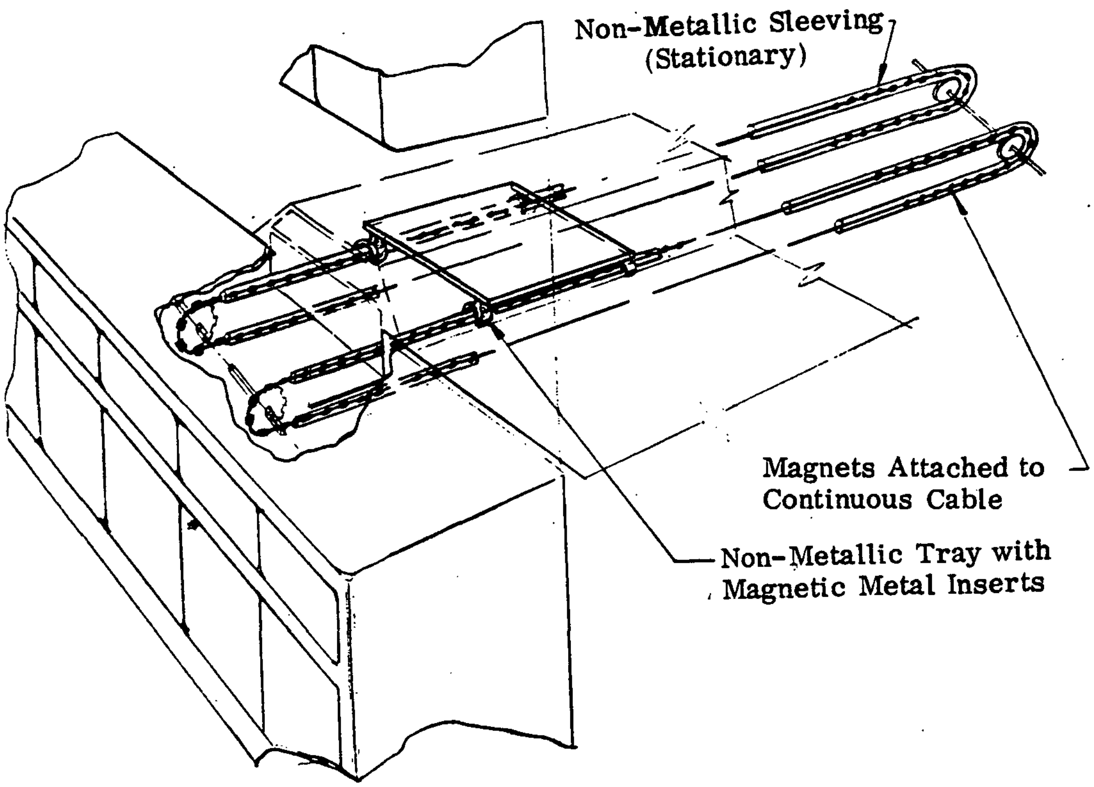
The car is held down (providing a gravitational effect) to the track by spring-loaded restraint rollers, two of which are located on each side of the undercarriage. Drive for level runs is accomplished through friction between the driven pair of wheels and the track surface. For uphill runs, the drive is by a rack-and-pinion arrangement incorporated in the track and the undercarriage.

Routing of cars can be programmed electronically. This scheme is equally applicable in the presence or absence of gravity forces.

D— 3.11 H

FOOD SYSTEM STUDY SKETCH

Title: Magnetic Conveyor System



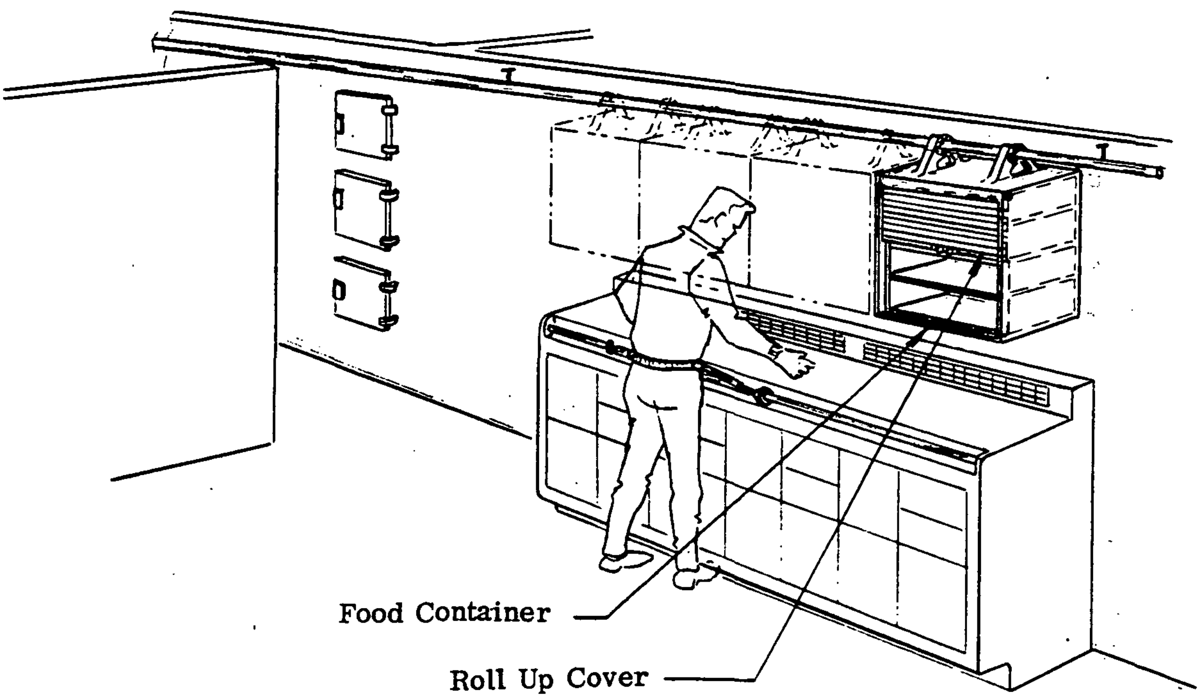
This automated conveyor system for transporting food will minimize the potential build-up of contamination by enclosing the conveyor cable within a non-metallic sleeving. Magnets are equally spaced and securely attached to the cable to allow it to be driven by a special sprocket and motor. The food container to be transported will be of a non-metallic material with molded-in magnetic metal inserts.

This design is applicable primarily to larger crew sizes where it is desired to reduce traffic flow patterns and crew involvement. Galley staffing requirements would be minimum and the design is adaptable to both zero- and partial-g. It is considered as state-of-the-art.

D— 3.11.2

FOOD SYSTEM STUDY SKETCH

Title: Mechanical Rail Transport System



An overhead rail system which can be used to propel or restrain the crewmen can also be used to attach a food container. The container is sized and constructed to be used as a storage cabinet in the preparation area.

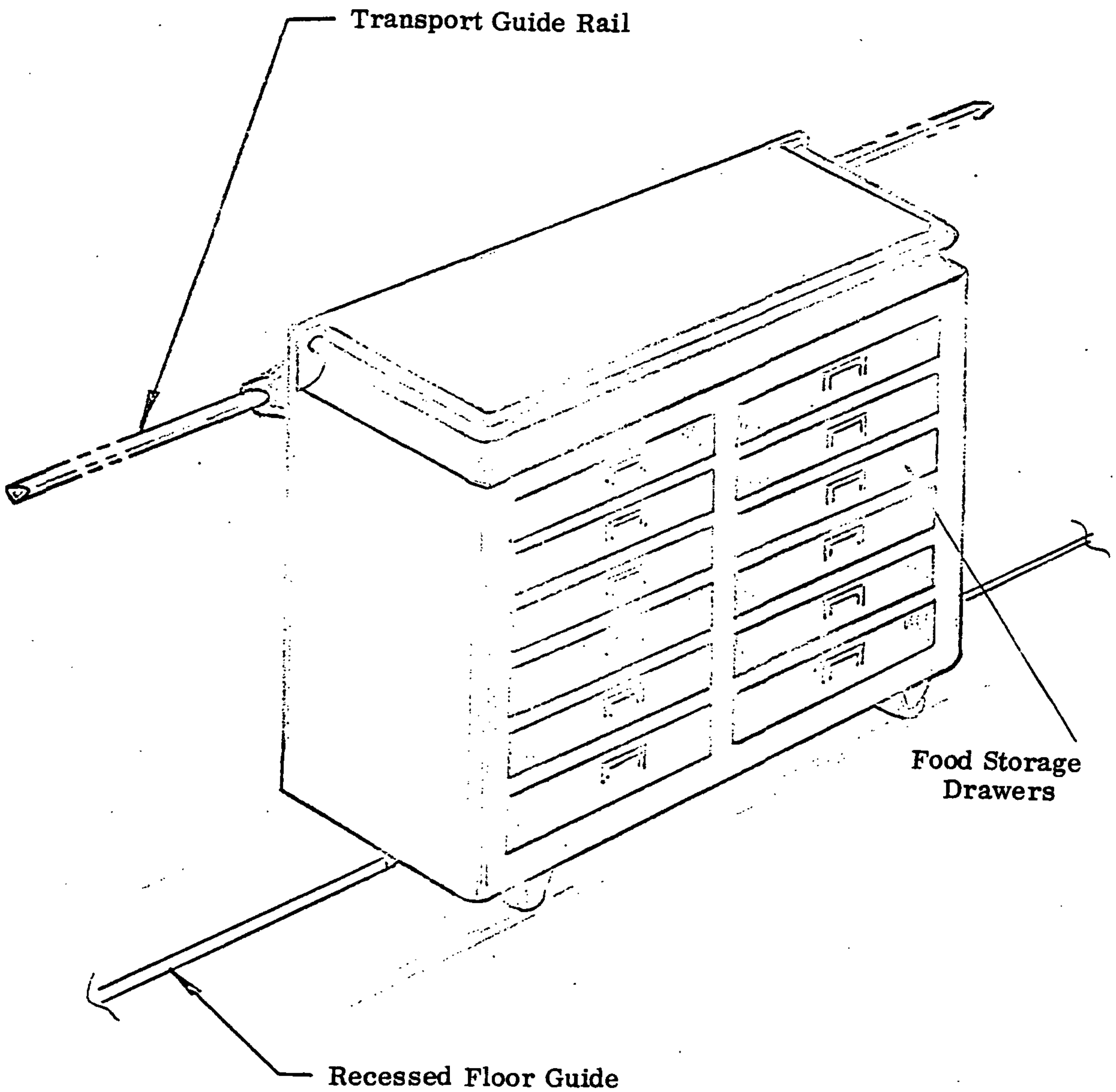
The container will be loaded at the ambient storage locker and transferred by overhead rail to the preparation area.

A minimum amount of design time is needed to fully develop this system which would be applicable in both zero-g and one-g.

D— 3.11.3

FOOD SYSTEM STUDY SKETCH

Title: Dolly Type Guided Cart



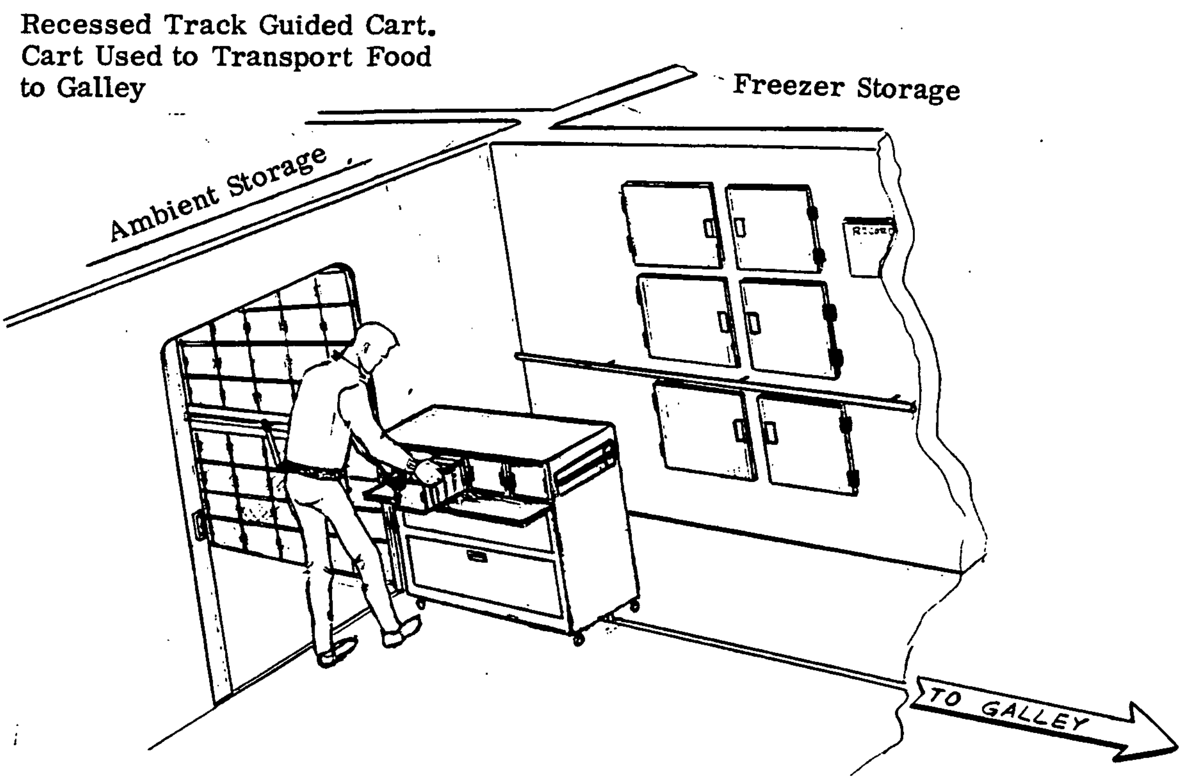
This cart is designed to perform diverse tasks such as (1) transfer food from storage to the preparation area in the galley, and (2) to use the top surface as a preparation counter top. The cart will have casters for stability in zero-g and to propel it in one-g conditions.

A recessed floor track will guide it to its destination. Due to the possibility of contaminants collecting in this track, it may be advisable to use a wall-mounted guide rail.

D— 3.11.4
(Sheet 1 of 2)

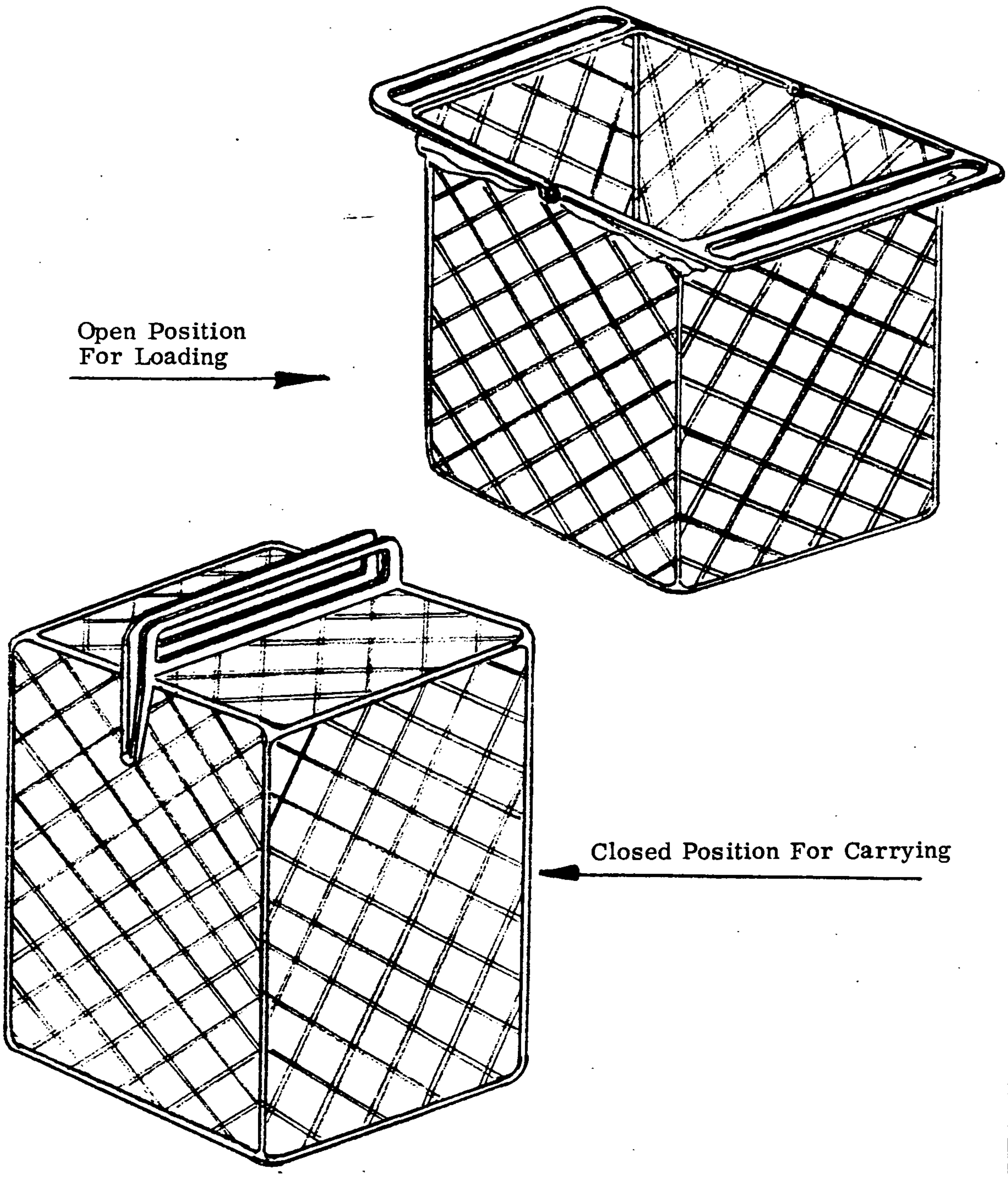
FOOD SYSTEM STUDY SKETCH

Title: Dolly-Type Guided Cart



FOOD SYSTEM STUDY SKETCH

Title: Net Type Bag



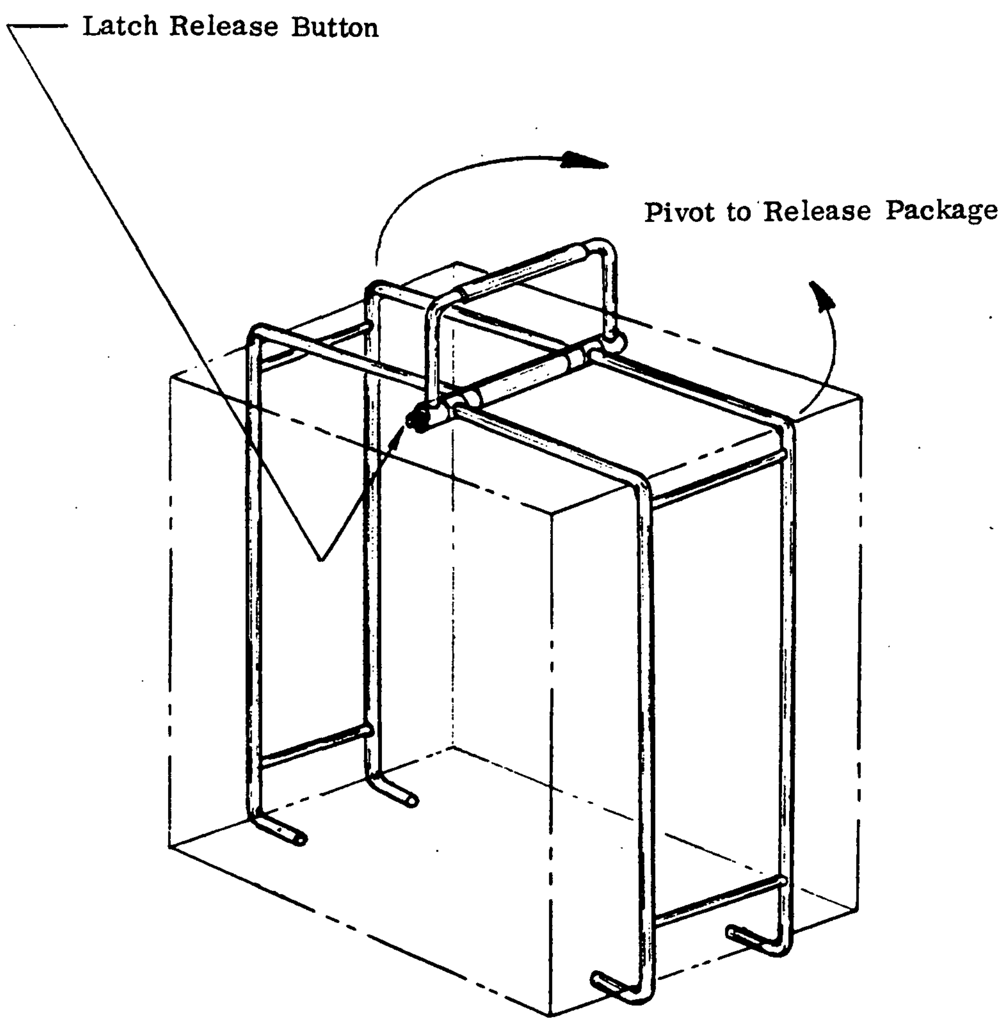
This non-metallic netting will have a metal hinged carrying handle. By spreading the handles apart, the bag will be fully opened to allow for insertion of food packages to be transported to the preparation area. The bag is closed by bringing the handles together.

This is a lightweight fully enclosed container which eliminates danger of spillage or droppage during transport.

D— 3.11.5

FOOD SYSTEM STUDY SKETCH

Title: Food Handling Tongs



This welded formed wire device is used in a manner similar to "ice tongs". It is carried with one hand and each tong pivots to allow for pick-up and removal of a food package. A spring-loaded latch prevents the tongs from opening during transfer.

This lightweight bracket will simplify handling of food packages during zero-g operations.

D— 3.11.7

4.0 Provide For Serving - Functional Subsystem Area 4.0

This function is concerned with providing concepts of serving techniques to create an earth-like environment aboard the space station/base. The basic concepts considered were self-service, steward service, and a mechanical delivery system. An additional approach was a variation of self-service where the crewman would assemble and consume his meal directly at a single point station, rather than transport food to a designated dining area.

Primary requirements considered in the evaluation of each concept included applicability to zero-gravity, crew time, contamination, convenience, and safety. This function was subdivided into two areas: delivery techniques for serving, and a storage requirement for food trays or meals prior to distribution.

4.1 Candidate Delivery Techniques

a. Concept: Self-Service (4.1.1)

Concept Description: This concept envisions the crewmembers withdrawing their own prepared meals from holding ovens or storage racks and individually transporting them to the dining area with no special assistance equipment, other than the food tray or dish containing the food itself. The meals would be prepared either by a single designated crewman or by each individual crewman responsible for his own meal. Each crewman would be obligated to return his food tray or dishes to the galley area, where again, a designated crewman may be responsible for clean-up.

Technical Analysis: This concept is felt to have good crew acceptability and to be particularly applicable to the smaller crew sizes. It would also be a candidate system if the meals were assembled Cafeteria-Style by the individual crewman. For intermediate (6-12 men) crews, the option of crew selection of a limited number of entrees and vegetables is more feasible than in 3-6 man crews, and would be desirable.

b. Concept: Steward Service (4.1.2)

Concept Description: The meals, after preparation and assembly, are carried to the crewman seated in the dining area by a steward who may also be the cook, depending on crew size. The steward would therefore be responsible for performing all the galley, serving, and clean-up tasks.

Technical Analysis: This concept is appropriate for larger crew sizes where galley/dining support tasks warrant specialists in these areas. It may also be applicable to the small crews if the transport of filled trays, etc. is difficult in zero-g when combined with the function of seating one's self. The concept is also dependent on the size of the galley/dining area and configuration, to ensure traffic flow patterns do not create safety hazards in transport of food trays.

c. Concept: Tray/Rail Conveyor (4.1.3)

Concept Description: This system utilizes a slotted tray with a guide rail extending from the preparation area to the consumption area. It would be used for the transporting of prepared meals to the seated crewman in zero-g. It would also be used for the return of the soiled tray to the galley for clean-up after the meal. A galley staff would prepare the complete meal assembled to the special tray, mate the tray to the guide and restraint rail and then mechanically move the tray to the dining area to its assigned crewman.

Technical Analysis: This system would be most applicable for intermediate to large crew sizes where dining takes place in an area somewhat removed from the galley. The meals would have to be distributed in sequence starting with the crewman at the farthest position along the rail. The guide rail, however, which can also serve as a dining table restraint for the tray, simplifies the necessary support equipment in the dining area.

d. Concept: Endless Belt Conveyor (4.1.4)

Concept Description: This system utilizes a link-type endless conveyor to which a tray with appropriate positioning and holding features is attached. The conveyor is energized and automatically delivers the tray with the prepared meal on it to the seated crewman. It would also be used for the return of the soiled trays to the galley. A power drive and galley controls would monitor conveyor belt movement.

Technical Analysis: This concept received a marginal rating of 8.9 on the Selection Rationale Sheet (Data Book - Book III), but was discarded from further study on the basis of potentially high maintenance and poor sanitation characteristics. In addition, the system requires excessive space in both the galley and dining areas.

e. Concept: Directed Air Current (4.1.5)

Concept Description: The prepared meal/tray would be delivered from the preparation area to the dining area utilizing the force of a directed airflow. A low velocity airflow would have to be maintained preferentially to the dining area to ensure directional control of the food tray. The concept could utilize either a free floating tray or a guided tray which is propelled solely by airflow.

Technical Analysis: This concept will not work in artificial-g and is also felt to be unreliable and require excessive development for use in zero-g. The Selection Rationale Sheet (Data Book - Book III) reflects these factors in that the total rating for this concept was only 7.0.

f. Concept: Eat In Galley (4.1.6)

Concept Description: The crewman would assemble his own meal onto a tray or heat a pre-assembled meal and consume the meal in the galley area itself, thus requiring no special serving equipment. Each man in this concept would be responsible for his own food preparation and clean-up tasks. The galley design would be specifically configured to accommodate this concept arrangement.

Technical Analysis: This concept is felt to have significant advantages on spacecraft with small crew sizes due to the impracticality of allocating separate spaces for galley and dining areas. For crew sizes over six (6) men, it is anticipated that a separate dining area would be available, thereby limiting the usefulness of this approach. The arrangement of preparation equipment and the location of storage facilities would be critical for crew time tasks of withdrawing, assembling, reconstituting, and heating individual meals.

g. Concept: Tray Rack/Rail Conveyor (4.1.7)

Concept Description: This system would utilize a shelved storage rack for tray storage and transport between the galley and the dining area by means of a track/rail system. The conveyor provides a restrained means of transporting food trays and can be of a modular design so as to adapt to various crew sizes that may occur at overlap rotation periods. Either a recessed floor or wall-mounted rail can guide the castored conveyor.

Technical Analysis: This concept is considered to be ideally suited for intermediate and large crew sizes as it provides for multiple delivery of food trays and eliminates the need for a special storage rack since the conveyor would be used to store trays when not in use. The conveyor could be enclosed and heated to warm meals or maintain temperature of the heatable portion of the meal. These additional features would be considered primarily for large crews, while use of the conveyor simply as a transport device is recommended for intermediate (6-12) man crews.

h. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-17 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-17

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 4.1	TITLE: Serve Food	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
4.1.1	Self-Service	14.7		X	-		X
4.1.2	Steward Service	15.3		X	-		X
4.1.3	Tray/Rail Conveyor	11.9		X	-		X
4.1.4	Endless Belt Conveyor	8.9	X		-		
4.1.5	Directed Air Current	7.0	X		-		
4.1.6	None (Eat In Galley)	15.5		X	-		X
4.1.7	Tray Rack/Rail Conveyor	11.6		X	-		X

For each of the concepts selected for detailed study, technical data are presented below.

1) Technical Data - Self-Service (Concept 4.1.1). Detailed data for this concept are presented on Element Concept Data Sheet 4.1.1.1 in Data Book - Book I.

2) Technical Data - Steward Service (Concept 4.1.2). Detailed data for this concept are presented on Element Concept Data Sheet 4.1.2.1 in Data Book - Book I.

3) Technical Data - Tray/Rail Conveyor (Concept 4.1.3). Detailed data for this concept are presented on Element Concept Data Sheets 4.1.3.1 through 4.1.3.3 in Data Book - Book I.

4) Technical Data - Eat In Galley (Concept 4.1.6). Detailed data for this concept are presented on Element Concept Data Sheet 4.1.6.1 in Data Book - Book I.

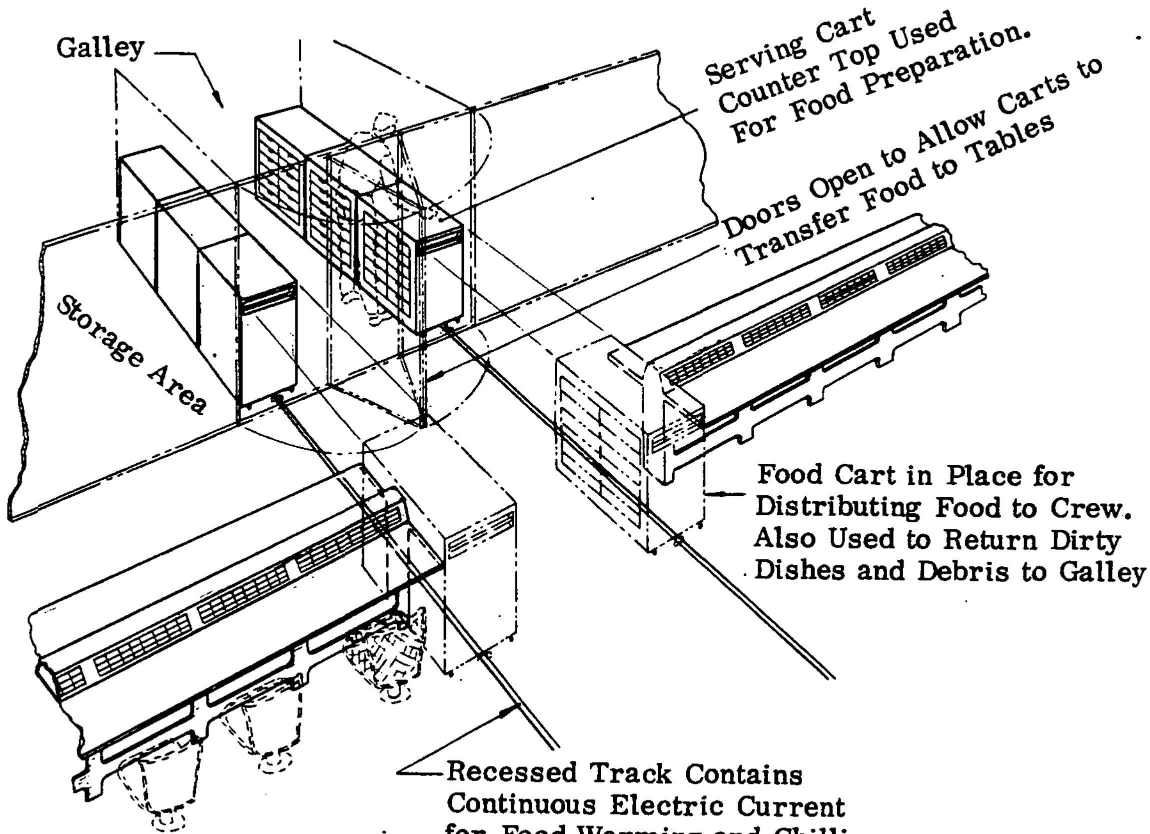
5) Technical Data - Tray Rack/Rail Conveyor (Concept 4.1.7). Detailed data for this concept are presented on Element Concept Data Sheets 4.1.7.1 through 4.1.7.3 in Data Book - Book I.

i. Applicable Sketches

The following sketches depict equipment concepts for each of the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Steward Service - Serving Cart Transport

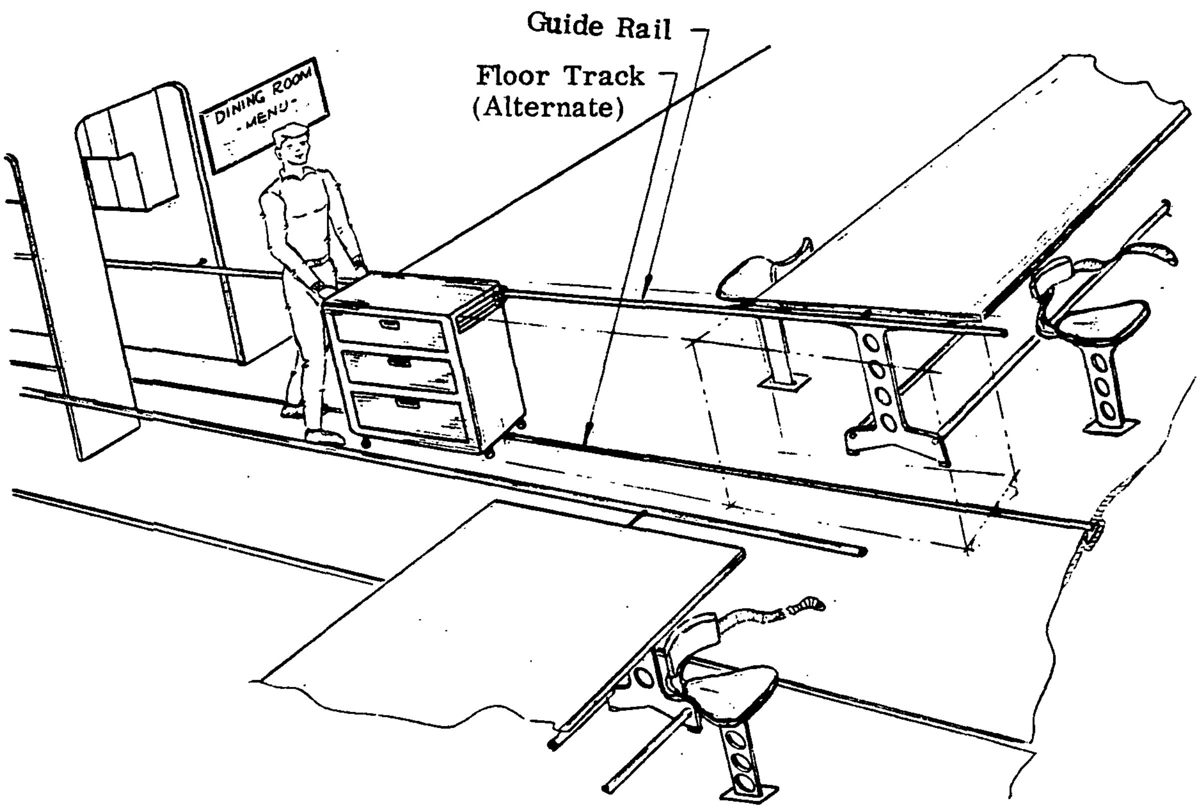


This concept depicts many of the functions of a serving cart concept. Upon completion of food preparation in the galley, the steward will deliver the meal to the dining area by propelling the cart which is mechanically restrained and guided. Each cart would contain enough food to feed all the occupants of one table. By this method various entrees may be served at specific tables utilizing an entree per serving cart. (See Concepts 3.4.4, 4.1.2, and 6.2.10)

D— 4.1

FOOD SYSTEM STUDY SKETCH

Title: Steward Service



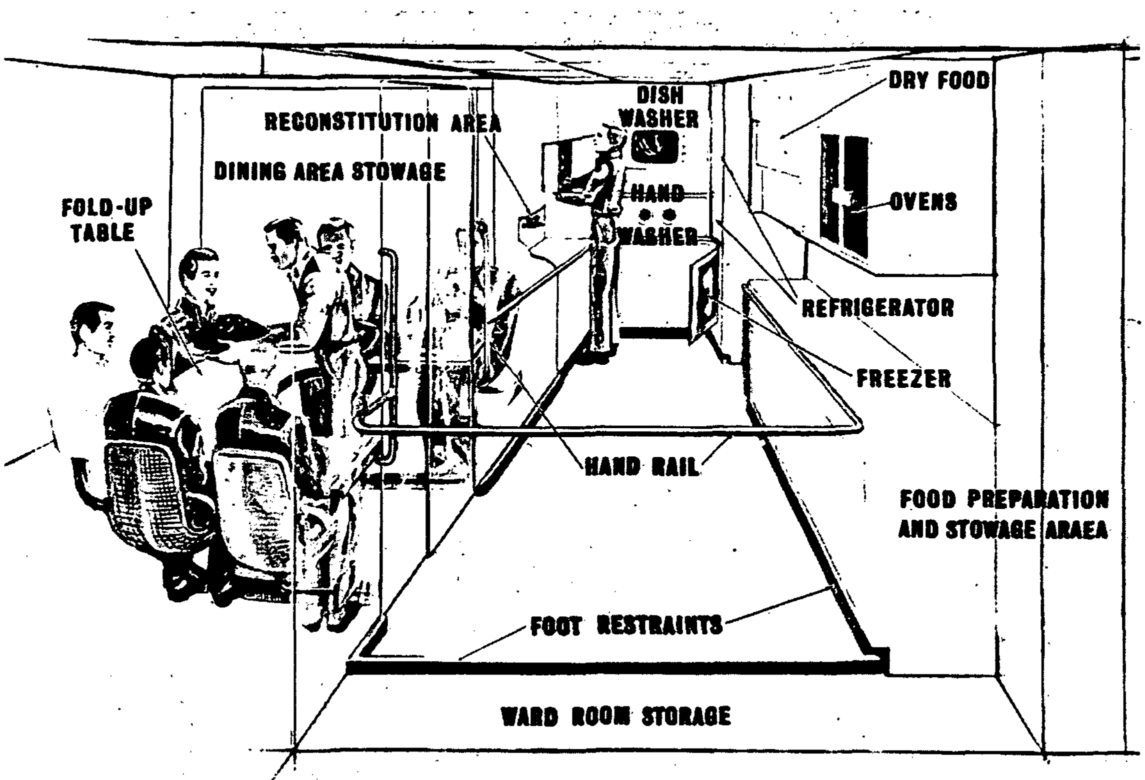
The meals, after preparation, are transported to the dining area by a steward pushing a serving cart. The cart may be attached to either a hand rail or a recessed track in the floor. The serving cart will hold enough food trays for the steward to serve at one table. This cart may also be used to transport soiled dishes and debris back to the galley for clean-up.

This concept is appropriate for large crew sizes where the transport of filled trays, etc. is difficult in zero-g when combined with the function of seating one's self. The rack would also be used for tray storage between meals.

D— 4.1.2 A

FOOD SYSTEM STUDY SKETCH

Title: Steward Service

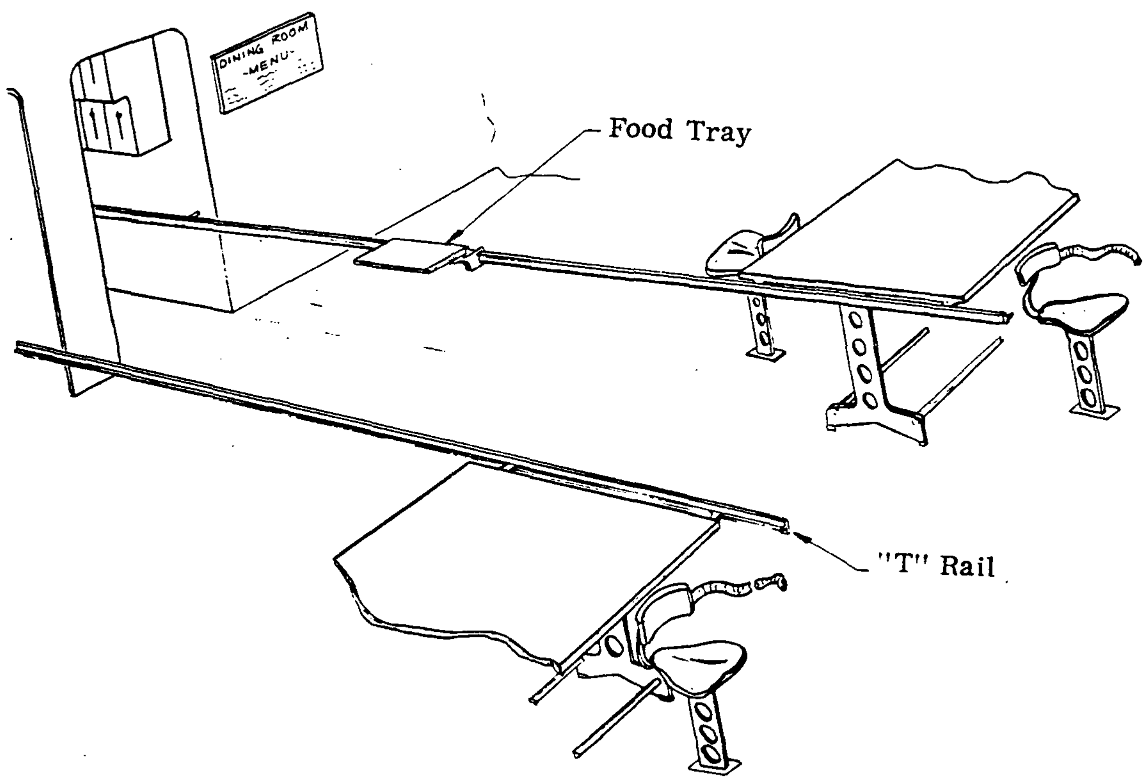


In this concept, the crew (preferably a 6-man crew) would be seated at a semi-circular table which is attached to the galley wall. The crew would be served individually by a galley attendant. Hand rails and foot restraints would be used by steward during zero- to partial-g serving.

D— 4.1.2 B

FOOD SYSTEM STUDY SKETCH

Title: Tray/Rail Conveyor



This system utilizes a slotted tray with a guide rail running from the preparation area to the consumption area. It would be used for the transport of prepared meals to the seated crewman in zero-g. It may also be used for the return of the soiled tray to the galley for clean-up after the meal. This system may be mechanically propelled or manually propelled.

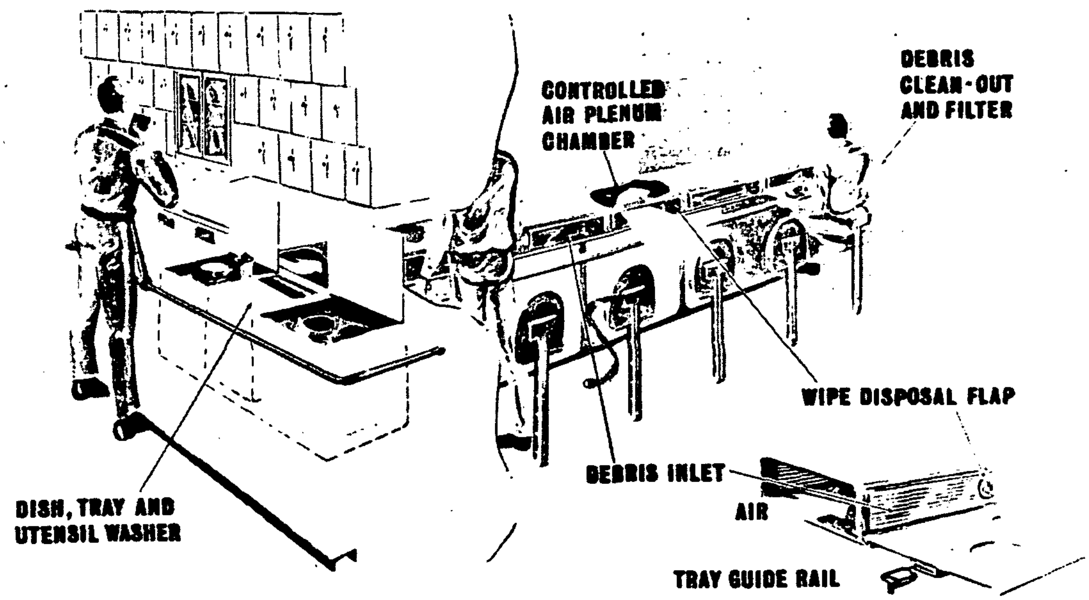
A minimum of further development would be needed to perfect this system which would be used basically in zero-g dining.

D— 4.1.3

(Sheet 1 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Tray/Rail Conveyor

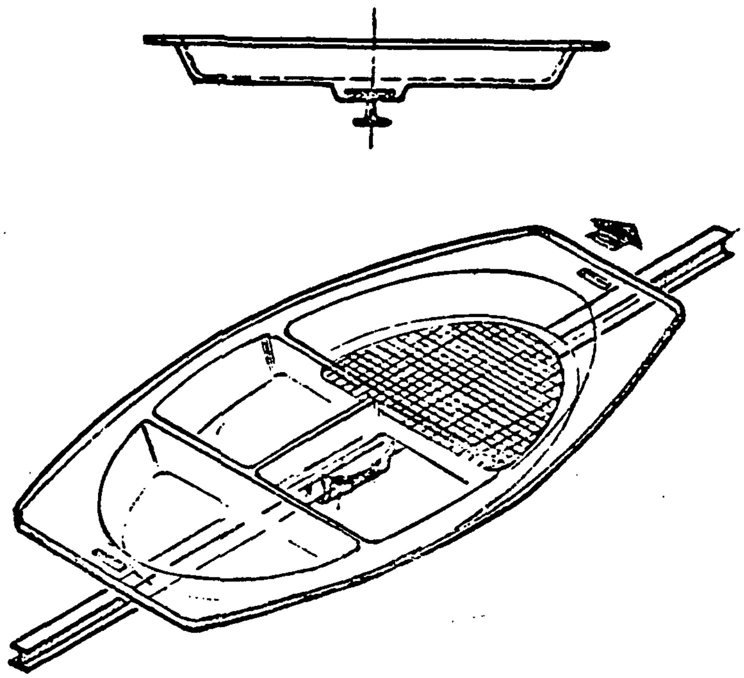


D— 4.1.3

(Sheet 2 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Tray/Rail Conveyor



Individual Meal Tray With Rail Transport and Restraint

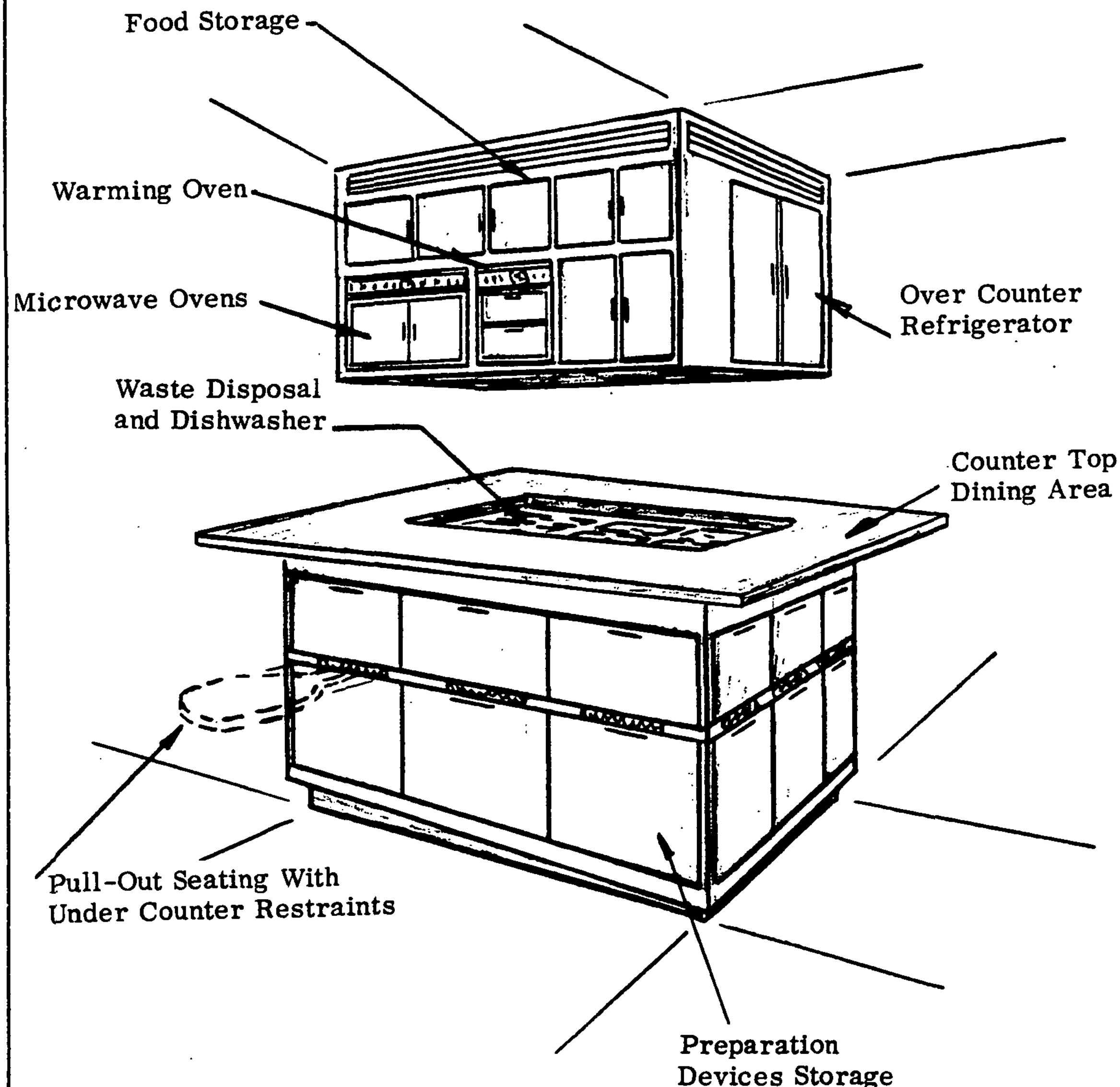
This meal tray is designed to accept a complete individual meal prepared and assembled by the kitchen staff in the galley and delivered mechanically to the dining area on a transport and restraint guide rail.

D– 4.1.3

(Sheet 3 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Eat In Galley



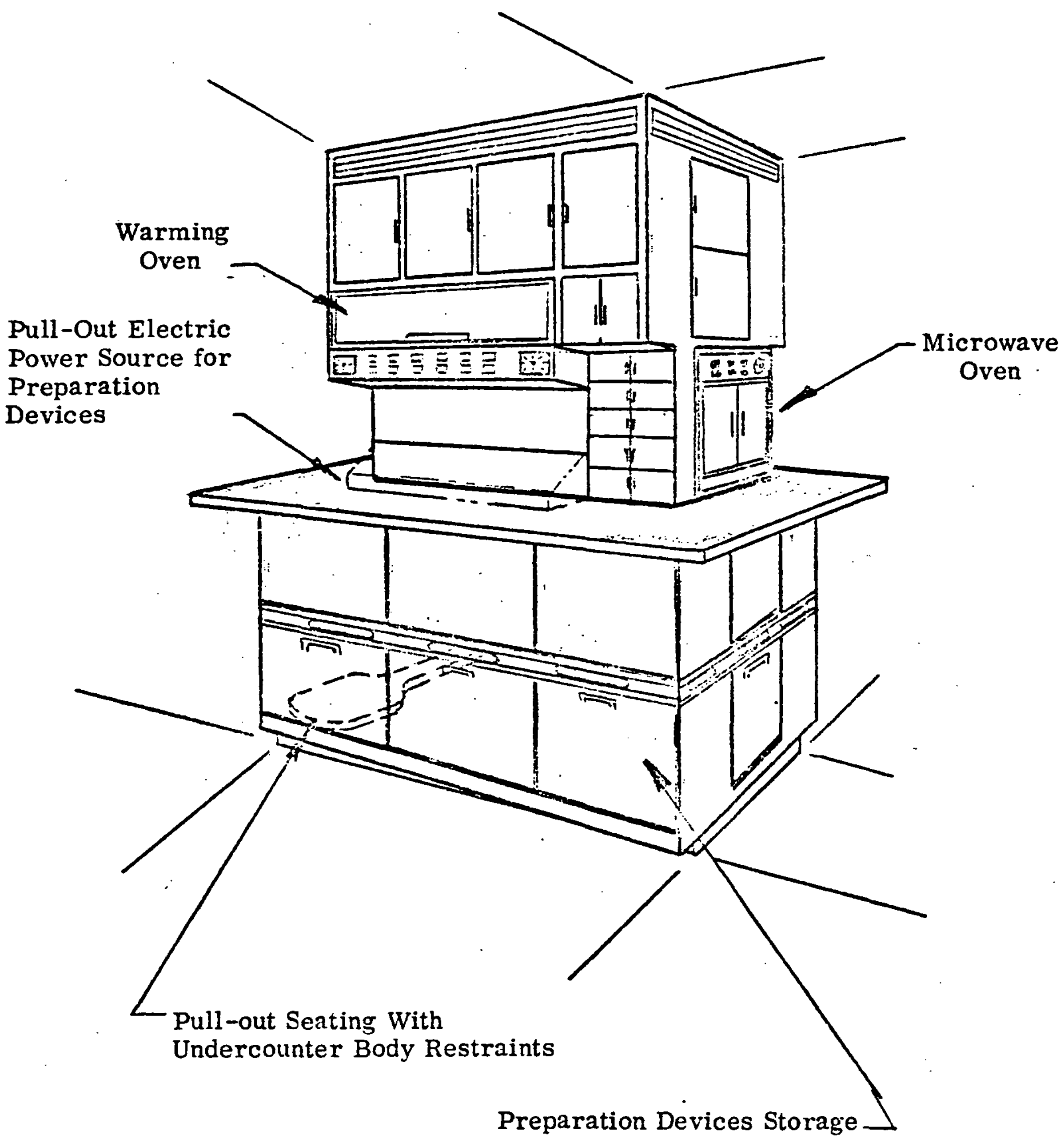
This concept is a four-sided grouping of preparation, dining, and clean-up devices. Overhead preparation and storage equipment allows for cross-talk when eating and full access to disposal and washing equipment. Pull-out seats with restraints will enable up to twelve men to eat at one time.

A minimum amount of further development is needed for this concept; applicable for both zero- and partial-g.

D— 4.1.6A

FOOD SYSTEM STUDY SKETCH

Title: Eat In Galley



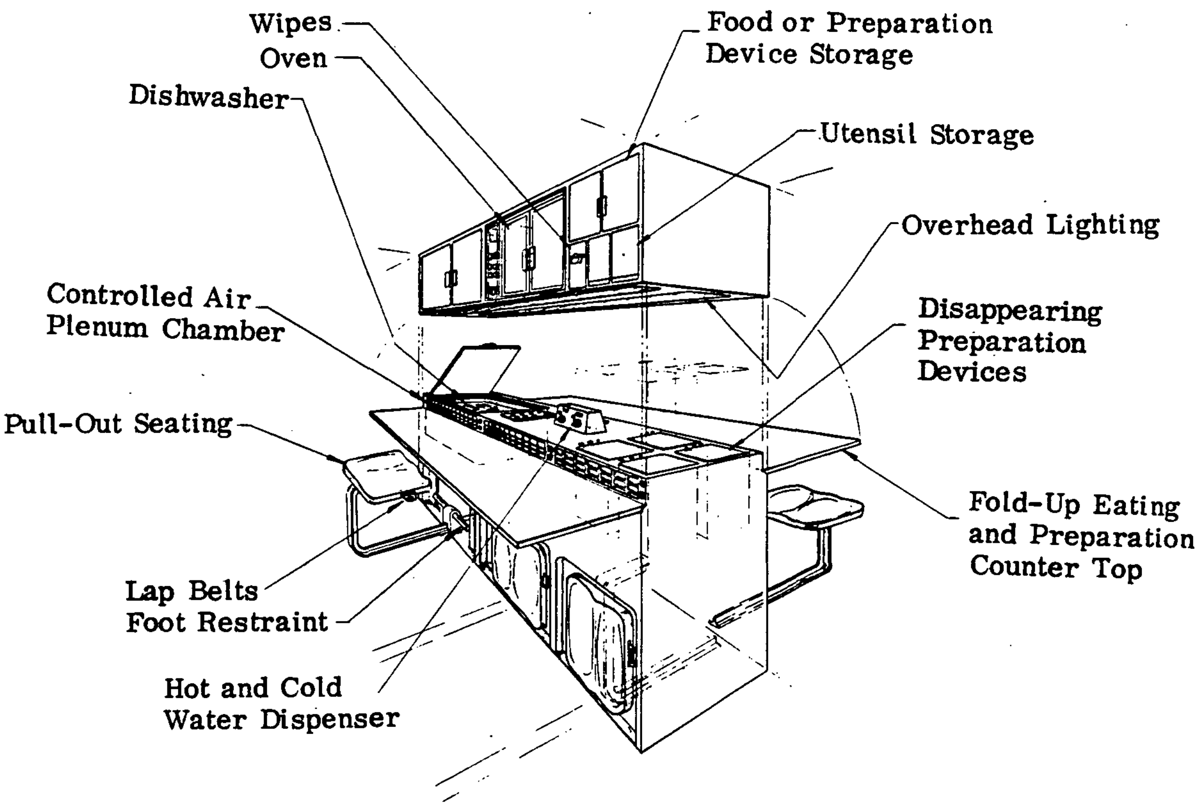
This concept is a four-sided grouping of preparation devices with built-in counters on four sides and preparation devices and storage above and below. Pull-out seats with undercounter body restraints will enable up to twelve men to eat at one time.

By incorporating preparation and eating into an "island" type module, galley and dining area sizing will be greatly reduced. This concept is applicable for both zero- and partial-g usage.

D— 4.1.6B

FOOD SYSTEM STUDY SKETCH

Title: Eat In Galley

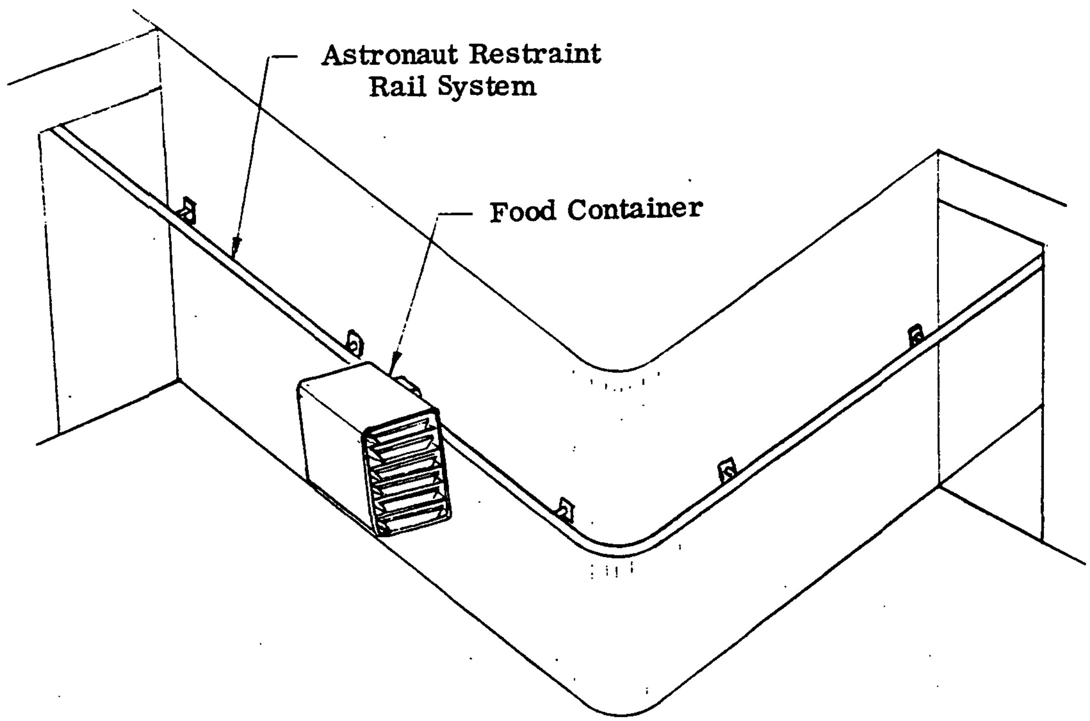


In this concept the crewman would assemble his own meal, prepare it, and consume the meal in the galley at the preparation counter. Pull-out type seating would allow for him to eat in comfort and be restrained in a zero-g environment. This concept would have significant advantages for small crew sizes. It would minimize galley and dining size by using fold-down preparation and eating counters. Further development would be required.

D— 4.1.6 C

FOOD SYSTEM STUDY SKETCH

Title: Tray Rack/Rail Conveyor



Use Astronaut Restraint Rail System for Food Transport

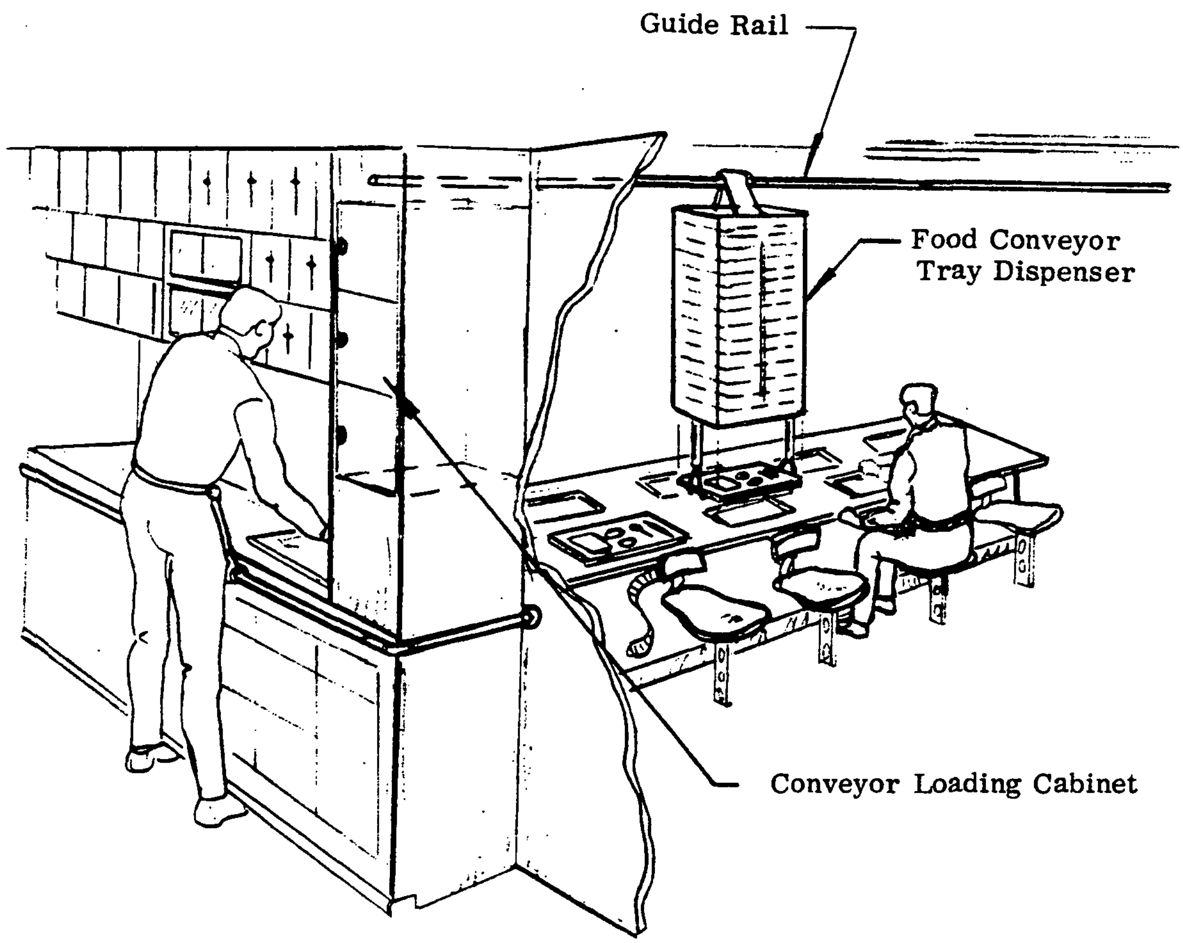
This tray container has been designed to attach to the astronaut restraint rail. This rail is used for guiding containers loaded with trays of food to the dining area and for returning used trays to the cleaning area. It is propelled along the rail.

A minimum amount of further design is needed to perfect this system for zero- and one-g application.

D— 4.1.7 A

FOOD SYSTEM STUDY SKETCH

Title: Tray/Rack Rail Conveyor



This system utilizes a shelved storage rack for tray storage and transport between the galley and the dining area by means of an overhead track/rail guide. The food conveyor and dispenser would be loaded in the galley and can be either electrically or mechanically dispatched to the dining area, where lever-actuated arms lower food trays to the dining positions.

This device is applicable to larger station facilities with crew sizes of 12 or more men and can be used in zero- and partial-gravity environments.

D— 4.1.7 B

4.2 Candidate Utensil Storage Techniques

a. Concept: Storage Rack (4.2.1)

Concept Description: This device is a simple shelved unit which is used to store prepared meals prior to distribution, dirty trays prior to cleaning, and cleaned trays prior to use. The device would be compartmented so as to also store in separate areas dishes, utensils, wipes, and napkins. It would provide a centralized storage unit convenient to all galley functions by its multipurpose use. Additional modifications considered would include the addition of a heated compartment for food temperature maintenance and control.

Technical Analysis: This unit is necessary to support all galley concepts that encompass food preparation, assembly in trays, and delivery to a dining area. It is applicable to all crew sizes and could be modularized in construction to adapt to the various crew configurations.

b. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-18 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-18

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 4.2	TITLE: Serve Food	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
4.2.1	Storage Rack	15.2		X	-		X

For the concept selected for detailed study, technical data are presented below.

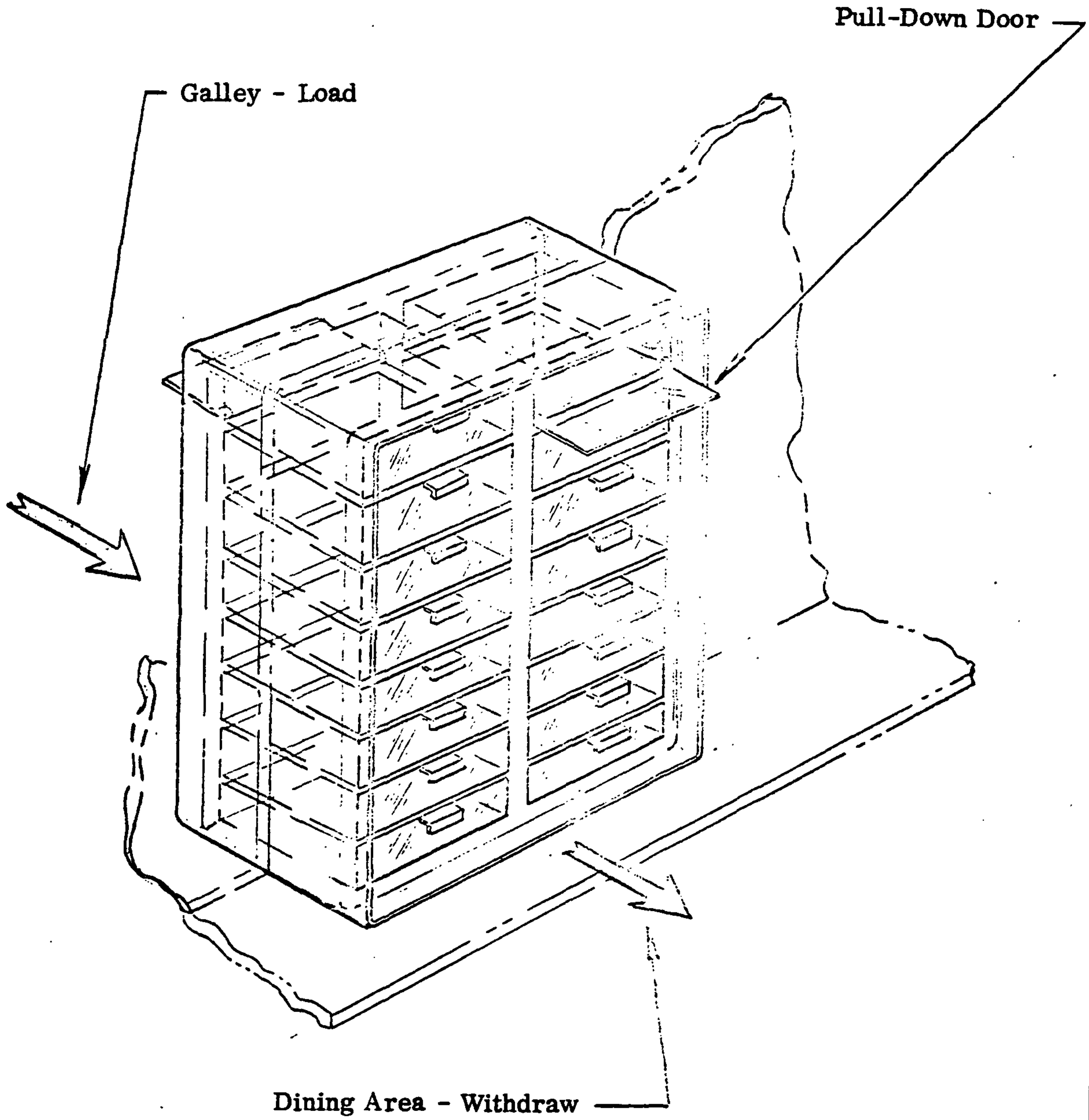
1) Technical Data - Storage Rack (Concept 4.2.1). Detailed data for this concept are presented on Element Concept Data Sheets 4.2.1.1 through 4.2.1.3 in Data Book - Book I.

c. Applicable Sketches

The following sketches depict equipment concepts for the technique described above.

FOOD SYSTEM STUDY SKETCH

Title: Storage Rack



This dispensing cabinet will be mounted on either a counter top or built into a wall dividing the galley from the dining area. It will be compartmentized with pull-down, see-through doors at both the dining and galley sides.

A steward may remove food to serve to a crewman or the crewman himself may take it for self-service. The interior will be designed to restrain the contents so that this unit may be used in either zero- or one-g. The concept is similar to the "automat" food system.

D— 4.2.1

5.0 Provide For Consumption - Functional Subsystem 5.0

This function is concerned with providing concepts of consumption (dining) equipment which would permit the realization of the earth-like dining environment aboard the Space Station/Base. The basic concepts considered were diet type, non-liquid and solid food restraint, dining utensils, equipment restraint, and personal restraint systems.

Primary requirements considered in the evaluation of each concept included applicability to zero-g, contamination, and crew convenience. This function was subdivided into providing equipment to restrain the man and his food, and providing the equipment with which to dine.

5.1 Candidate Passive Consumption Techniques

a. Concept: Passive Consumption Formula Diet (5.1.1)

Concept Description: Passive consumption dictates that the individual be provided nutrition by methods other than ingesting food through the mouth. These methods include (1) intravenous feeding, and (2) tube feeding directly into the stomach.

Technical Analysis: This method of feeding provides well defined nutrition and might be applicable to animal studies or totally controlled man nutritional studies. The problems of sterile technique for intravenous feeding and aseptic technique for tube feeding present one disadvantage. The other disadvantage results from crew discomfort and psychological unacceptability.

b. Concept Evaluation Summary and Technical Data

The concept described above is summarized in Table III-19 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-19

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 5.1	TITLE: Passive Consumption Formula Diet	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.1.1	Concept/Description: Provide Nutrition Other Than Ingesting Food Through Mouth	7.8	X				

5.2 Candidate Formula Consumption Techniques

a. Concept: Active Consumption Formula Diet (5.2.1)

Concept Description: Active consumption dictates that the individual be provided nutrition by means of self-feeding. The concept descriptions are as follows: (1) Drinking from preprocessed formula containers (liquid formula), (2) hand feeding of bite-sized bars, cubes, and pellets (dry formula), and (3) hand and utensil eating from wet pack containers (menu formula).

Technical Analysis: These methods of feeding provide well defined and controlled nutrition and are applicable for manned missions where controlled nutritional studies are required. The concept is discarded on the basis of low crew acceptability.

b. Concept Evaluation Summary and Technical Data

The concept described above is summarized in Table III-20 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-20

CONCEPT EVALUATION SUMMARY

FUNCTIONAL NO.: 5.2	SUBSYSTEM SUB-FUNCTION TITLE: Active Consumption Formula Diet	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.2.1	Concept/Description: Individual Provided Nutrition By Self-Feeding of Formula Diet	(9.2)	X				

5.3 Candidate Menu Consumption Techniques

a. Concept: Active Consumption of Menu Diet of Mixed Food Types (5.3.1)

Concept Description: Consumption of a menu diet dictates that the individual be provided nutrition by self-feeding one or more of the following food types: Dry Food, Frozen Food, Shelf Stable Food, Fresh Food, Mixture of these food types.

Technical Analysis: Each of the food types listed will impact the spacecraft feeding system and each by itself might be applicable to a particular set of mission constraints. The purpose of providing such mixes is to create an earth-like dining environment with familiar food and familiar utensils. For a wide range of mission constraints, percentages of these food types can be varied to make up the total menu.

b. Concept Evaluation Summary and Technical Data

The concept described above is summarized in Table III-21 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-21

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 5.3	TITLE: Active Consumption of Menu Diet	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.3.1	Concept/Description: Menu Diet Dictates That The Individual Be Provided Nutrition By Self-feeding Of Various Food Types	9.2		X	-		X

A detailed discussion of diet mixes and their Space Station/Base impact appears in Functional Subsystem 1.0 - Provide For Food.

5.4 Candidate Non-Liquid Food Restraints

a. Concept: Tray With Formed Recesses (5.4.1)

Concept Description: Recesses in a tray could be sized according to menu quantities such that packaged or unpackaged menu items could be kept separate and consumed from a tray.

Technical Analysis: Vanderveen(*) has observed that cohesive foods tend to remain in place when in contact with a smooth formed surface. Such a tray would lend itself to limited movement while food is in place, ease in cleaning by reason of smooth surfaces, and the establishment of familiar earth-like dining.

(*) Vanderveen, J.E. et al, "Consumption of Rehydratable Food in Zero-Gravity Environments Using Conventional Utensils," Aerospace Medicine, March 1970.

b. Concept: Tray Without Recesses (5.4.2)

Concept Description: A flat tray on which food or packaged food could be placed serves as a location for consumable food.

Technical Analysis: (1) Such a tray would require additional restraint attachments to hold down contained or packaged menu items. Such restraints could just as easily be positioned on a dining table. The item would therefore be extraneous. (2) Dictates plate or package on tray concept which precludes transport of complete meal from galley to dining area.

c. Concept: Tray With Spiked or Ribbed Surfaces (5.4.3)

Concept Description: Tray with spikes or nubs would provide for more positive retention of food in the horizontal plane. It could be constructed with or without recesses.

Technical Analysis: This type of tray configuration might be more applicable to retention of menu items which require cutting where tangential forces would be applied. Ribbed surfaces present a potential contamination hazard if particular care is not taken to ensure all food debris has been removed.

d. Concept: All Cohesive Menu Components (5.4.4)

Concept Description: All menu components will be covered with a viscose sauce or coating which would impart cohesive and adhesive properties.

Technical Analysis: Viscose sauces can be made with or without taste. The taste can be matched to the menu item or can be made to provide flavoring. The sauces can be made inert or to provide starch, protein, or any nutrients as required. The sauces would allow for more adhesion to surfaces allowing for easy consumption and defined spills.

e. Concept: Precut Bite-Sized Menu Items (5.4.5)

Concept Description: All solid and semi-solid menu items (i.e., meats, large vegetables, breads, and cakes) prepared and placed on tray as bite-sized items.

Technical Analysis: This system would allow for eating with fork or spoon only leaving little possibility of spillage due to the impact of tangential forces while cutting or tearing apart. The cost of preparing and packaging menus in this form may be high. Due to increased food handling during preparation, severe sanitary procedures would be required.

f. Concept: Package Containment of Menu Items (5.4.6)

Concept Description: All menu items would be reconstituted (oven, refrigerator, water) in package and served in package. All packages would be fitted with a front opening tear flap for easy utensil access.

Technical Analysis: This system represents no real improvement over existing Apollo feeding techniques. Its packaging represents severe volume and weight penalties when compared to bulk packaging techniques applicable to larger crews and longer mission times. The system concept should be studied to compare with other systems.

g. Concept: Tray With Cover (5.4.7)

Concept Description: An individual meal tray with sections covered by either lay over flaps or sliding covers. The purpose of such covers is to permit non-spill transport and provide positive retention of food on the tray.

Technical Analysis: In such a system of food retention there are two basic problems. The first is opening the cover without spilling the underlying food free from the tray surface, and the second is freeing the covers and/or sliding components of food particles such that sanitation hazards do not occur.

h. Concept: Electrostatic Attraction (Ion Shower) (5.4.8)

Concept Description: A simulated gravitational force on food and food handling devices generated by an ion shower over the dining area.

Technical Analysis: The concept is rejected from further study at this time on the basis of development risks and limited application.

This concept is considered beyond the scope of this study in terms of generating detailed performance data. However, as a major advancement in the state-of-the-art, a preliminary analysis of the feasibility of this technique was performed and is reported in Section VII of this volume.

i. Concept: Impingement Airflow (5.4.9)

Concept Description: One possible method of retaining food and its holding container onto a flat surface is to direct air into its surface to impart a positive downward force.

Technical Analysis: The impingement airflow concept is inadmissible for the following reasons: Undue cooling of hot foods, vortex motions over portions of food, and entrapment of debris would require filtering system and accompanying sterilization procedure.

j. Concept: Have Fellow Astronaut Hold Food (5.4.10)

Concept Description: One man would hand hold food onto the surface of a tray or table such that the other man could cut and retrieve the food at will.

Technical Analysis: This concept is inadmissible on the basis of crew unacceptability and sanitization hazard. Selection rationale score of 10.6 is primarily the result of low power, weight, and volume.

k. Concept: Edible Membranous Coating on Menu Items (5.4.11)

Concept Description: Food on each tray or tray section could be covered with an edible coating. This coating could be applied with a brush or specially designed spray prior to serving.

Technical Analysis: Although the technique of application is ill defined, an edible coating over the menu item would allow for transport and easy consumption of food with good heat and chill retention. Since there are no flaps or moving covers to clean, cleaning presents no unusual difficulties.

l. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-22 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-22

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 5.4 TITLE: Food Restraints (Non-Liquid)

CONCEPT NUMBER	CONCEPT TITLE	INITIAL STUDY SUMMARY RATING	DISCARD	STUDY	INTERIM STUDY SUMMARY RATING	DISCARD	STUDY
5.4.1	Trays With Recesses	11.2		X	-		X
5.4.2	Trays Without Recesses	8.5	X				
5.4.3	Trays With Spiked or Ribbed Surfaces	11.7		X	-		X
5.4.4	All Cohesive Menu Conponents	13.7		X	-		X
5.4.5	Pre-Cut Bite-Sized Menu Items	15.5		X	-		X
5.4.6	Package Containment of Menu Items	11.9		X	-		X
5.4.7	Tray With Cover	10.6		X	-		X
5.4.8	Electrostatic Attraction (Ion Shower)	(9.1)	X				
5.4.9	Impingement Airflow	6.7	X				
5.4.10	Have Fellow Astronaut Hold Food	(10.6)	X				
5.4.11	Edible Membranous Coating on Menu Items	12.4		X	-		X

For the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Trays With Recesses (Concept 5.4.1). Detailed data for this concept are presented on Element Concept Data Sheets 5.4.1.1 through 5.4.1.3 in Data Book - Book I. Additional back-up analyses of weight, volume, and costs are presented under Concept 5.4.1 in Data Book - Book II.

2) Technical Data - Trays With Spiked or Ribbed Surfaces (Concept 5.4.3). Detailed data for this concept are presented on Element Concept Data Sheets 5.4.3.1 through 5.4.3.3 in Data Book - Book I. Additional back-up analyses of weight, volume, and costs are presented under Concept 5.4.3 in Data Book - Book II.

3) Technical Data - All Cohesive Menu Components (Concept 5.4.4). Applicable detailed data for this concept are presented on Element Concept Data Sheet 5.4.4.1 in Data Book - Book I. Initial and resupply cost analyses are presented under Concept 5.4.4 in Data Book - Book II.

4) Technical Data - Pre-Cut Bite-Sized Menu Items (Concept 5.4.5). Applicable detailed data for this

concept are presented on Element Concept Data Sheet 5.4.5.1 in Data Book - Book I. Initial and resupply cost analyses are presented under Concept 5.4.5 in Data Book - Book II.

5) Technical Data - Package Containment of Menu Items (Concept 5.4.6). Applicable detail data for this concept are presented on Element Concept Data Sheet 5.4.6.1 in Data Book - Book I. Initial and resupply cost analyses are presented under Concept 5.4.6 in Data Book - Book II.

6) Technical Data - Tray With Cover (Concept 5.4.7). Detail data for this concept are presented on Element Concept Data Sheets 5.4.7.1 through 5.4.7.3 in Data Book - Book I. Additional back-up analyses of weight, volume, and costs are presented under Concept 5.4.7 in Data Book - Book II.

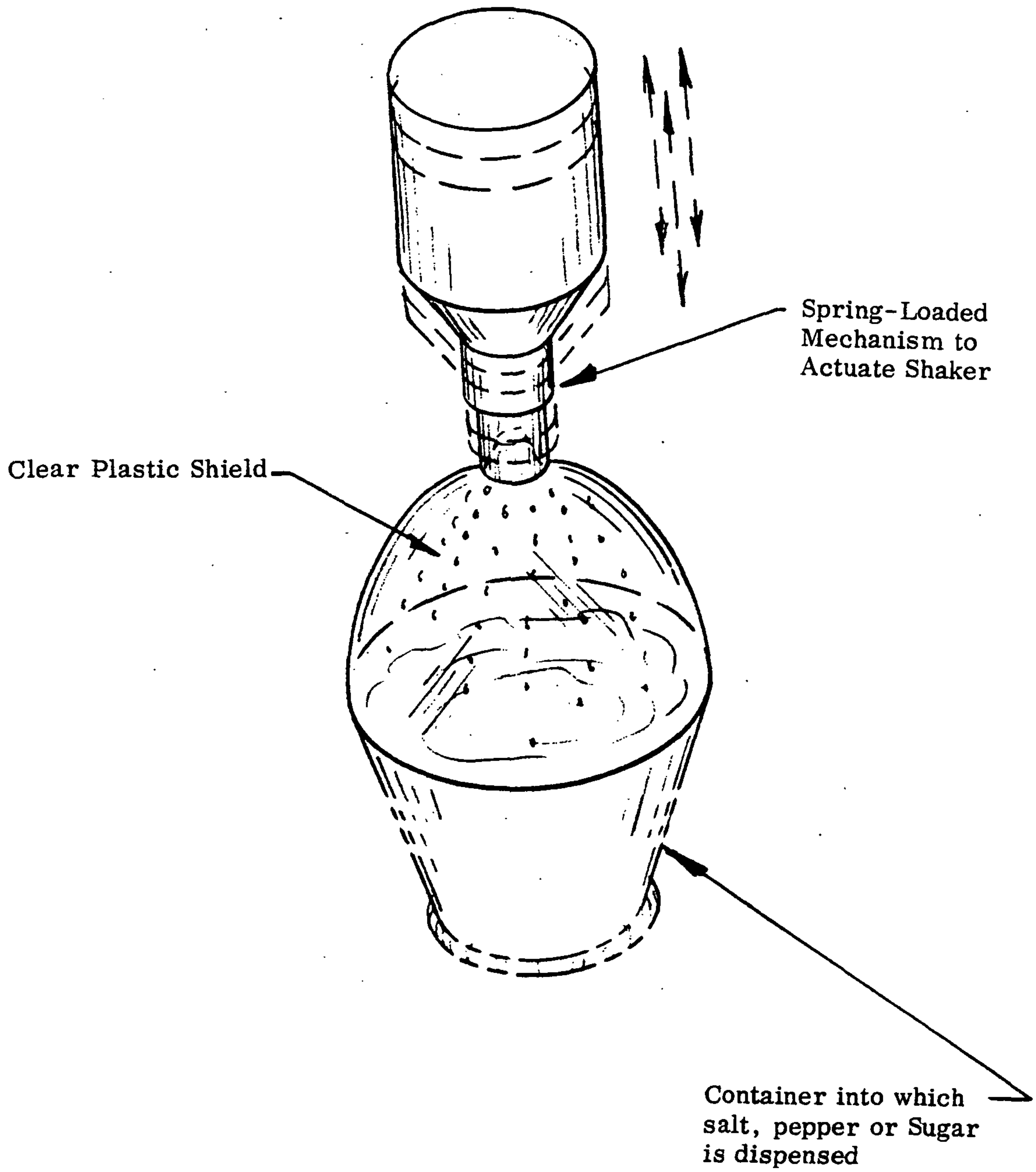
7) Technical Data - Edible Membranous Coating on Menu Items (Concept 5.4.11). Detailed data for this concept are presented on Element Concept Data Sheet 5.4.11.1 in Data Book - Book I. Initial and resupply cost analyses are presented under Concept 5.4.11 in Data Book - Book II.

m. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Food Consumption - Sugar, Salt or Pepper Dispenser



In this concept the dispenser for sugar, salt, or pepper is a cylindrically shaped container which contains a spring-loaded actuating mechanism which thrusts the granular item out of the container by pushing on the container.

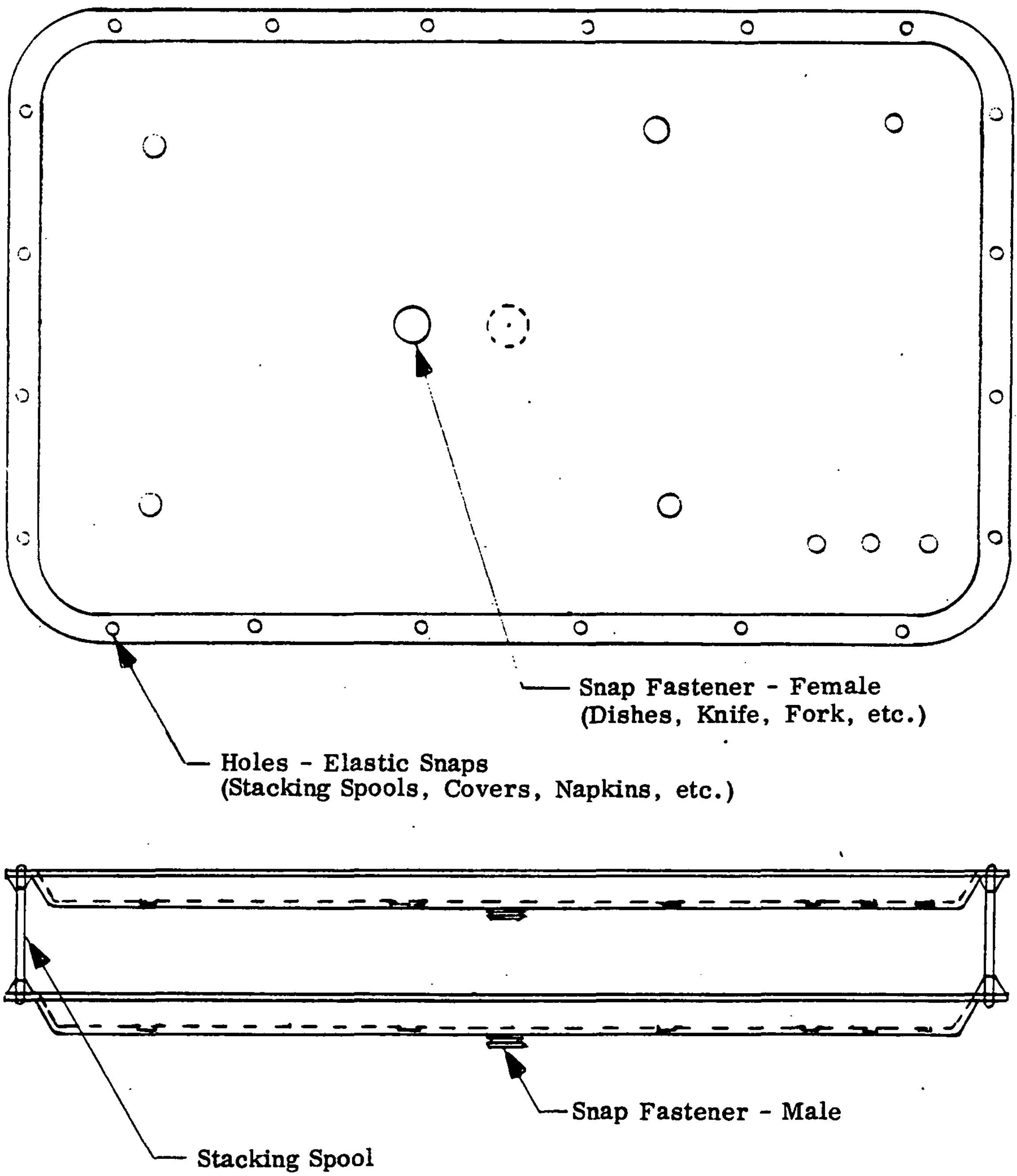
A clear plastic shield, preferably configured to the shape of the receiving container, prevents the granular items from bouncing out of the receiving container.

This concept is for zero-g usage only.

D— 5.0

FOOD SYSTEM STUDY SKETCH

Title: Food Restraints - Tray

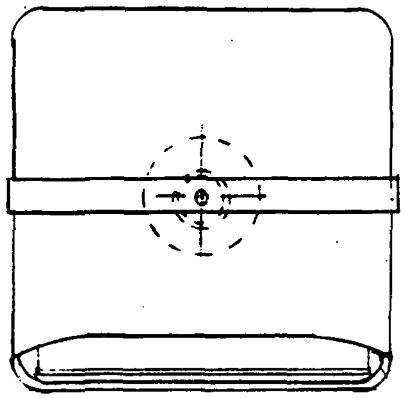


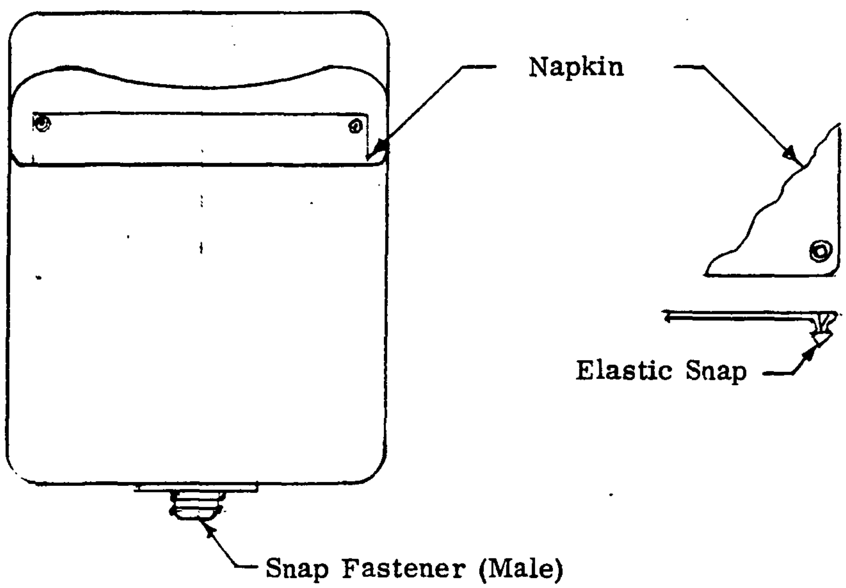
The tray must provide for its own attachment to the table and attaching points for all dishes, knives, forks, spoons, napkins, etc. to the tray. In addition, a stacking spool is provided to hold stacks of loaded trays together. These devices will operate in both zero- and partial-g.

D— 5.4 A

FOOD SYSTEM STUDY SKETCH

Title: Food Restraints - Napkin Holder



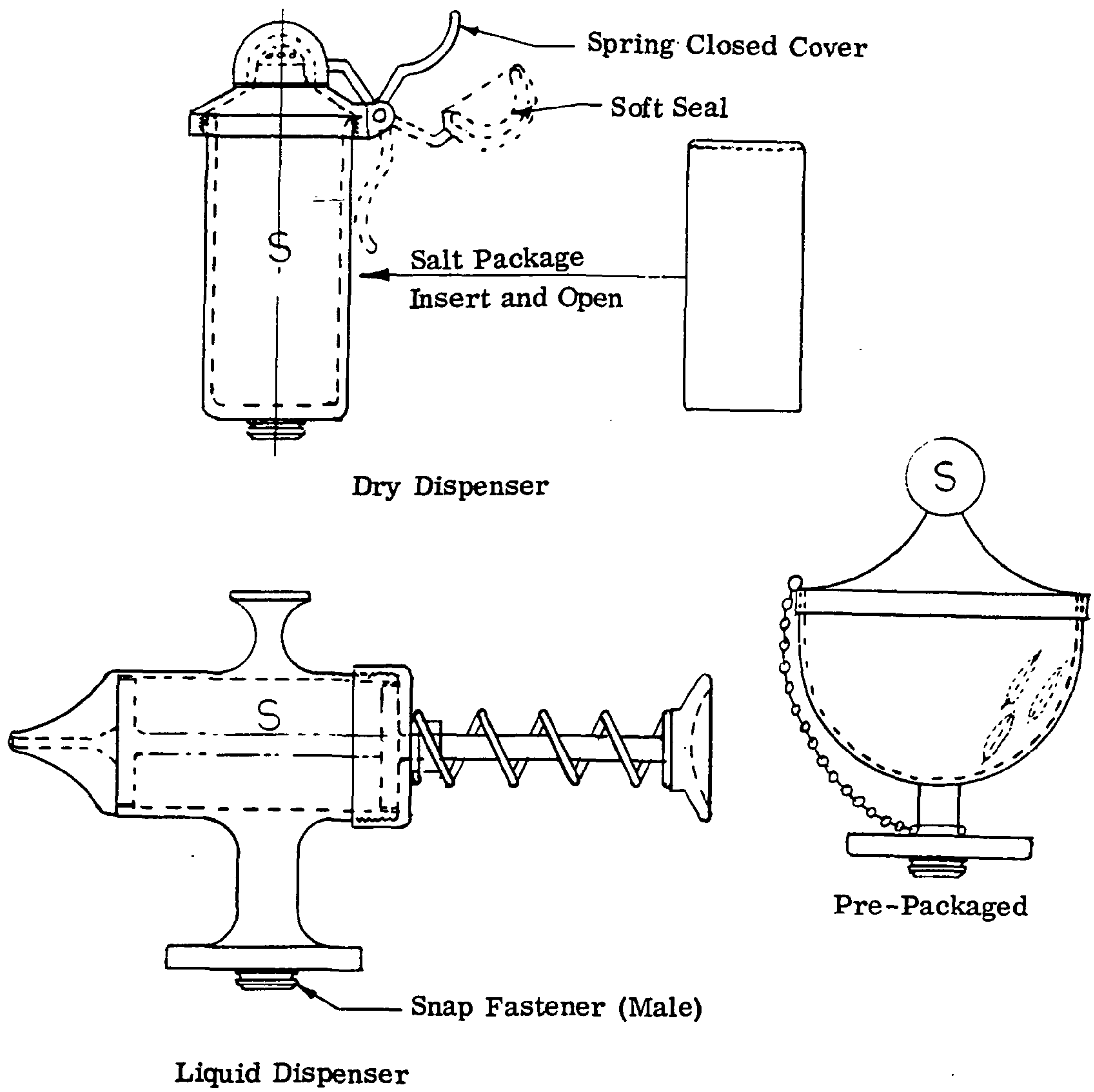


This device is an adaptation of a conventional spring-loaded napkin holder containing a snap fastener for attaching to work areas or tables as required. The napkins contain integral plastic snaps for retention to trays, dishes, or tables.

D— 5.4B

FOOD SYSTEM STUDY SKETCH

Title: Non-Liquid Food Restraints - Salt Shakers



Salt Dispensers

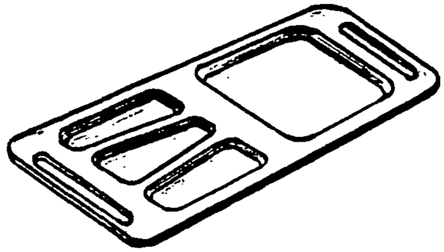
Three kinds are depicted. First is the dry salt shaker. It has a small dispensing area with a sealed cover. It can be used on moist foods for salt adherence. Second is a liquid saline solution. It can be used on both wet and dry foods. Third is a totally enclosed container for prepackaged salt.

These concepts are applicable for both zero- and one-g usage.

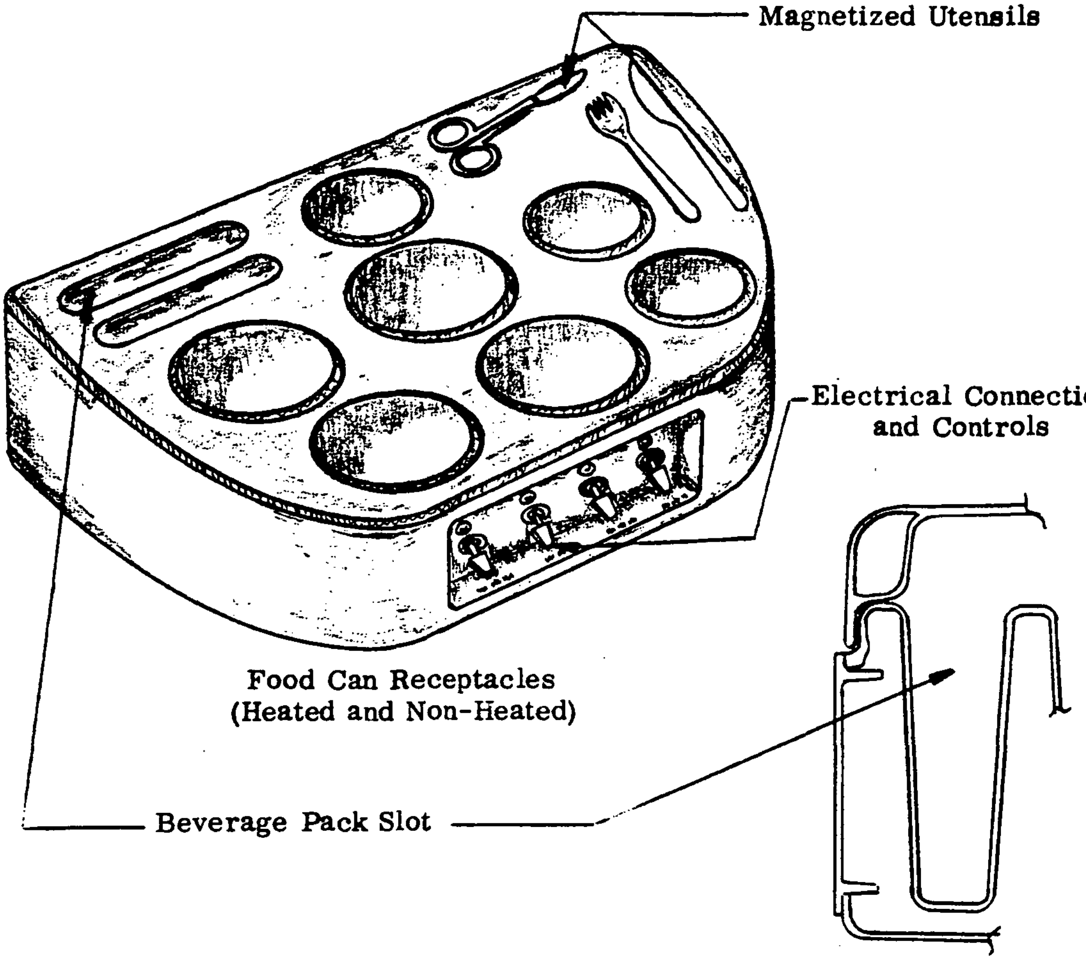
D— 5.4 C

FOOD SYSTEM STUDY SKETCH

Title: Tray With Recesses



The food compartments are pressure formed in this one-piece tray used primarily for foods with high adhesive and cohesive properties. Cavities contain generous radii for ease of cleaning. Limitations are questionable zero-g restraint and possible restrictions on compatible food types.

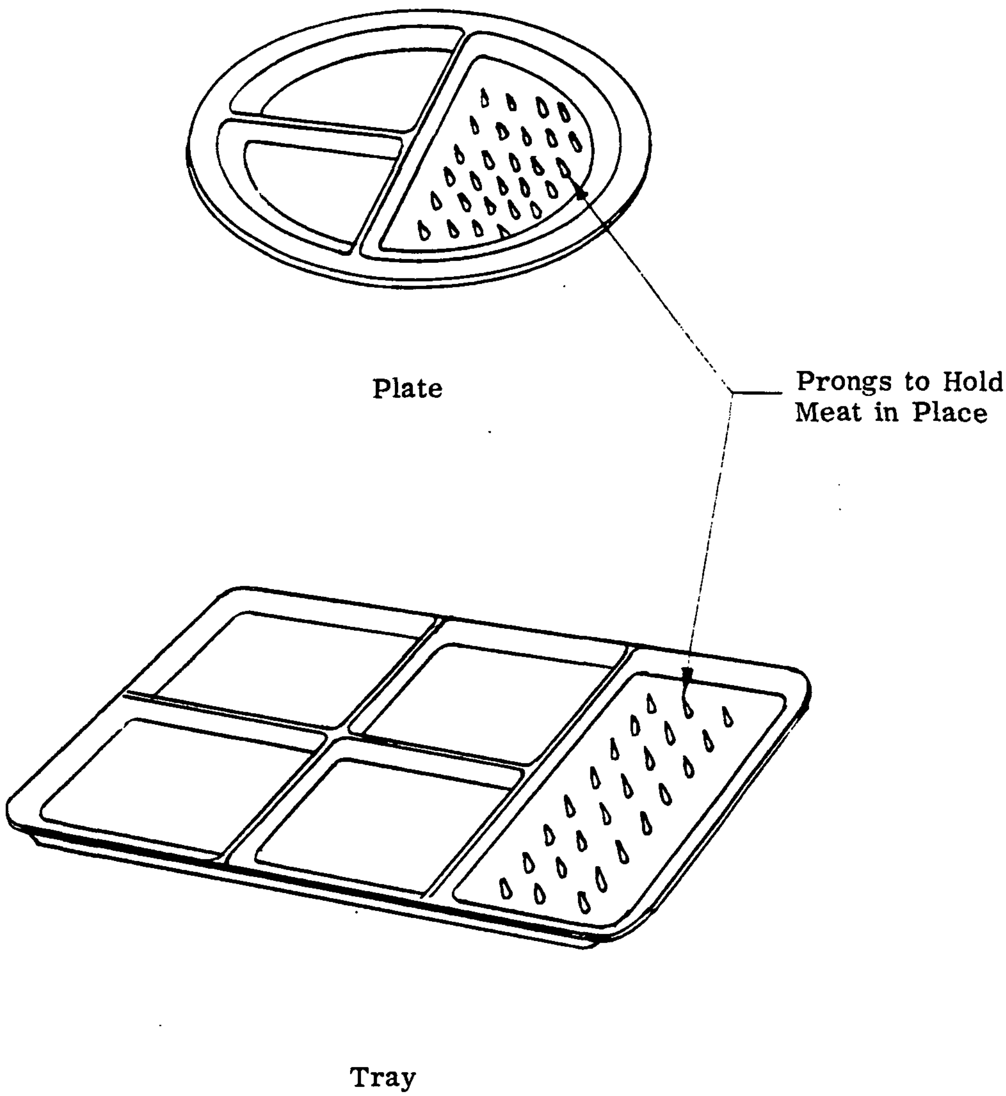


The Skylab food tray concept consists of a lid that covers a lower portion during food heating and can be used as part of a Wardroom table. The tray contains cylindrical cavities of varying sizes to accept food cans, and of two beverage recesses. Four of the cavities have heater elements to permit food warming. Electrical connections to mate with a spacecraft conduit and three-position (off, heat, and thaw/heat) control switches are located on the side of the tray.

D— 5.4.1

FOOD SYSTEM STUDY SKETCH

Title: Tray With Spiked or Ribbed Surfaces



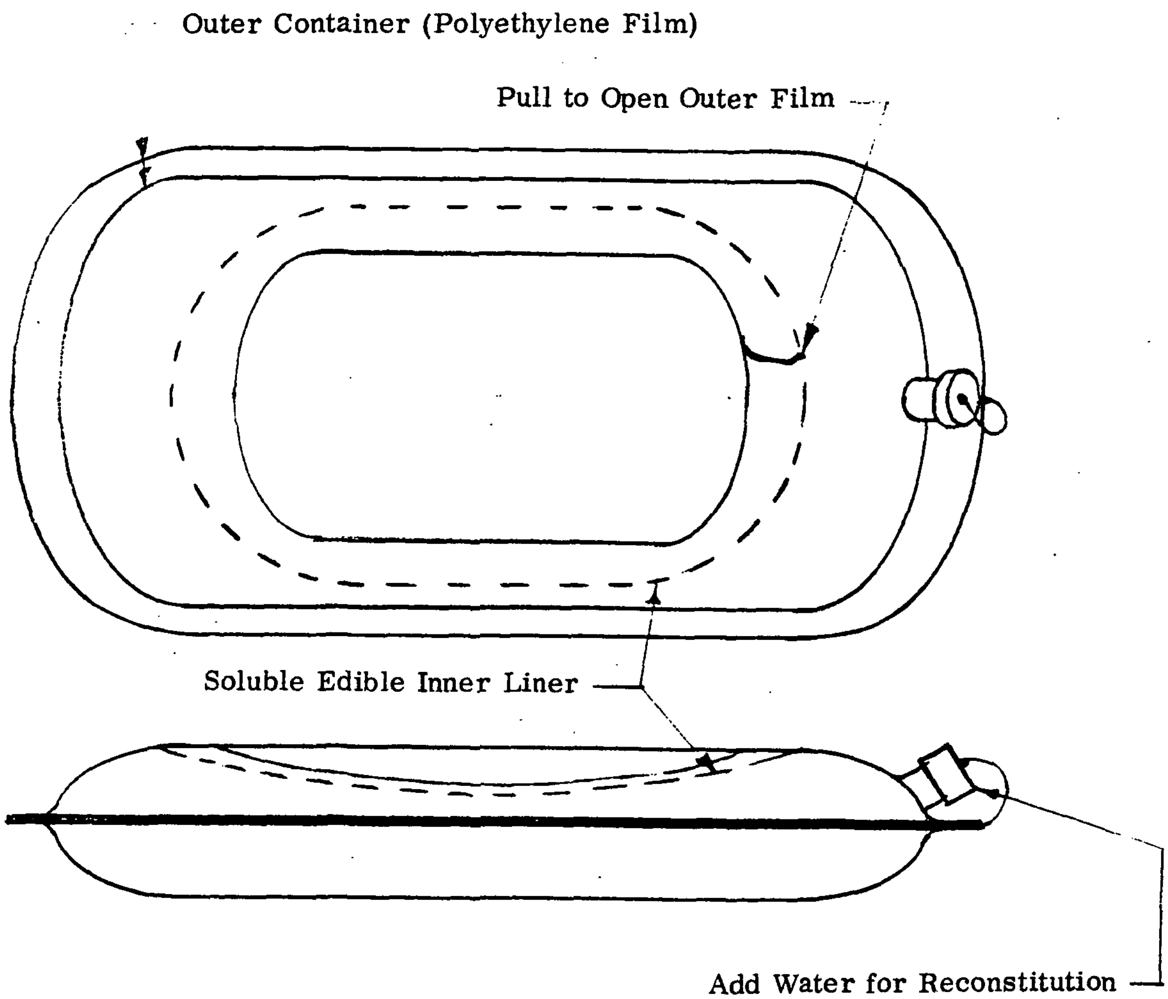
The tray and plate are divided into compartments for food separation. One compartment is spiked to secure foods that require bite-size cutting. The spike ends are to be rounded for safety. This tray would only be used in cutting and holding large pieces of meat.

A disadvantage of this design may be in difficulty of cleaning and possible safety hazards. Primary use would be in zero-g.

D— 5.4.3

FOOD SYSTEM STUDY SKETCH

Title: Package Containment of Menu Items



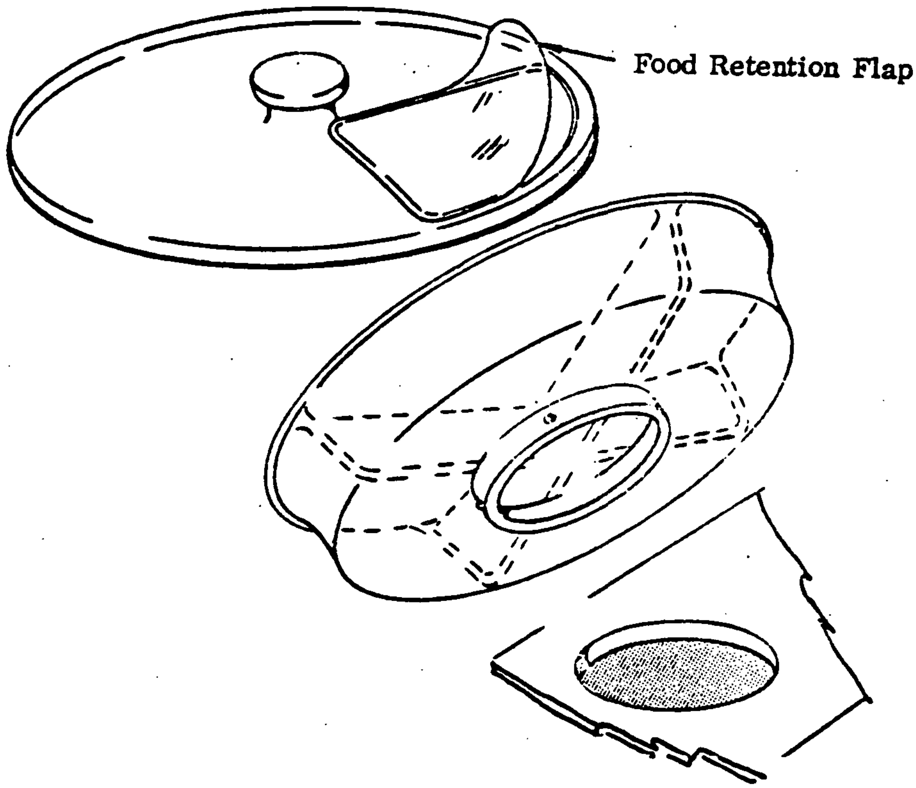
This food package is fabricated from a polyethylene film. It provides a simple fingertip device for opening the package. An edible soluble film is provided just under the package opening to retain the food during the process of opening. The edible film is activated by reconstitution of the food.

An advantage of this system is in its ability to restrain the food after the package has been opened. Applicability may be primarily for small crew sizes and for off-site or emergency use. Some development would be required to ensure proper usage.

D— 5.4.6

FOOD SYSTEM STUDY SKETCH

Title: Tray With Cover



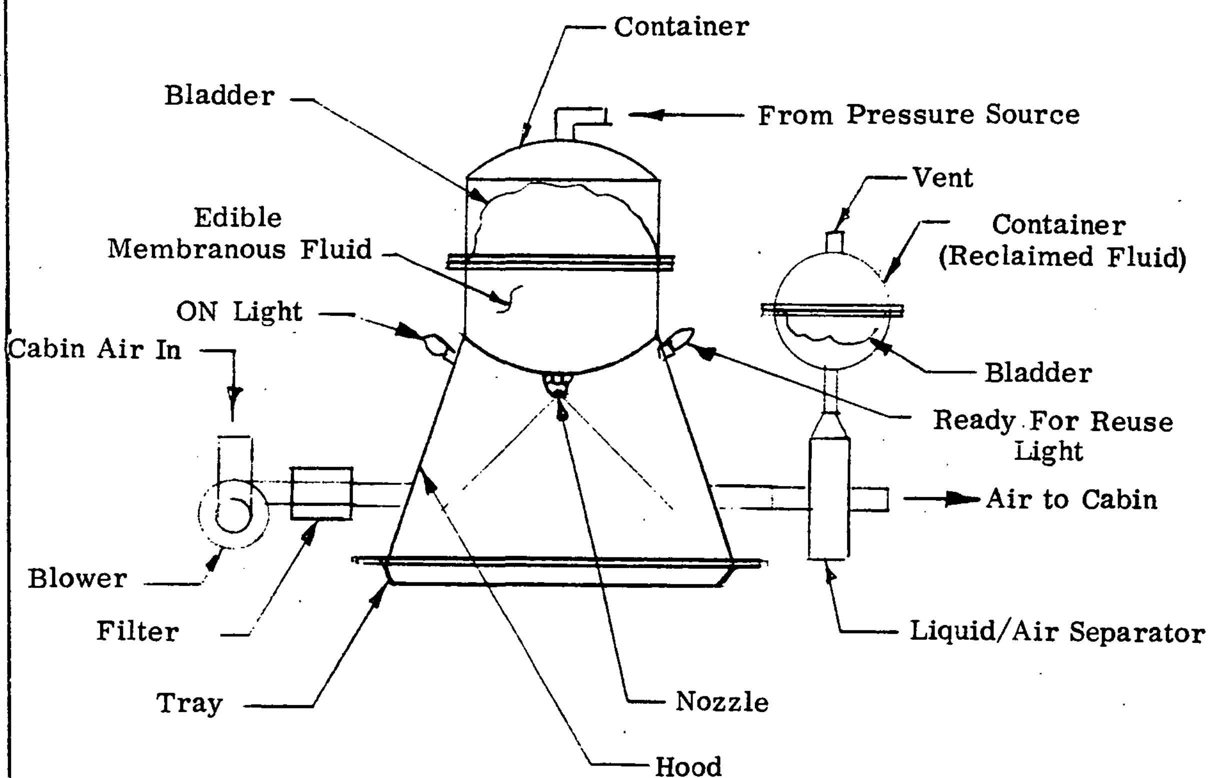
This meal tray is a circular compartmentized container with a rotating cover having one opening. The cover is rotated to allow removal of food from one compartment at a time. A mylar flap over the cover opening prevents spillage during serving.

The advantage of this concept is that all compartments are accessible, but only one compartment is open at a time. The tray is an adaptation of existing technology and is applicable to both zero- and one-g.

D— 5.4.7

FOOD SYSTEM STUDY SKETCH

Title: Spray Applicator - Edible Membranous Coating



This design consists of a fluid container with a bladder expulsion unit, a spray nozzle, tray hood, blower, filter, air/fluid separator, reclamation container, and a control switch.

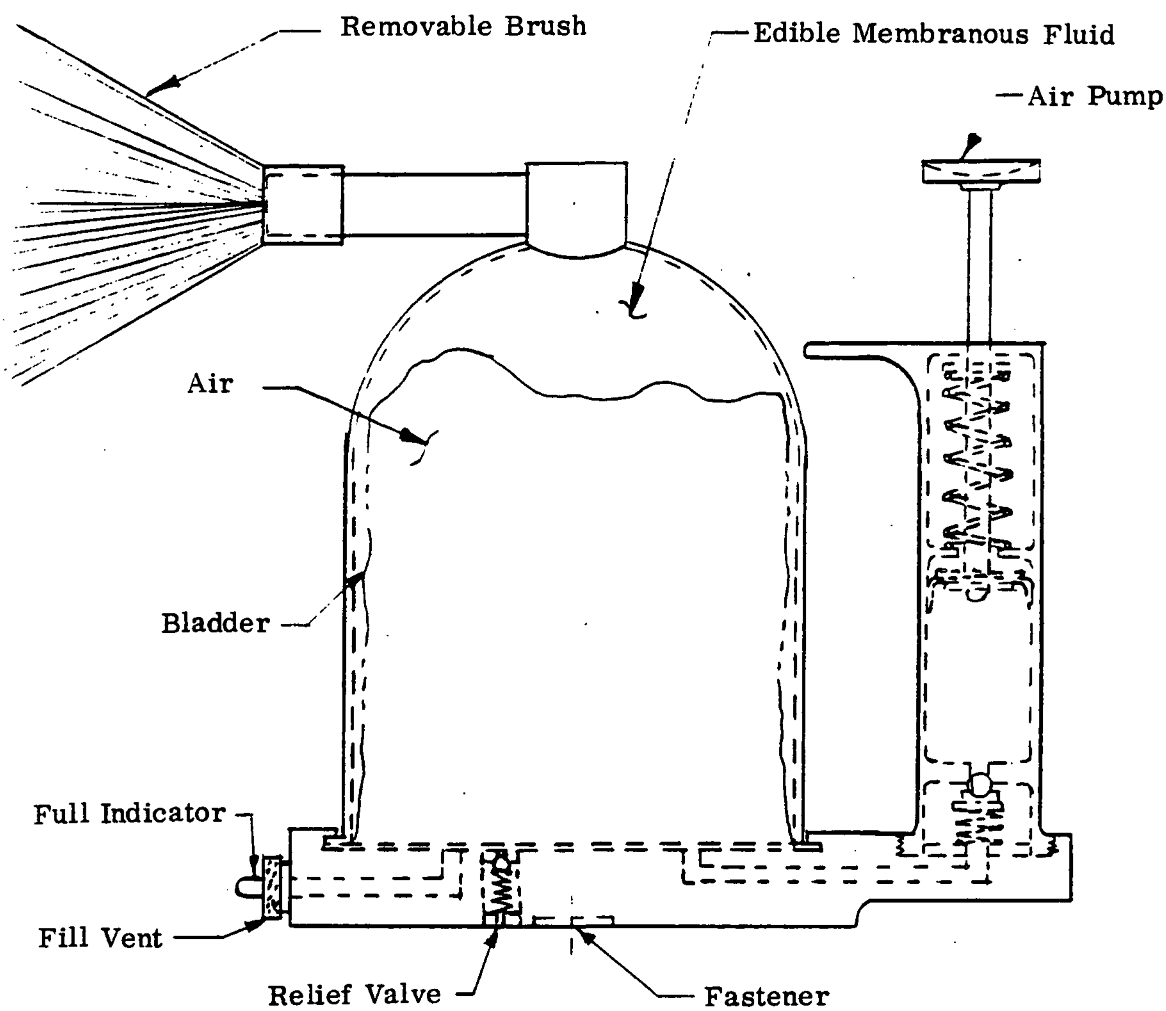
To operate, the tray is pressed against the hood. This causes pressure to be applied against the bladder in the container, forcing the membranous fluid to be sprayed through the nozzle.

This design is primarily applicable to partial-g since aerosol sprays are not recommended for zero-g. Minimum development would be required.

D— 5.4.11 A

FOOD SYSTEM STUDY SKETCH

Title: Brush Applicator - Edible Membranous Coating



The design consists of a hollow brush and an air pump controlled bladder expulsion system. The container is vented and filled with edible membranous fluid. To apply, the pump plunger is depressed forcing fluid into the brush. The container is used to apply the membranous coating to the food.

The unit is applicable to both zero- and partial-g and will require minimum development.

D— 5.4.11 B

5.5 Candidate Liquid Food Restraint

a. Concept: Open Liquid Containers (5.5.1)

Concept Description: Open drinking vessels include cups, glasses, bowls, and cans (both with and without holders). They may be insulated for maintaining hot and cold liquids. These items would be more in line with conventional design configuration utilizing wide mouth and low profile.

Technical Analysis: This concept is inadmissible on the grounds of the obvious crew safety hazard in the zero-g environment.

b. Concept: Closed Liquid Containers (5.5.2)

Concept Description: Liquid containers with cover. Covers might include either straw placement provision or be configured to permit mouth withdrawal of contents through a lip port.

Technical Analysis: This concept will consider positive and negative pressure liquid displacement techniques.

c. Concept: In Package Liquid Restraints (5.5.3)

Concept Description: All liquid portions of the menu will be package contained. Either they will be brought aboard as liquid or reconstituted aboard. Each package will be equipped with a rehydration valve, if applicable, and a tube sufficient for emptying the contents into the mouth of the man.

Technical Analysis: This system has been proven in previous space flight. It is considered primarily as a supplementary technique since it does not lend itself to package volume optimization.

d. Concept: No Liquid Restraint (5.5.4)

Concept Description: Once beverages or liquid meal portions have been reconstituted or otherwise prepared, the restraint will be removed such that the liquid is free to move in any direction and the astronaut is free to catch it with whatever means he can utilize.

Technical Analysis: This concept is unacceptable because of crew safety. Catching liquid with the mouth could result in choking and aspiration of liquid into the lungs.

e. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-23 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-23

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 5.5	TITLE: Food Restraint (Liquid)	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.5.1	Open Liquid Containers	8.9	X				
5.5.2	Closed Liquid Containers	13.4		X	-		X
5.5.3	In Package Liquid Restraints	13.1		X	-		X
5.5.4	No Liquid Restraint	8.0	X				

For each of the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Closed Liquid Containers (Concept 5.5.2). Detailed data for this concept, including both positive and negative pressure displacement techniques, are presented on Element Concept Data Sheets 5.5.2.1 through 5.5.2.3 and 5.5.2.5 through 5.5.2.7 in Data Book - Book I. Additional analyses of weights, volumes, and costs are presented under Concept 5.5.2A and 5.5.2B in Data Book - Book II.

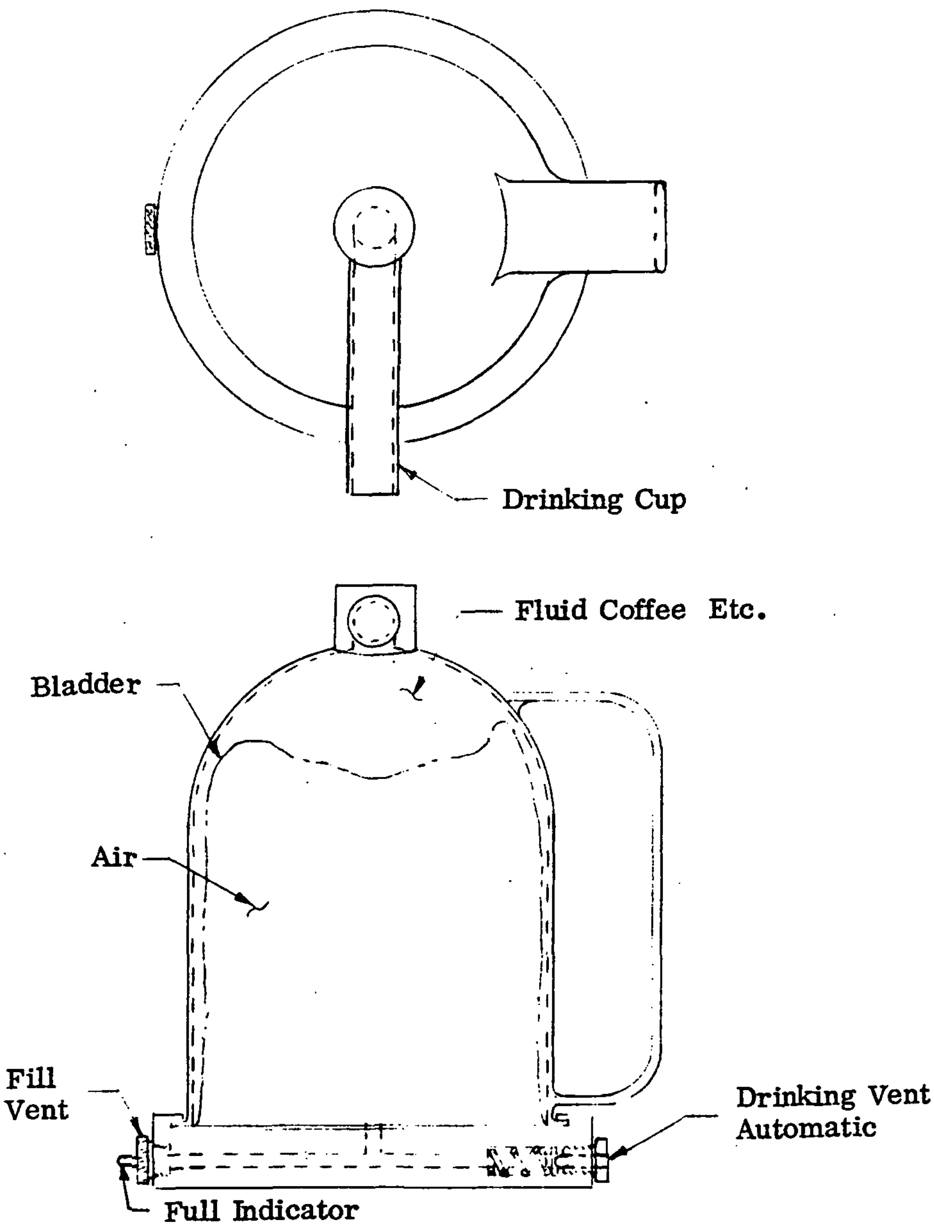
2) Technical Data - In Package Liquid Restraint (Concept 5.5.3). Applicable data for this concept are presented on Element Concept Data Sheet 5.5.3.1 in Data Book - Book I. Initial and resupply cost analyses are presented under Concept 5.5.3 in Data Book - Book II.

f. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Liquid Food Restraint - Drinking Cup

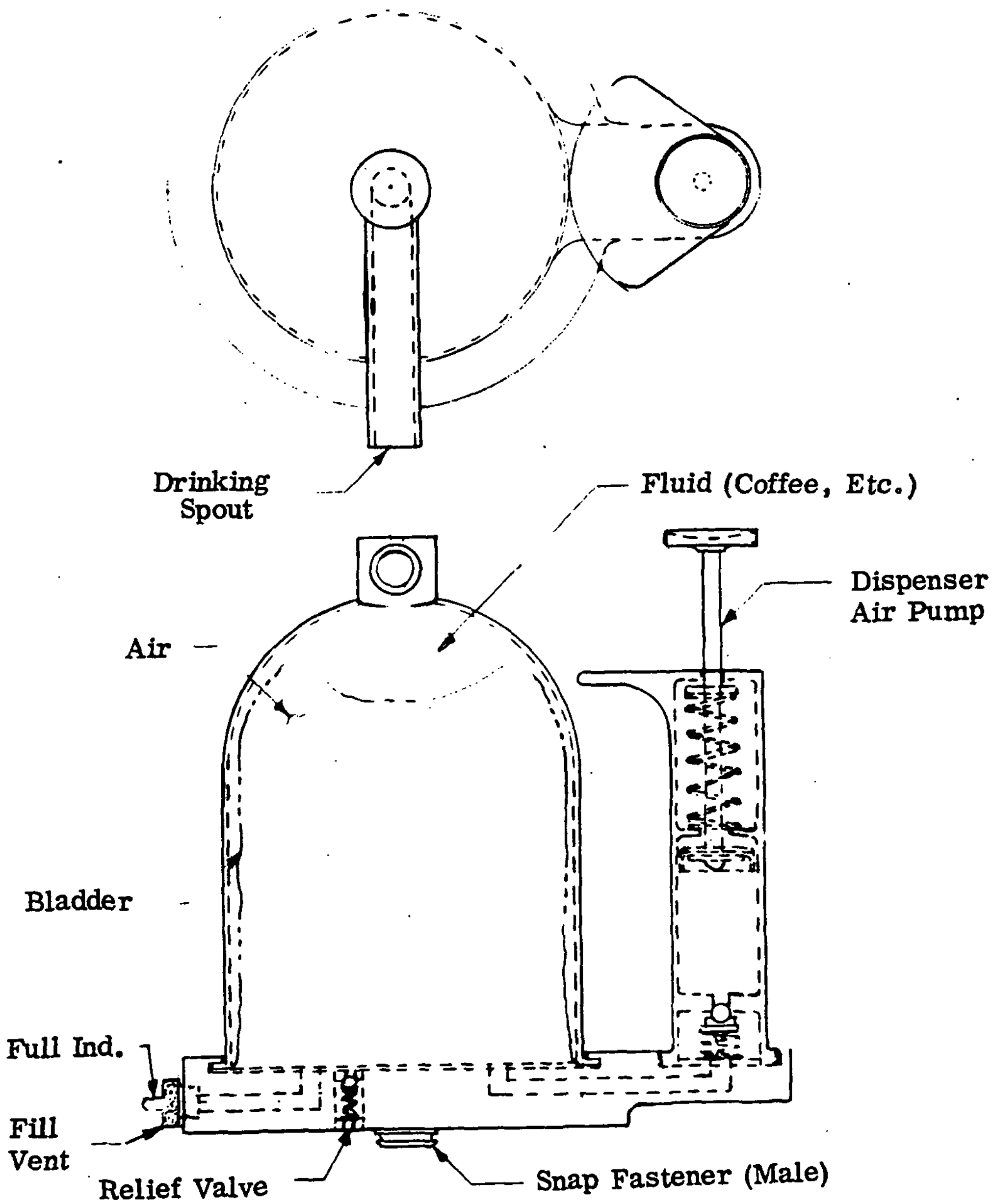


This cup consists of a drinking spout, container, bladder, fill vent valve and drinking check valve. The container is filled through the drinking spout by dispensing the liquid from an urn. The fluid will displace the bladder, forcing the air out through the fill vent. Close the fill vent. Drinking is accomplished by sucking on the spout. Air enters through the drinking vent check valve and displaces the bladder as the fluid leaves the cup.

D— 5.5 A

FOOD SYSTEM STUDY SKETCH

Title: Liquid Food Restraint - Drinking Cup



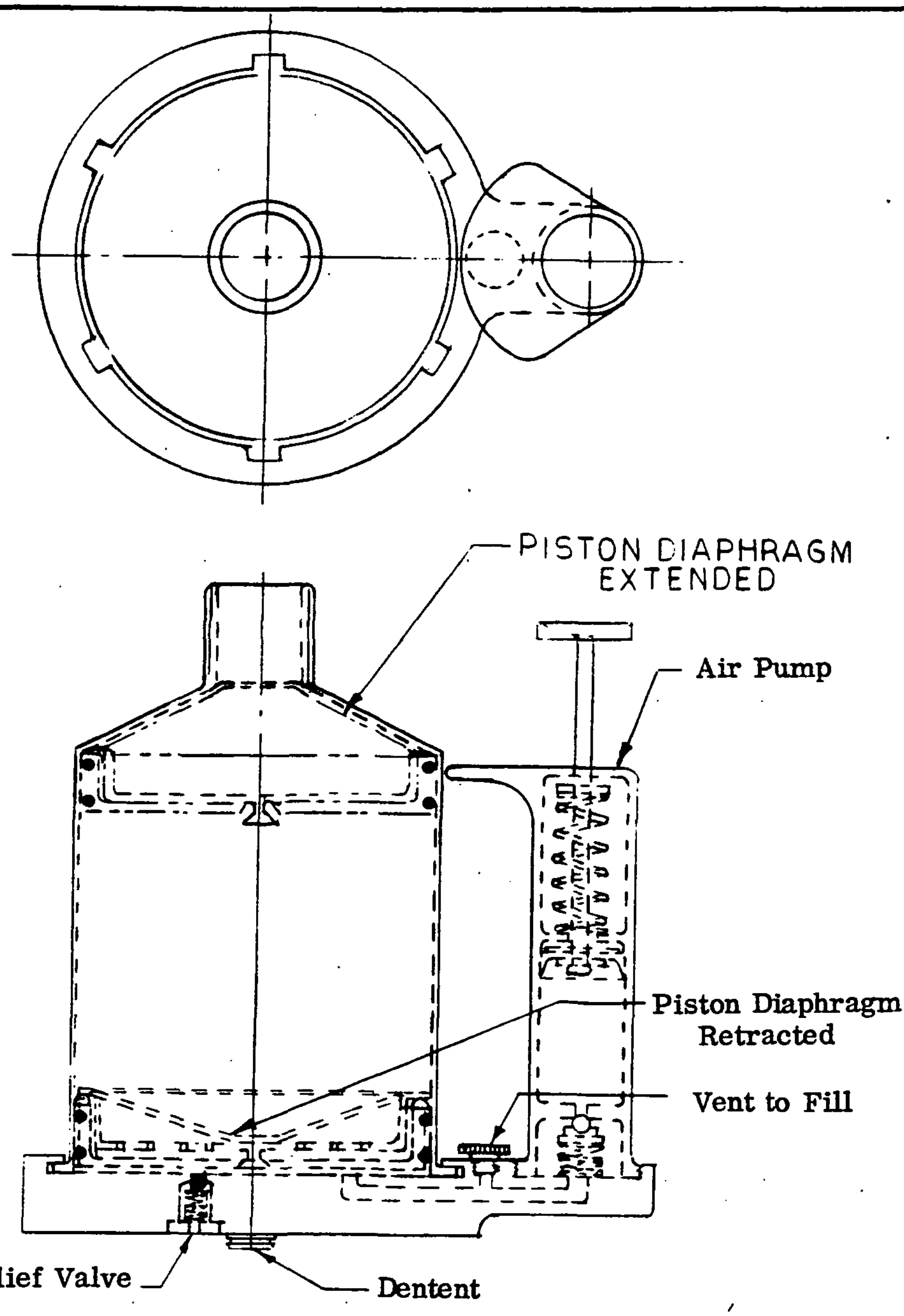
This cup consists of a drinking spout, container bladder liner, air pump, check valve, and fill vent valve. The cup can be filled by pumping coffee, etc. in through the drinking spout. The fluid will displace the bladder and the air will exit through the fill vent. The indicator will extend to show a full cup. Close the fill vent. Fluid can be forced out the drinking spout by depressing the pump plunger.

This is a zero-g concept requiring further development.

D— 5.5B

FOOD SYSTEM STUDY SKETCH

Title: Liquid Food Restraints - Soup Cup



The cup consists of a drinking spout, container, piston with flexible diagragm, air pump, and fill vent valve.

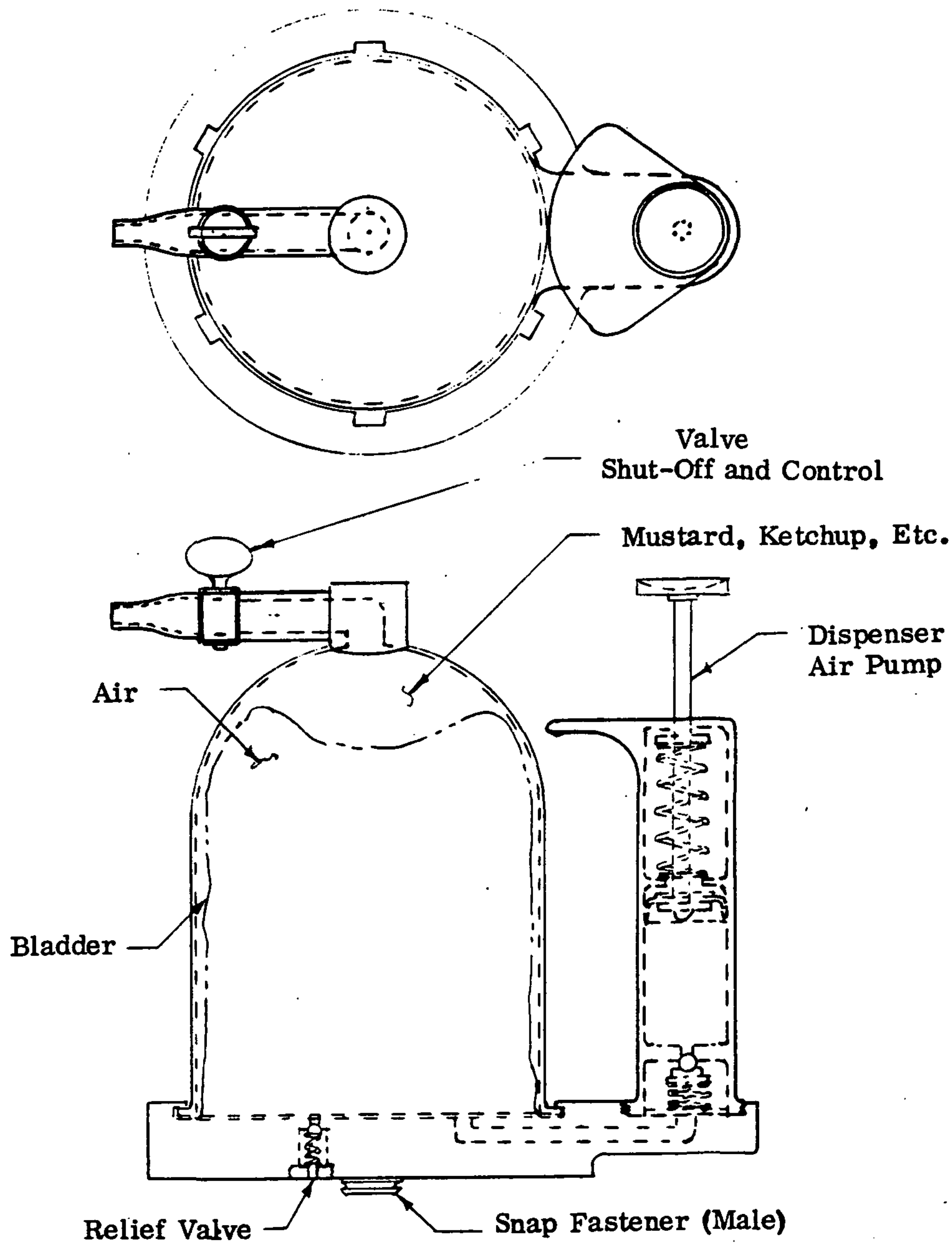
The cup is filled by pumping soup in through the spout, displacing the piston to the bottom of the cup as the air escapes through the fill vent valve. Close the fill vent. When the air pump plunger is depressed the piston pushes soup out the drinking spout. When the piston reaches the top of the cylinder, a valve opens and air will expand the outer periphery of the diaphragm first and the center last expelling the last chunks of soup without crushing them.

This is a zero-g concept.

D— 5.5C

FOOD SYSTEM STUDY SKETCH

Title: Liquid Food Restraint - Condiment Dispenser

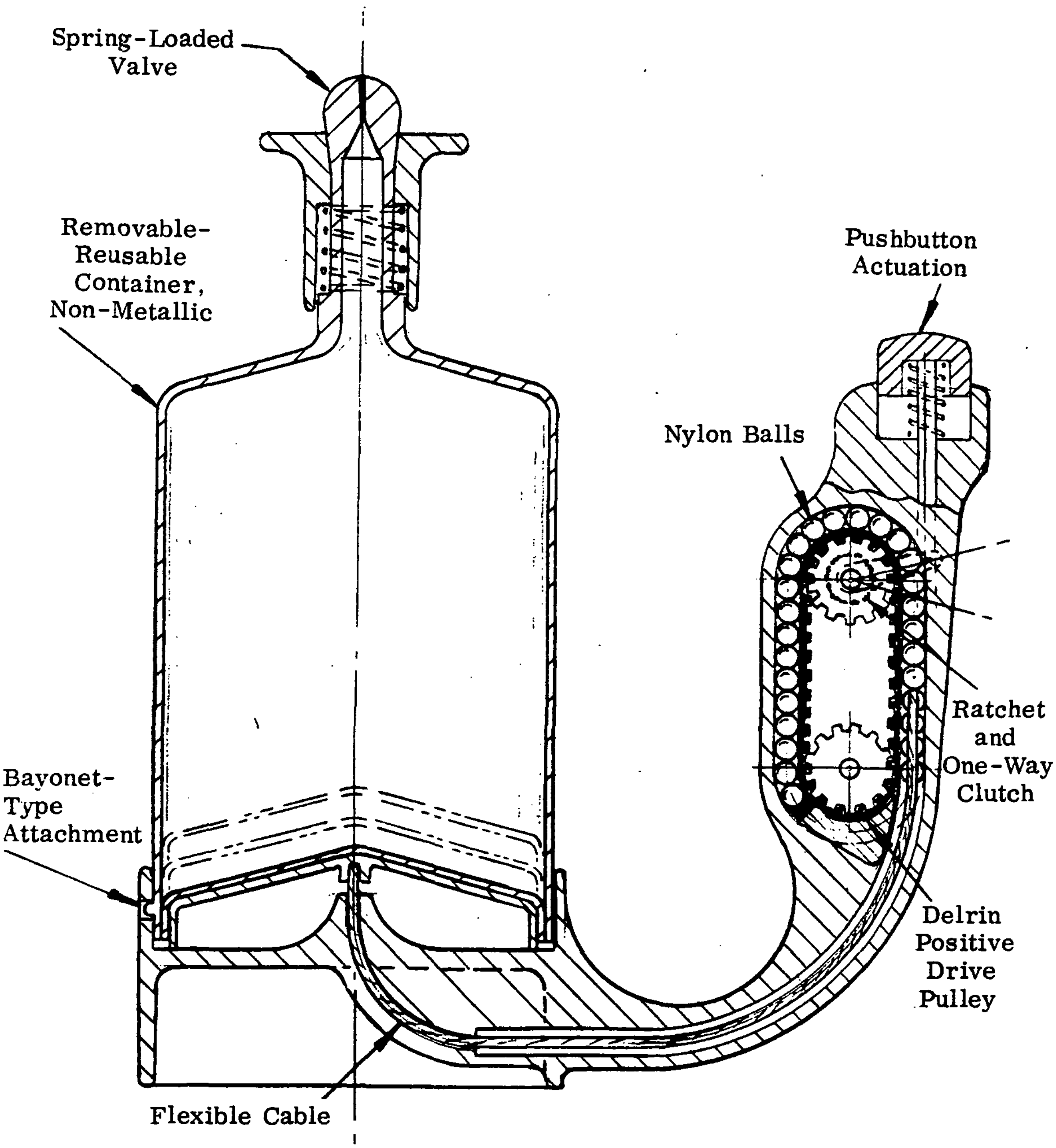


Condiments, such as mustard and ketchup, can be dispensed by an air pump bladder type system. The dispenser can be filled by inserting a plastic container or squeeze filling the dispenser container. With the shut-off valve closed, the air pump is operated which pressurizes the bladder. The condiment is then dispensed by opening and closing the shut-off valve for both zero- and partial-g conditions.

D— 5.5D

FOOD SYSTEM STUDY SKETCH

Title: Closed Liquid Containers - Positive Displacement



These drinking devices shown on Sheet 1 through 3 are portable, hand-held, thumb- or trigger-actuated, piston operated, positive displacement dispensing devices.

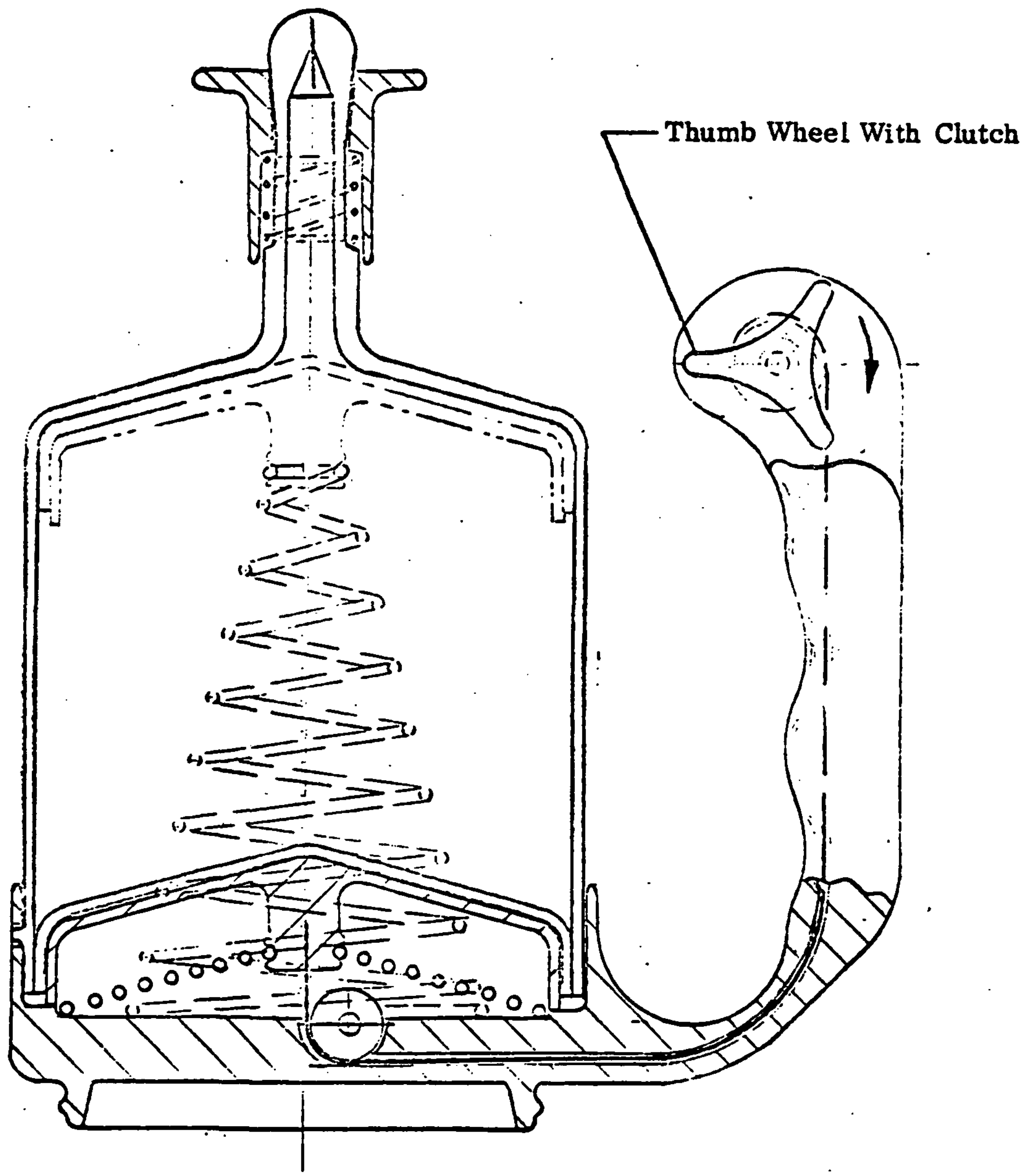
The delivery end is fitted with a non-metallic tip and a valve sealing mechanism which remains sealed until opened by pressure of lips against the sealing mechanism. These devices are for zero- to partial-g usage only.

D— 5.5.2

(Sheet 1 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Closed Liquid Containers - Positive Displacement

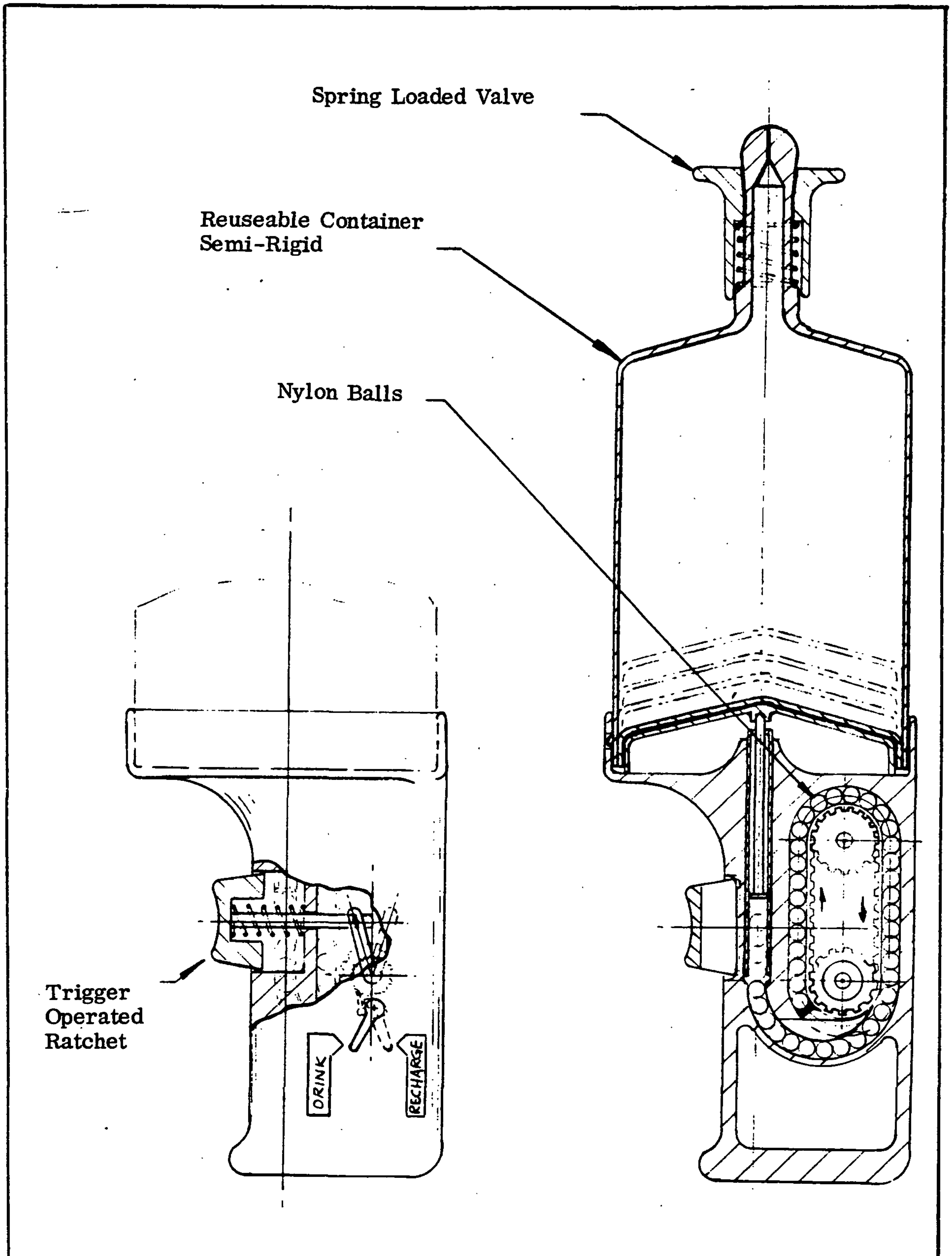


D— 5.5.2

(Sheet 2 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Closed Liquid Containers - Positive Displacement

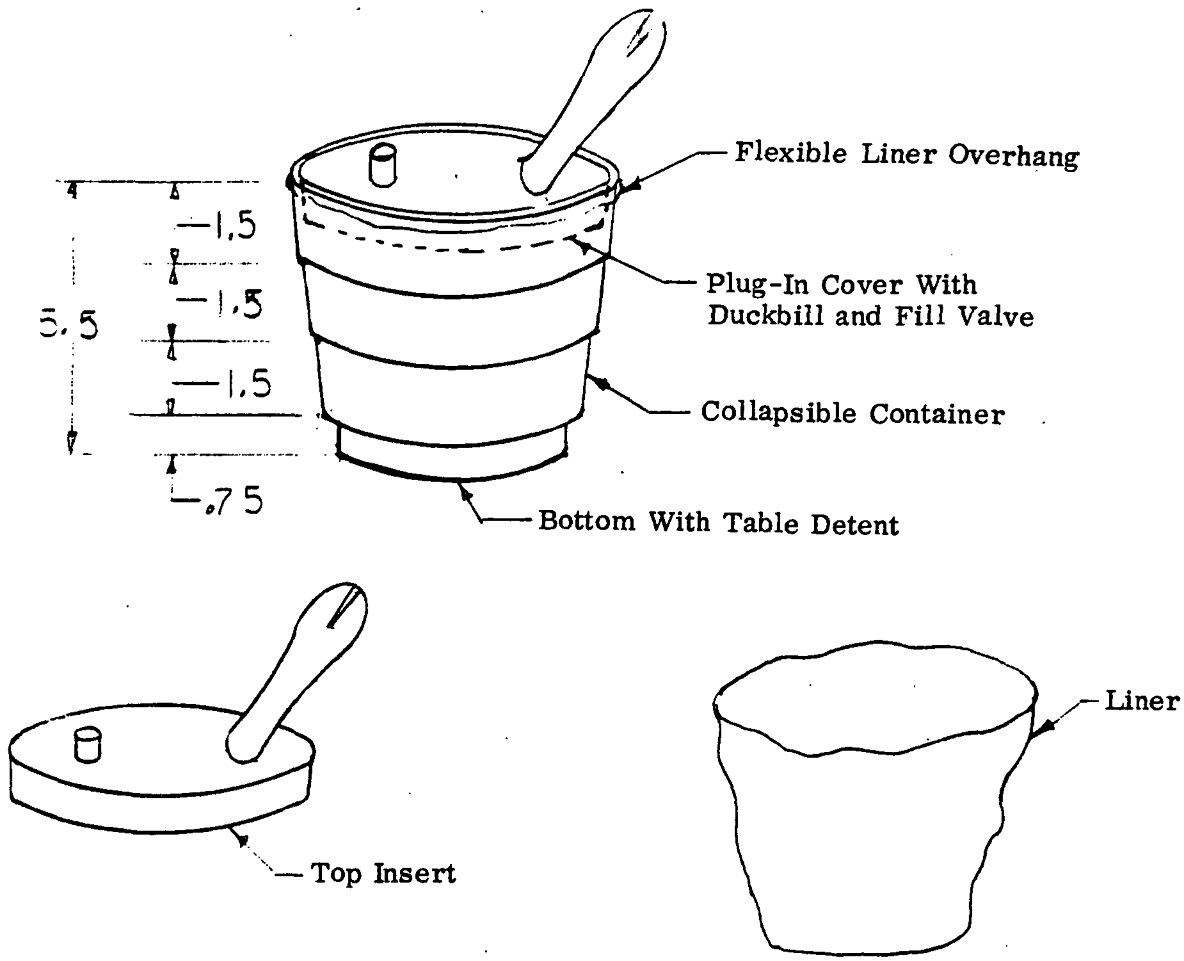


D— 5.5.2

(Sheet 3 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Closed Liquid Container - Positive Displacement



The unit consists of a collapsible container, liner, and a top insert which contains a check valve in the fill connection and a duckbill type drinking spout.

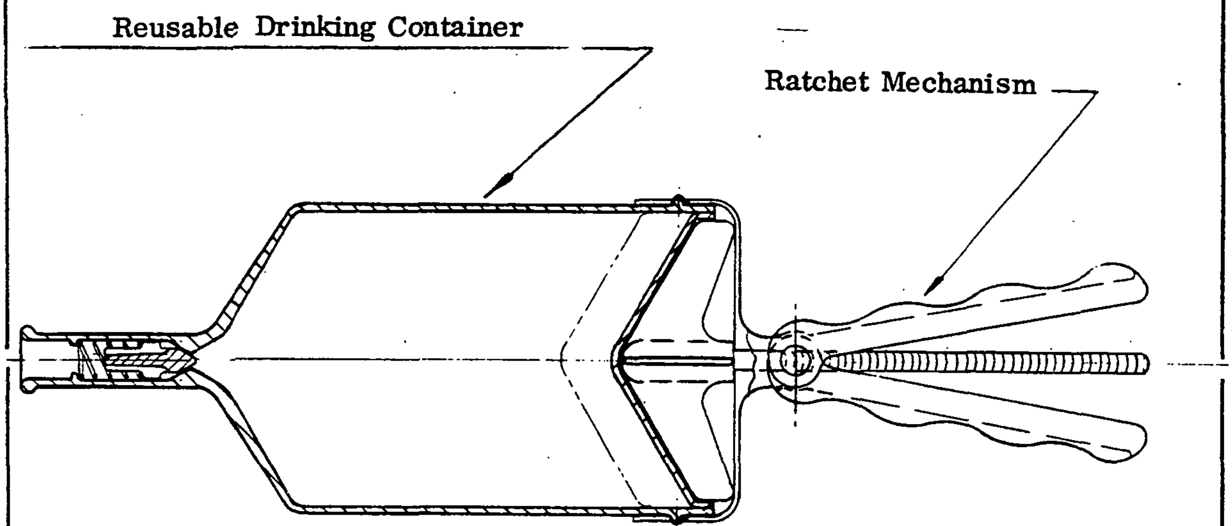
To use, the duckbill is placed into the mouth. The bottom of the container is squeezed toward the top forcing the liquid into the mouth as desired.

This unit is designed for zero-g usage only and is considered state-of-the-art.

D— 5.5.2 A

FOOD SYSTEM STUDY SKETCH

Title: Closed Liquid Container - Positive Displacement



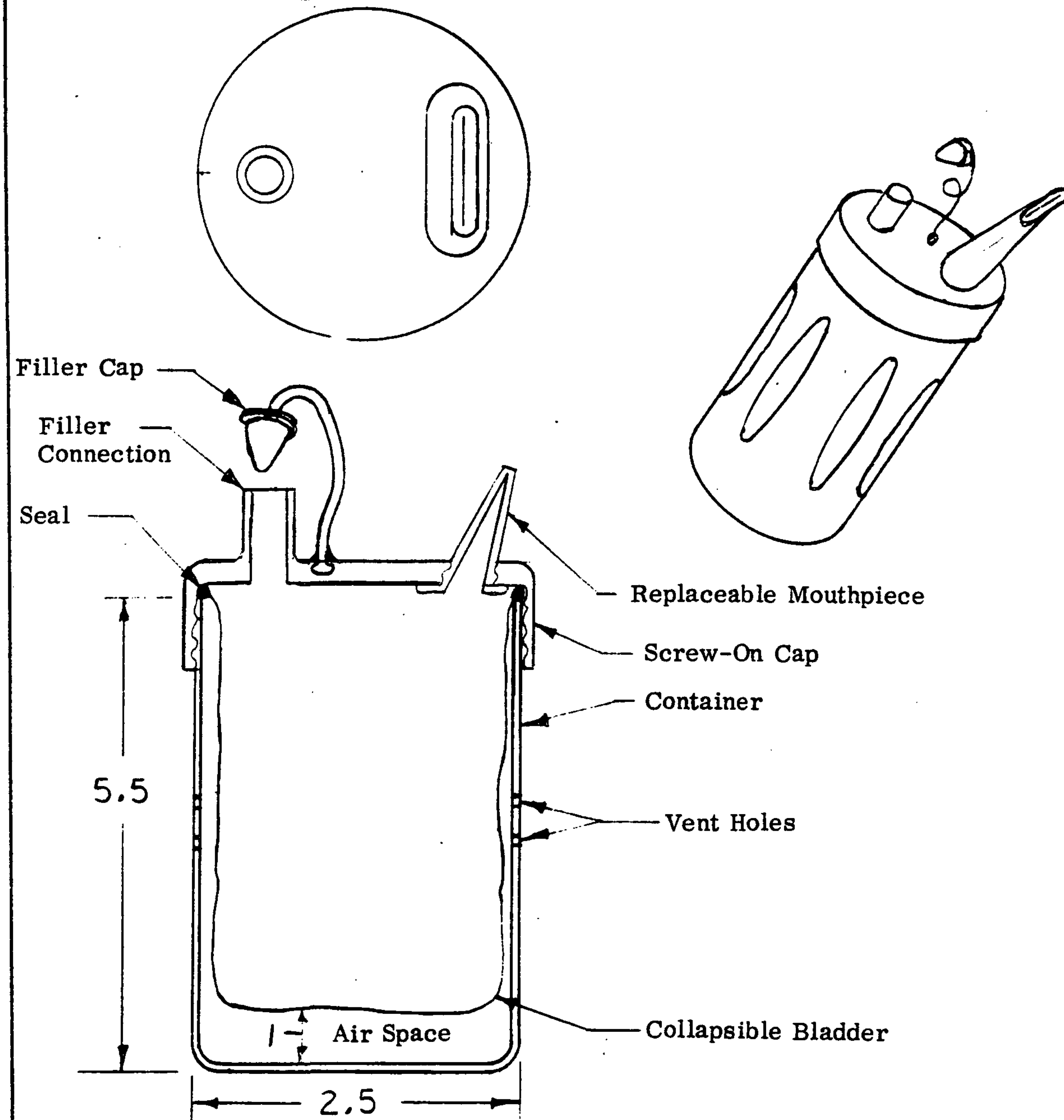
This concept is a hand-held, hand-actuated, piston-operated, positive displacement drink dispensing device. By squeezing the handles, a ratchet mechanism advances the piston a predetermined distance, the force of which opens the spring-loaded valve and pushes the liquid into the user's mouth.

This concept is for zero- to partial-g usage only.

D— 5.5.2B

FOOD SYSTEM STUDY SKETCH

Title: Closed Liquid Container - Negative Pressure



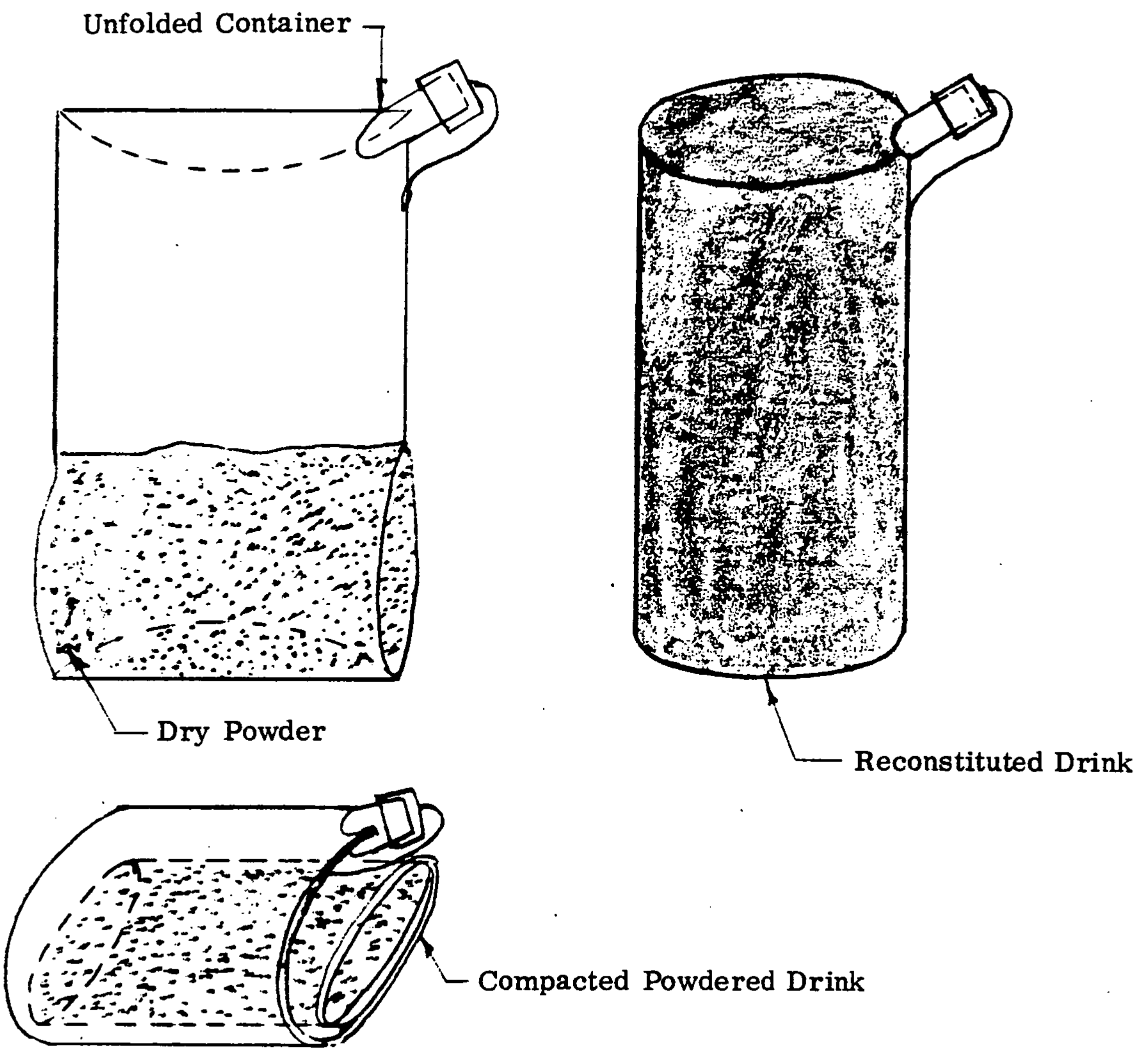
This cup consists of a lightweight vented container, a liner, a screw-on cap having a fill connection, filler cap, and removable mouthpiece. The liner is installed in the collapsed position. A fill connection is made. The filling pressures extend the liner bladder until it is filled. The fill connection is removed and the fillter cap is installed. The mouthpiece is placed into the mouth to extract the amount of fluid required.

This design is applicable to both zero- and one-g and is an adaptation of existing commercial drinking devices.

D— 5.5.2 C

FOOD SYSTEM STUDY SKETCH

Title: In Package Liquid Restraint



The package consists of a plastic bag containing a drink mix, a fill connection, and cap.

To reconstitute a dry mix, the cap is removed and the bag filled with water. The cap is replaced and the container agitated to mix the contents. The container may be sucked on or squeezed to remove the contents.

This design is basically the standard drink package design and is recommended for either small crew sizes or in an individual drink size. The package could be disposable or reusable.

D— 5.5.3

5.6 Candidate Dining Utensils

a. Concept: Eat Only With Hands (5.6.1)

Concept Description: The astronaut would direct all food to his mouth with his hands.

Technical Analysis: This system has been employed through Apollo and has proven adequate although less aesthetic than more conventional approaches. It requires that all beverages, soups, and semi-solid food be consumed from their package, and it requires that solid food be provided as bite-size cubes. The system of eating only with the hands represents no improvement over the present state-of-the-art and is, therefore, rejected from further consideration. In this case, the concept dictates the food type which is inadmissible. The concept is therefore rejected.

b. Concept: Eat With Conventional Reusable Utensils (5.6.2)

Concept Description: The astronaut would utilize a knife, fork, and spoon either individually or one in combination with the other; i.e., knife and fork for cutting while holding.

Technical Analysis: According to Vanderveen(*) this system is possibly the most simple and most realistic approach to zero-gravity consumption.

(*) Vanderveen, J.E. et al, Aerospace Medicine, March 1970.

c. Concept: Eat With Unconventional Reusable Utensils (5.6.3)

Concept Description: Unconventional utensils include the following:

Spork: Combination spoon-fork; i.e., tines on the end of a spoon depression.

Combination Knife/Fork/Tong: Hand-held, hand-operated tongs integrating one knife edge, one flat edge, and opposing pronged ends. Uses include holding, scraping, pushing, pinching, and transfer.

Technical Analysis: Such devices might be applicable to the zero-g or partial-g environment since they would provide for more positive control of food than would the conventional eating utensils.

d. Concept: Eat With Conventional Utensils (Disposable) (5.6.4)

Concept Description: The astronaut would utilize a disposable knife, fork, and spoon either individually or one in combination with the other; i.e., knife and fork for cutting while holding.

Technical Analysis: The obvious advantage to disposable utensils is the convenience of not requiring cleansing and thus eliminating the need for dishwashing facilities. Each utensil would require chemical bacterial decontamination unless it were to be destroyed within two hours after use.

e. Concept: Eat With Unconventional Utensils (Disposable) (5.6.5)

Concept Description: Unconventional utensils are disposable versions of the "Spork" and combination knife/fork/tong described in Concept 5.6.3.

Technical Analysis: The obvious advantage to disposable utensils is the convenience of not requiring cleansing and thus eliminating the need for dishwashing facilities. Each utensil would require chemical bacterial decontamination unless it were to be destroyed within two hours after use.

f. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-24 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-24

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 5.6	SUB-FUNCTION TITLE: Eating Utensils	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.6.1	Eat Only With Hands	(11.5)	X				
5.6.2	Eat With Conventional Utensils (Reusable)	11.6		X	-		X
5.6.3	Eat With Unconventional Utensils (Reusable)	13.0		X	-		X
5.6.4	Eat With Conventional Utensils (Disposable)	-*			-		X
5.6.5	Eat With Unconventional Utensils (Disposable)	-*			-		X
	*Concepts 5.6.4 and 5.6.5 were not included in either the Initial or Interim Study.						

For the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Eat With Conventional Reusable Utensils (Concept 5.6.2). Detailed data for this concept are presented on Element Concept Data Sheets 5.6.2.1 through 5.6.2.3, 5.6.2.5 through 5.6.2.7, and 5.6.2.9 through 5.6.2.11 in Data Book - Book I. Additional size and cost data are presented under Concept 5.6.2 in Data Book - Book II.

2) Technical Data - Eat With Unconventional Reusable Utensils (Concept 5.6.3). Detailed data for this concept are presented on Element Concept Data Sheets 5.6.3.1 through 5.6.3.3 and 5.6.3.5 through 5.6.3.7 in Data Book - Book I. Additional size and cost data are presented under Concept 5.6.3 in Data Book - Book II.

The following figure (Figure III-93) illustrates the accumulated wash weight (less water) of reusable conventional and unconventional utensils in combination as a function of man days. This type data may be applicable to reliability and size design requirements for an onboard dishwasher.

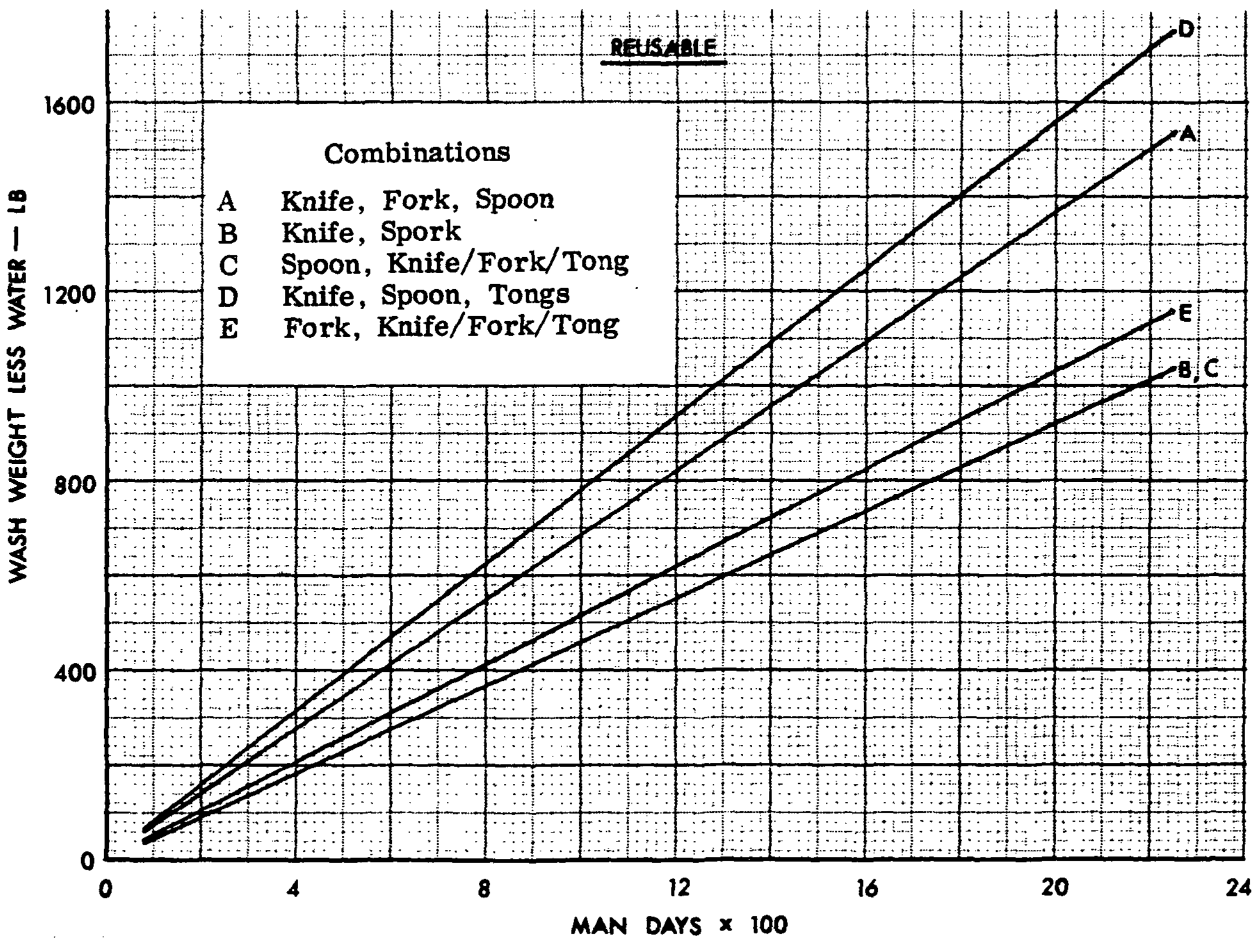


Figure III-93. Supply Weight and Wash Weight of Reusable Utensils versus Man Days

Figure III-94 illustrates the worst and best cases of accumulated wash weight (less water) of reusable tray and utensil combinations as a function of man days. All other combinations, i.e., Round Tray (5.4.7) or Flat Tray (5.4.1) and utensil combination (A), (B) or (E), will fall in the area between the two plots.

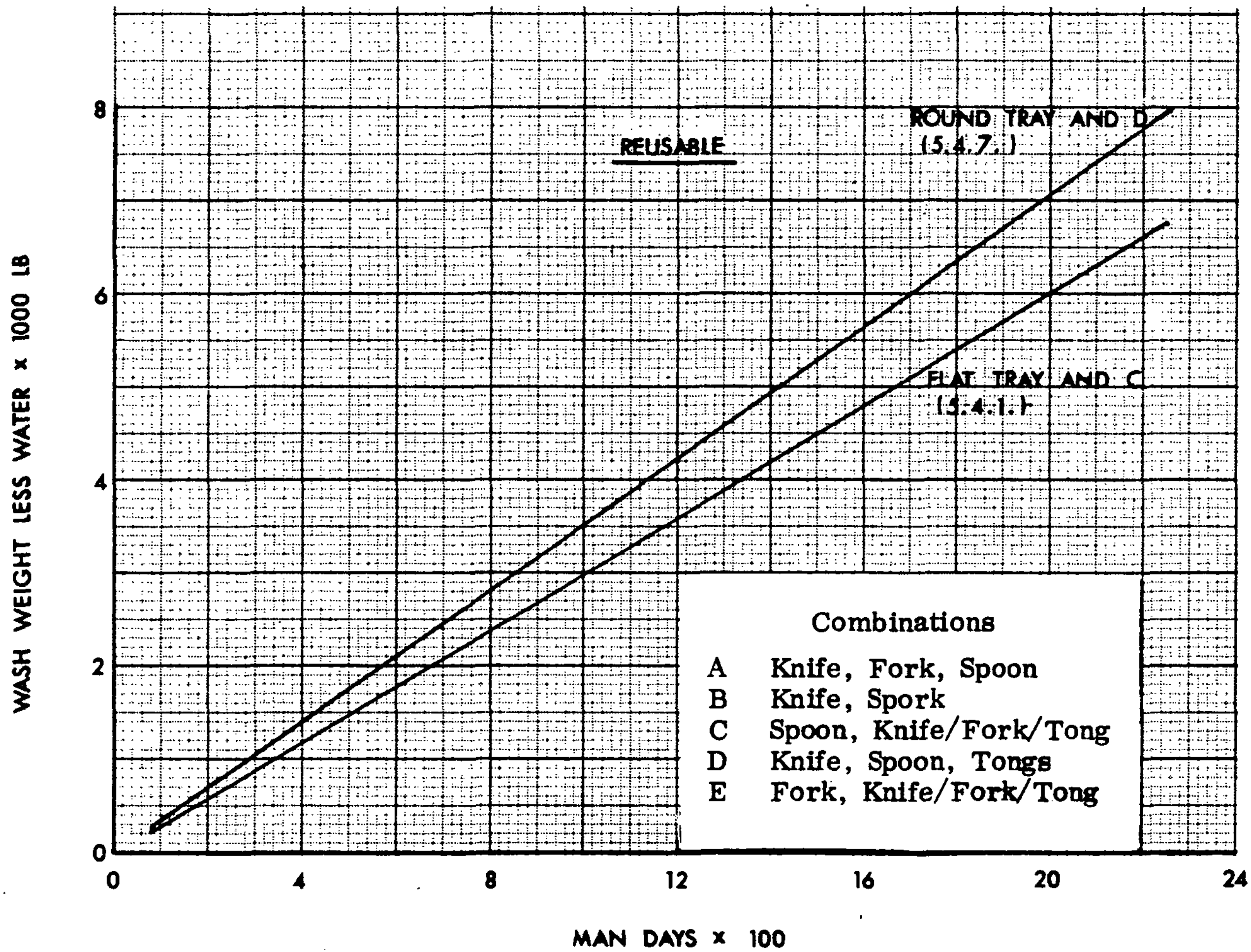


Figure III-94. Wash Weight (Less Water) of Reusable Tray and Utensil Combinations versus Man Days

3) Technical Data - Eat With Conventional Utensils (Disposable) (Concept 5.6.4). Detailed data for this concept are presented on Element Concept Data Sheets 5.6.4.1 through 5.6.4.18 in Data Book - Book I. Additional weight, size, and cost data are presented under Concept 5.6.4 in Data Book - Book II.

Table III-25 summarizes the mission and 10-year resupply weight and volume requirements for conventional disposable utensils.

TABLE III-25. DISPOSABLE UTENSILS (CONVENTIONAL)

Men	6		12		25		
Resupply Days	14	90	14	90	14	90	
Meals/Day	18	18	36	36	75	75	
Meals/Mission	252	1620	504	3240	1050	6750	
Meals/10 Years	65,520	64,800	131,040	129,600	273,000	270,000	
*KNIFE							
Weight (lb)	1.66	10.7	3.33	21.4	6.93	44.6	Mission Resupply
Volume (ft^3)	.25	1.62	.50	3.24	1.05	6.75	
Weight (lb)	432.	427.	866.	855.	1800.	1780.	10 Year Resupply
Volume (ft^3)	65.5	64.8	131.	129.	273.	270.	
*FORK							
Weight (lb)	1.39	8.91	2.77	17.8	5.78	37.1	Mission Resupply
Volume (ft^3)	.25	1.62	.50	3.24	1.05	6.75	
Weight (lb)	361.	356.	720.	713.	1500.	1480.	10 Year Resupply
Volume (ft^3)	65.5	64.8	131.	129.	273.	270.	
*SPOON							
Weight (lb)	1.49	9.56	2.97	19.1	6.20	39.8	Mission Resupply
Volume (ft^3)	.25	1.62	.50	3.24	1.05	6.75	
Weight (lb)	387.	382.	772.	765.	1610.	1590.	10 Year Resupply
Volume (ft^3)	65.5	64.8	131.	129.	273.	270.	

*Knife weight = .0066 lb/ea, loose pack volume estimated at $1000/ft^3$
*Fork weight = .0055 lb/ea, loose pack volume estimated at $1000/ft^3$
*Spoon weight = .0059 lb/ea, loose pack volume estimated at $1000/ft^3$

4) Technical Data - Eat With Unconventional Utensils (Disposable) (Concept 5.6.5). Detailed data for this concept are presented on Element Concept Data Sheets 5.6.5.1 through 5.6.5.12 in Data Book - Book I. Additional weight, size, and cost data are presented under Concept 5.6.5 in Data Book - Book II.

Table III-26 summarizes the mission and 10 year resupply weight and volume requirements for unconventional disposable utensils.

TABLE III-26. DISPOSABLE UTENSILS (UNCONVENTIONAL)

Men	6		12		25		
Resupply Days	14	90	14	90	14	90	
Meals/Day	18	18	36	36	75	75	
Meals/Mission	252	1620	504	3240	1050	6750	
Meals/10 Years	65,520	64,800	131,040	129,600	273,000	270,000	
*SPORK							
Weight (lb)	1.44	9.23	2.87	18.5	5.98	38.5	Mission Resupply
Volume (ft^3)	.25	1.62	.50	3.24	1.05	6.75	
Weight (lb)	387.	382.	772.	765.	1610.	1590.	10 Year Resupply
Volume (ft^3)	65.5	64.8	131.	130.	273.	270.	
*KNIFE/FORK/TONG							
Weight (lb)	2.22	14.3	4.43	28.5	9.24	59.4	Mission Resupply
Volume (ft^3)	.50	3.24	1.02	6.48	2.10	13.5	
Weight (lb)	577.	570.	1150.	1140.	2400.	2380.	10 Year Resupply
Volume (ft^3)	131.	129.	262.	258.	546.	540.	

*Spork weight = .0057 lb/ea, loose pack volume estimated at 1000/ft^3
*Knife/Fork/Tong weight = .0088 lb/ea, loose pack volume estimated at 500/ft^3

Figure III-95 illustrates the resupply weights of five possible combinations of disposable eating utensils as a function of man days per mission.

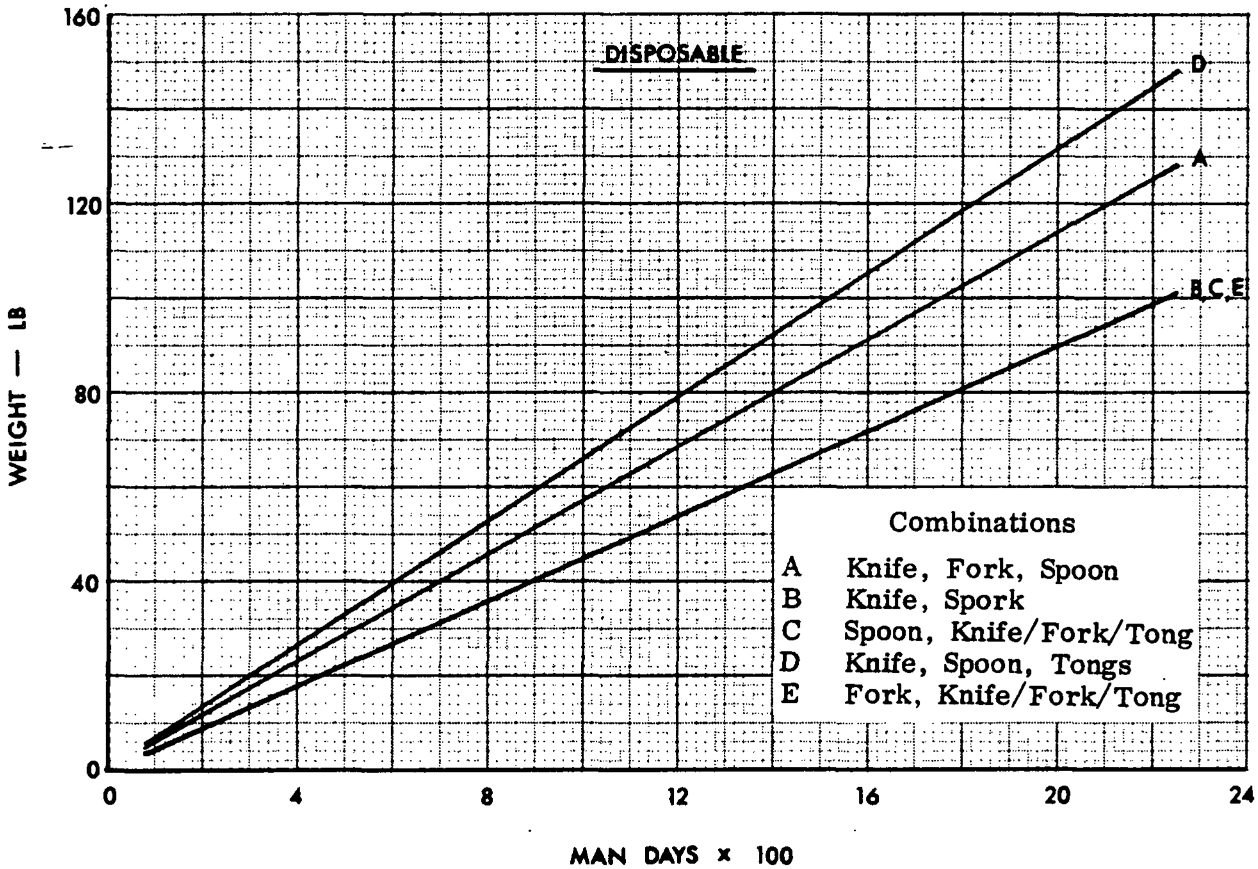


Figure III-95. Resupply Weight of Disposable Utensil Combinations versus Man Days

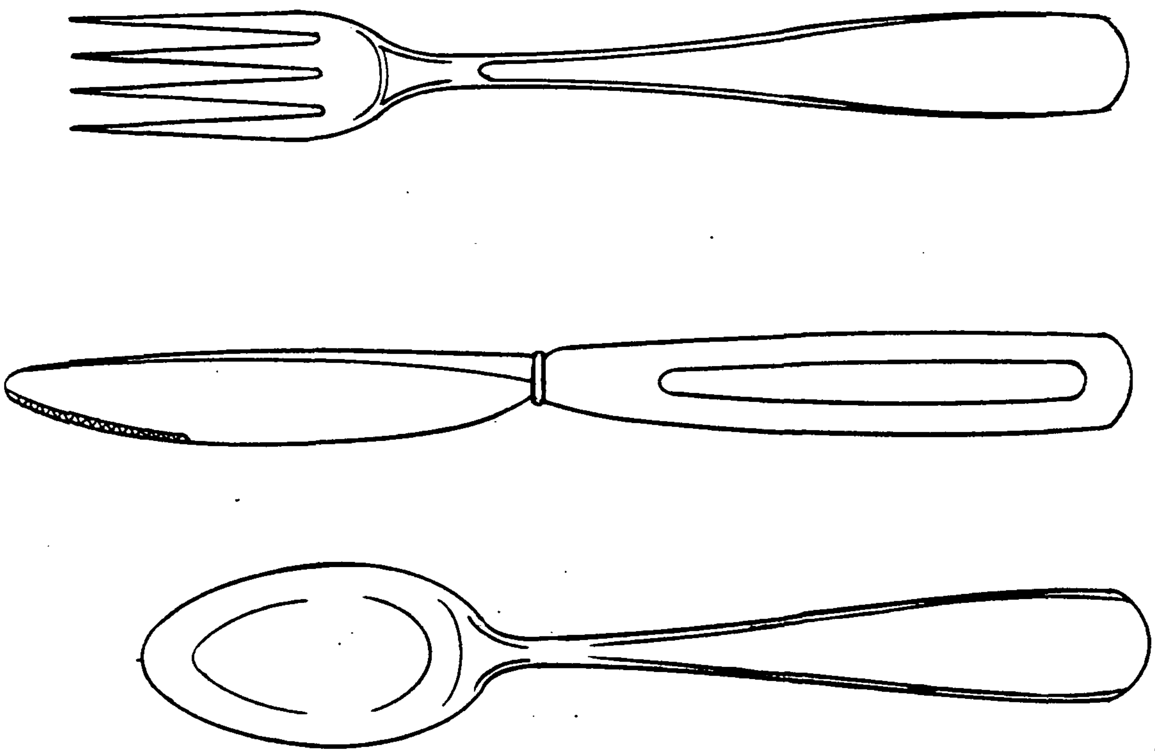
Additional detail data on disposable utensil combinations are presented in Table III-33, Section 6.0, Subsection 6.4 of this section.

g. Applicable Sketches

The following sketches depict equipment concepts for the concepts described above.

FOOD SYSTEM STUDY SKETCH

Title: Eat With Conventional Utensils (Knife, Fork Spoon - 3/4th Size)

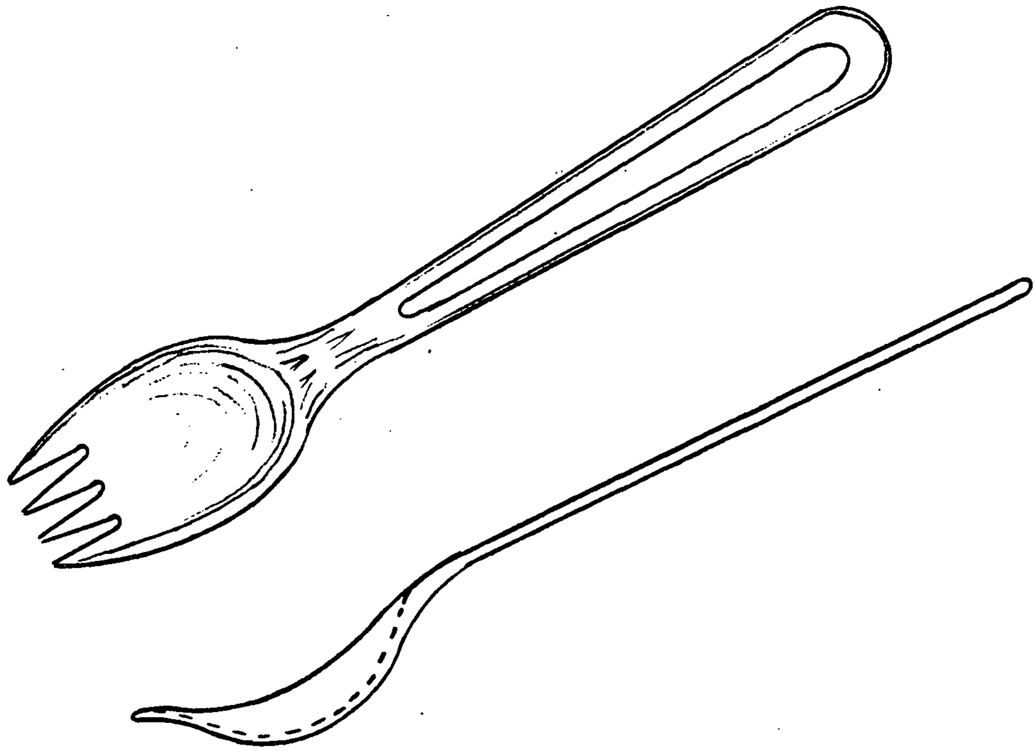


The use of these reusable three-quarters sized type eating utensils may be advantageous with cohesive and adhesive type food items. With proper training and care they may also be adaptable to all food types. Primary recommendation would be for partial-g usage.

D— 5.6.2

FOOD SYSTEM STUDY SKETCH

Title: Unconventional Utensils - Spoon/Fork ("SPORK")

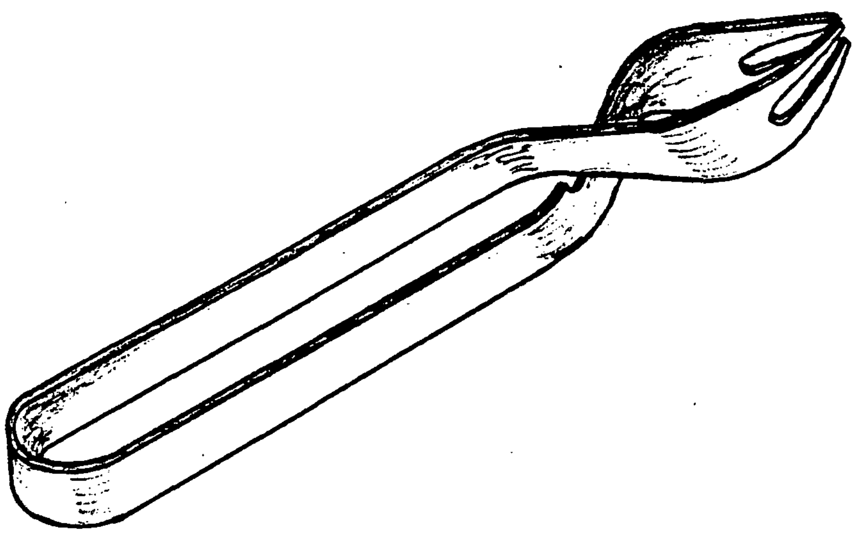


This item can be used either as a spoon or a fork in the conventional fashion. The advantage of this utensil is that it reduces the quantity of utensils but performs the functions of a spoon and fork equally as well.

D— 5.6.3 A

FOOD SYSTEM STUDY SKETCH

Title: Eat With Unconventional Utensils - Food Tongs



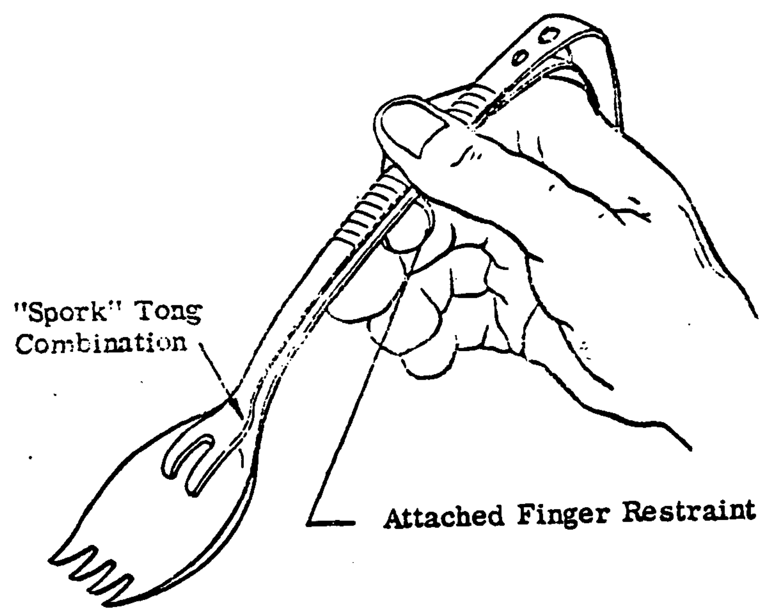
This is a stainless steel, spring acting, reusable tong-type eating utensil for holding and transporting to the mouth bite-sized solid morsels for consumption.

This is a simple one-piece unit which will be used basically for zero-g consumption, but may also be applicable for one-g usage.

D— 5.6.3 B

FOOD SYSTEM STUDY SKETCH

Title: Eat With Unconventional Utensils - "SPORK"/Tong



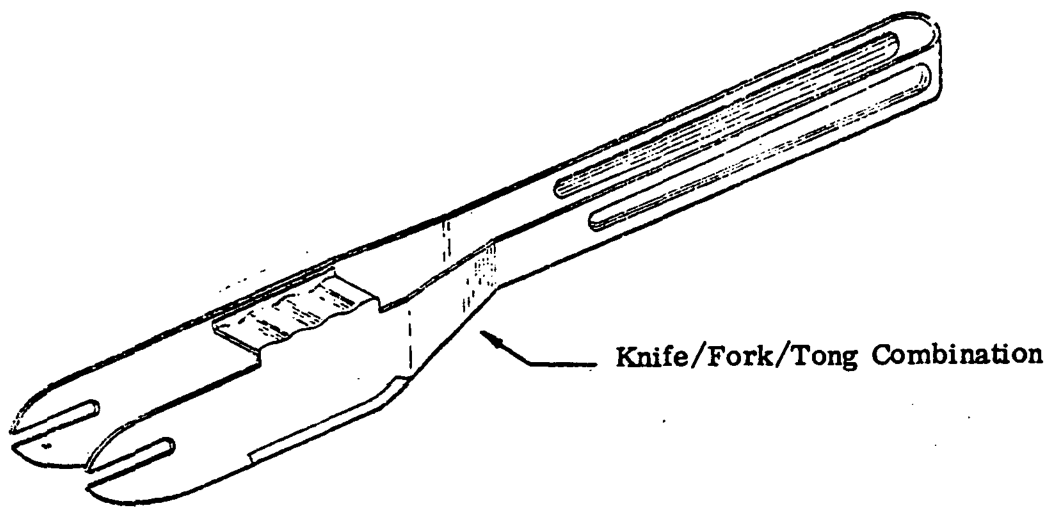
This device is a hand-held, thumb-actuated tong, the lower arm of which ends in a fork-spoon configuration. The opposing upper arm ends in a small fork. The unit is hand-held, with the lower arm of the device secured to the index finger by means of an attached ring. The upper arm is actuated by a back-and-forth movement of the thumb.

Its functional uses are the entrapment of solid and semi-solid foods and transfer of food to the mouth in zero-g conditions.

D— 5.6.3C

FOOD SYSTEM STUDY SKETCH

Title: Unconventional Utensils - Knife/Fork/Tong



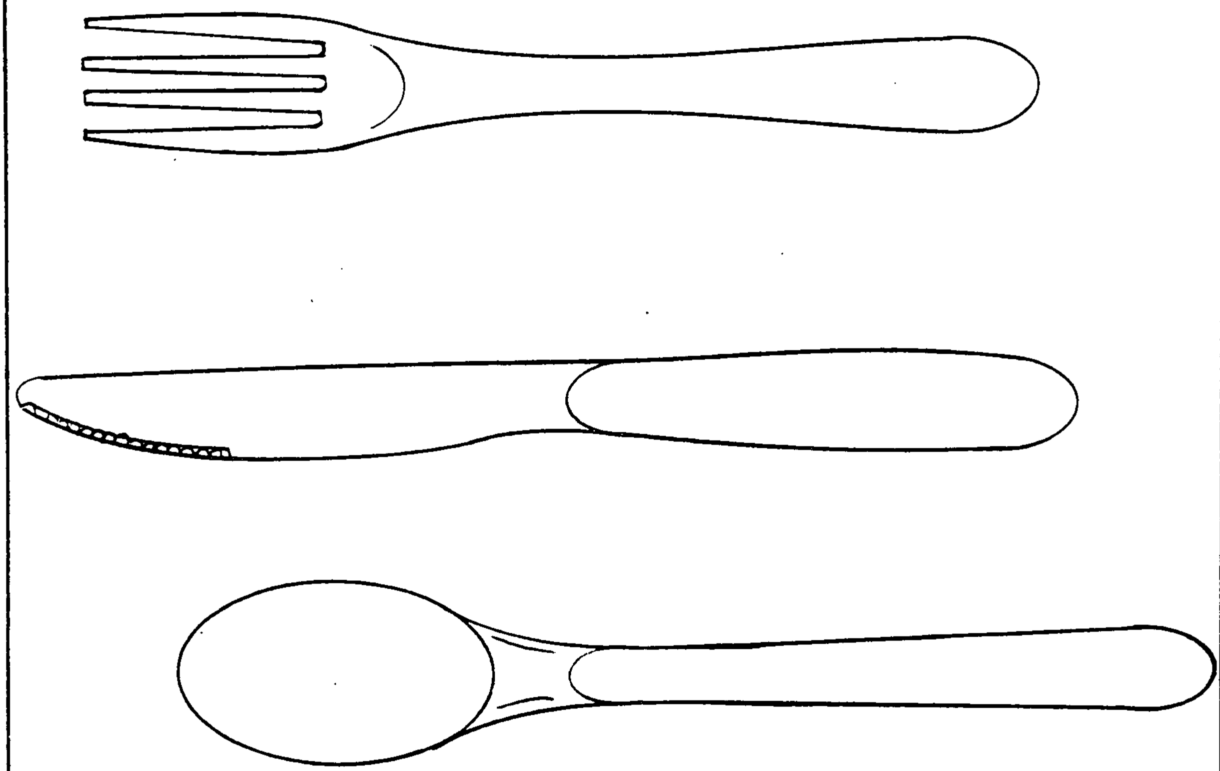
This combination utensil will, when used in conjunction with another holding device, contain the meat as it is being cut and allow it to be picked up by the tong action.

An advantage of this utensil is that it reduces eating time by allowing the food item to be cut and transferred to the mouth with the same utensil.

D— 5.6.3D

FOOD SYSTEM STUDY SKETCH

Title: Knife, Fork, Spoon - Disposable Type



This type of disposable table utensils are commercially available in many forms of non-metallic material.

D— 5.6.4

5.7 Candidate Personal Hygiene Concepts

a. Concept: Napkins (Dry) (5.7.1)

Concept Description: (1) Dry linen napkins are provided for personal cleanup of food soiling. (2) Dry paper napkins are provided for personal cleaning of food soiling. Both are applicable to area wiping of food spillage.

Technical Analysis: Dry wipes preclude bulk in packaging associated with wet wipes. Linen napkins generate additional requirements for the housekeeping washing functions.

b. Concept: Napkins (Wet) (5.7.2)

Concept Description: Wet wipes are provided for personal cleanup of food soiling and refreshment.

Technical Analysis: Wet wipes necessitate special moisture barrier packaging which would in turn generate more bulk volume in storage. They do provide an excellent vehicle for bactericidal or static solutions.

c. Concept: Wipe Hands on Clothes or Clothes of Fellow Astronaut (5.7.3)

Concept Description: After eating the individual simply wipes up food spillage with his hands and transfers it onto his clothes or clothes of his fellow astronaut.

Technical Analysis: This concept is unacceptable from the standpoint of aesthetics and sanitation. Selection rationale score of 13.1 is attained by reason of low power, weight, and volume impact. It is considered invalid.

d. Concept: Wear Eating Overgarment (5.7.4)

Concept Description: When the individual is dining he shall wear an overgarment. After eating, this garment can serve as a napkin.

Technical Analysis: This concept offers one advantage in that clothes washings could be reduced if the criteria for washing were only external soiling. It is more likely that clothes washing would be scheduled and that extra clothing could be provided in the event of a severe food spill accident.

e. Concept: Vacuum Cleaning of Person and Garment (5.7.5)

Concept Description: After dining, food debris could be cleaned off the person and garment by use of a hand-held vacuum probe. Debris would be collected onto a filter.

Technical Analysis: This method of cleaning is a poor choice for at least two reasons: (1) A vacuum probe on the soft tissues of the face is uncomfortable and unfamiliar, and (2) This type of collection against a filter provides a potential environment for uncontrolled bacterial populations. The system, when compared with wipes, would be time consuming and cumbersome.

f. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-27 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-27

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 5.7	SUB-FUNCTION TITLE: Personal Hygiene (Dining Accessories)	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.7.1*	Napkins (Dry)	17.2		X	-		X
5.7.2*	Napkins (Wet)	13.9		X	-		X
5.7.3	Wipe Hands on Clothes or Clothes of Fellow Astronaut	(13.1)	X				
5.7.4	Wear Eating Overgarment	8.2	X				
5.7.5	Vacuum Cleaning of Person and Garment	6.9	X				
	*Refer to Section 6.2						

For the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Napkins (Dry) (Concept 5.7.1). Detailed data for this concept are presented on Element Concept Data Sheets series 6.2.2 (Dispenser For Reusable Personal Wipes) in Data Book - Book I.

2) Technical Data - Napkins (Wet) (Concept 5.7.2). Detailed data for this concept are presented on Element Concept Data Sheets series 6.2.3 (Dispenser For Impregnated Personal Cleansing Wipes) in Data Book - Book I.

5.8 Candidate Dining Equipment Restraint

a. Concept: Magnetized Equipment (5.8.1)

Concept Description: All equipment, i.e., trays, drinking devices, and utensils are fitted with a magnet or magnets such that they can be suitably restrained.

Technical Analysis: This concept is advisable providing electromagnetic constraints for the entire spacecraft do not negate it. With all equipment magnetized, there would be less hazard of dropping individual utensils or equipment items during transport to and from the dining area. During washing, however, items would be necessarily kept separate to avoid creating food particle traps between attracted items.

b. Concept: Fitted Recesses For Trays and Utensils (5.8.2)

Concept Description: For each tray and utensil there would be provided fitted recesses at the individual dining area.

Technical Analysis: Unless the food on the tray were completely restrained, there is great risk of spillage from the tray during positioning. Spillage into the detents represents a cleaning problem and sanitation hazard.

c. Concept: Mechanical Hold Downs (5.8.3)

Concept Description: Mechanical hold downs include spring clamps, belts with clamps, Velcro attachments, elastic belts, and suction cups.

Technical Analysis: Restraint devices of this nature all require hinged or rigid attachment to either the utensil or restraint location. This means a protrusion to collect food particles. Each item must be evaluated for ease of cleaning.

d. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-28 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-28

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 5.8	TITLE: Dining Equipment Restraint	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.8.1	Magnetized Equipment	13.8		X	-		X
5.8.2	Fitted Detents For Trays and Utensils	8.8	X				
5.8.3	Mechanical Hold Downs	(10.5)	X				

For each of the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Magnetized Equipment (Concept 5.8.1). Detailed data for this concept are presented on Element Concept Data Sheets 5.8.1.1 through 5.8.1.15 in Data Book - Book I.

e. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above.

5.9 Candidate Man Restraints (Dining Area)

a. Concept: No Personnel Restraint (5.9.1)

Concept Description: The astronaut would collect his menu items in the preparation area and find any convenient place to eat.

Technical Analysis: This concept is applicable for a contingency diet or snacks. For organized scheduled dining it is not consistent with familiar dining practice.

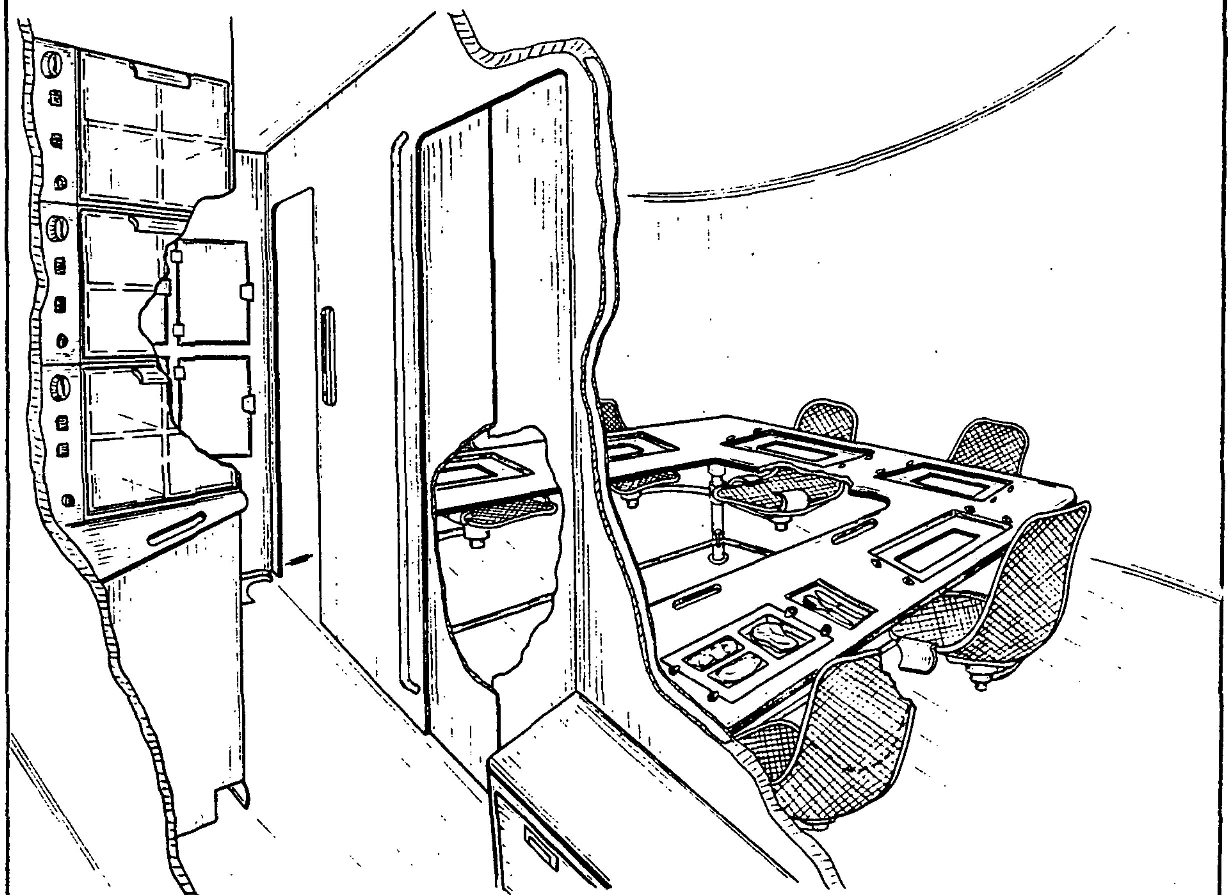
b. Concept: Cocoon or Net Restraint (5.9.2)

Concept Description: The astronaut would be held in one stationary position by a net envelope or arm-through partition.

Technical Analysis: Food spillage would collect on the net or partition. This type of restraint is unfamiliar and unnecessary in the light of simpler methods.

FOOD SYSTEM STUDY SKETCH

Title: Dining Equipment Restraint



This concept shows a method of restraining food trays and eating utensils. The dining room table will have a recessed cut-out configured to accept a meal tray. Swivel-type tray hold-down tabs will be rotated in place to securely hold the tray onto the table.

The utensils will have a recessed compartment in the table. The recess will contain magnetic strips which will magnetically couple the utensils to the table. (See Concept 5.8.1)

D— 5.8

c. Concept: Chair With Restraint System (5.9.3)

Concept Description: At each individual dining station a chair with fold-out and fold-over restraints is provided such that the individual sits and folds a rigid contoured strap or straps over some part of his body.

Technical Analysis: Such devices could allow for unrestricted upper torso movement while still providing total body restraint. For the purpose of sitting at the dining table, it would be advisable to allow simple straightforward access to the seat. This can be accomplished most easily by providing a chair with a stomach support with attached restraint system rather than a chair with a back support.

d. Concept: Foot Restraint (5.9.4)

Concept Description: At the dining table area a rail or series of foot straps is provided by which the individual is restrained in the standing position. It is also possible the astronaut might be provided with magnetic shoes.

Technical Analysis: This concept represents a relatively simple system which is applicable to most areas of the Space Station/Base. The concept does not, however, lend itself to a conventional familiar seated position for dining; and it may have serious limitations in a partial-gravity mode.

e. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-29 below. Rating numbers are derived from the detailed Selection Rationale Sheets in Data Book - Book III.

TABLE III-29

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 5.9	SUB-FUNCTION TITLE: Personal Restraint	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
5.9.1	No Personnel Restraint	7.1	X				
5.9.2	Cocoon or Net Restraint	8.9	X				
5.9.3	Chair With Strap Restraint	13.6		X	-		X
5.9.4	Foot Restraint	(11.0)	X				

For each of the concepts selected for detailed study, technical data are presented below:

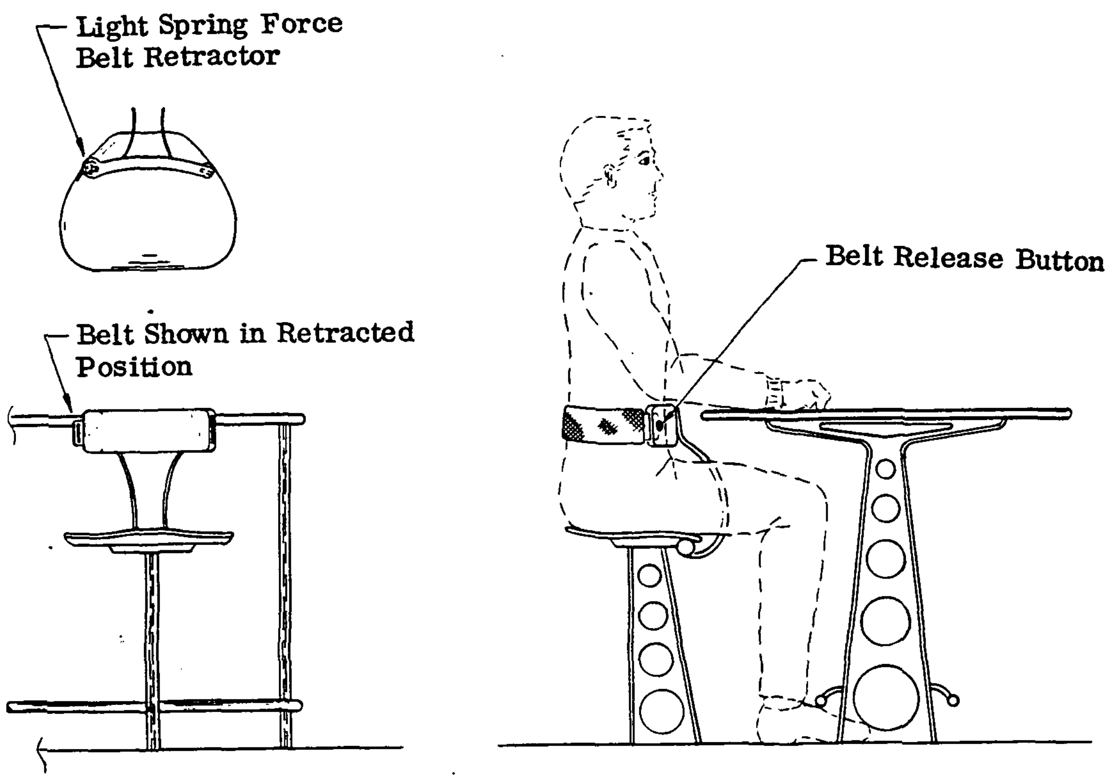
1) Technical Data - Chair With Strap Restraint (Concept 5.9.3). Detailed data for this concept are presented on Element Concept Data Sheets 5.9.3.1 through 5.9.3.6 in Data Book - Book I. Additional size and cost data are presented under Concept 5.9.3 in Data Book - Book II.

f. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above.

FOOD SYSTEM STUDY SKETCH

Title: Personal Restraint - Stomach Support Body Restraint



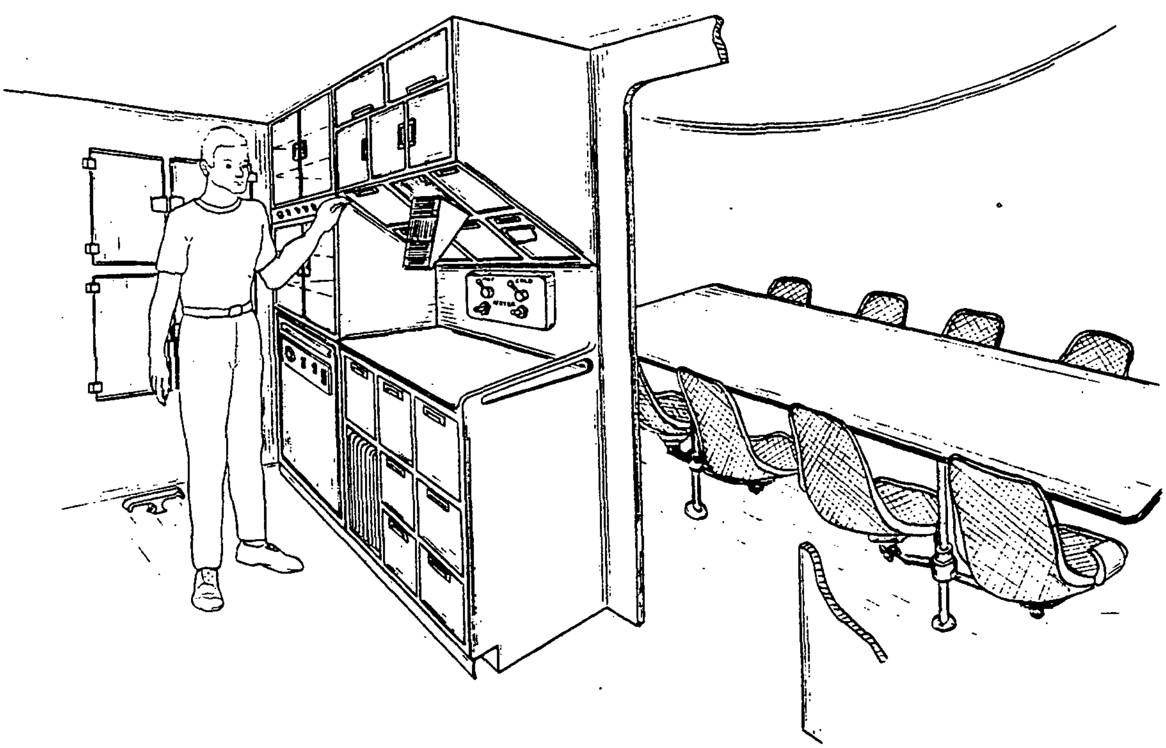
This concept is used basically for zero-g applications. A man carrying a food tray and trying to restrain himself may have great difficulty in maneuvering himself into a conventional back support seat. With the support in front, he can slide directly onto the seat, put his food tray in place on the table, and then proceed to attach the seat belt.

A minimum amount of development is required to perfect this system.

D– 5.9 A

FOOD SYSTEM STUDY SKETCH

Title: Personal Restraint - Chair With Lap Strap

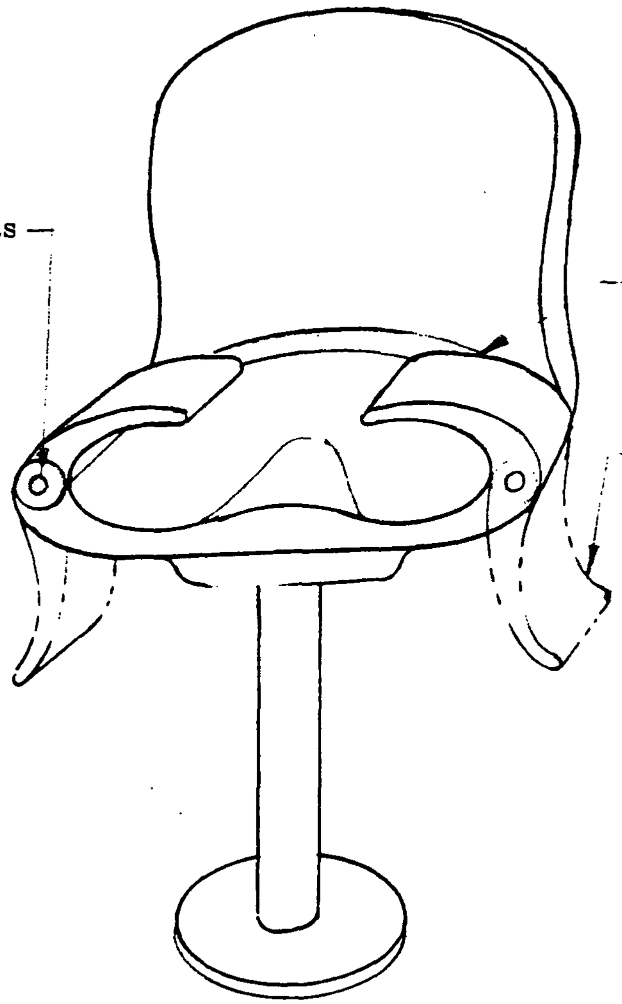


This concept depicts a galley, dining area configuration utilizing light-weight web-type chairs individually supported in pairs and pivoted from a dining table center post. Spring loaded, overcenter, contoured lap restraints are incorporated on each chair.

See 5.9.3 for further concept description.

FOOD SYSTEM STUDY SKETCH

Title: Chair With Lap Strap



These restraints are form fitting metal shapes hinged on each side of the chair. Springs are installed so that they are both spring-loaded open and spring-loaded closed. After being seated, the occupant rotates both restraints. As they pass the midpoint position, they spring-load closed.

This device allows for more movement of the upper body and is primarily a zero-g design.

D— 5.9.3

6.0 Provide For Clean-Up - Functional Subsystem Area 6.0

This functional subsystem area is primarily concerned with providing concepts of "clean-up" techniques appropriate for the galley and dining facilities within a space vehicle (i.e., space station/base). It is, therefore, limited in scope, excluding functions which are considered to be of a general nature applicable to all "onboard" housekeeping requirements. For this reason, there was no attempt made to conduct detailed study of general waste or debris processing/disposal techniques, general water reclamation techniques, general laundering techniques, or other services for which separate remotely located facilities would be contemplated. Because of uncertain olfactory effects, bactericidal effects, food contamination effects, and human physical effects, there is no attempt made to suggest detergent/germicide materials.

The basic considerations were: maintaining a sanitary environment in the galley and dining facilities through cleaning of confining surfaces and installed equipment, collection of escaped food particles (spillages, dry or wet), collection and temporary retention of generated debris, cleaning of food preparation and dining utensils, superficial personal hygiene, and removal of debris. Associated techniques or equipment considered were: reusable and/or disposable wipes, vacuum cleaning devices, surface washing devices, handwashing unit, automatic dishwashing/drying unit, debris containers, debris shredding devices, debris compaction devices, and debris removal means.

Primary requirements considered in the evaluation of each concept included applicability to operation in a zero-g environment, crew time, convenience, and safety.

This functional subsystem was subdivided into three areas: clean-up requirements common to both the galley and the dining facilities, clean-up requirements peculiar to the dining facility, and clean-up requirements peculiar to the galley facility. The candidate concepts for each of the three subareas are generally described in paragraphs 6.1, 6.2, and 6.3 herein, accompanied by an evaluation summary. For those concepts selected for study, a technical brief is included in which its relation to the Food System is stated along with the space vehicle interface requirements. Detailed descriptions of the selected concepts, mission oriented data, and supporting or back-up information associated with the study effort, are provided in Books I and II of the Supplementary Data Book. For those concepts involving the use of either disposable or reusable wipes, a comparison of applicable mission requirements is also included to assist in future trade studies for selective purposes.

A summary of galley and dining area debris generated in all selected concepts encompassed by this Food System Study is provided in paragraph 6.4 herein.

6.1 Candidate Galley/Dining Area Clean-Up Techniques

a. Concept: Hand Brushing and Collection of Food Particles (6.1.1)

Concept Description: Hand brushing or sweeping of food particles from work counters, food preparation equipment, tables, or general confines of galley and dining area, into a hand-held collector.

Technical Analysis: This concept would represent a simple, inexpensive means for collection of solid food particles which is possible in a partial-g environment; however, even in such environment, the sanitary aspects are compromised by questionable complete retrieval. In a zero-g environment, the concept is non-valid since there is no positive retrieval, for which reason it was discarded during the initial study phase.

b. Concept: Hand-Held Vacuum Cleaner Unit (6.1.2)

Concept Description: Hand-vacuum device collection of food particles from work counters, food preparation equipment, tables, or general confines of galley and dining area.

Technical Analysis: Vacuuming provides a positive method for retrieval of dry or wet food particles, whether static (at rest) or dynamic (free floating) in the zero-g environment as well as under partial-g conditions. The use of a hand-held vacuum device may have distinct advantages for immediate cleaning of small areas. Without a lengthy pick-up hose, it becomes ideally suitable for the collection of vomitus minimizing sanitation functions.

c. Concept: Guided Transport Vacuum Cleaner Unit (6.1.3)

Concept Description: Portable, restrained guidance, vacuum device with flexible pick-up hose for collection of food particles and small debris from work counters, food preparation equipment, tables, or general confines of galley and dining area.

Technical Analysis: Acknowledging that vacuuming provides a positive method for retrieval of food particles, a portable vacuum device of greater capacity than the hand-held unit per Concept 6.1.2 would be more suitable for general cleaning of larger areas. The zero-g restraint for this piece of equipment would be adapted to a common restrained guidance system for serving carts or other transportable units within/or between the galley and dining areas.

d. Concept: Back-Pack Vacuum Cleaner Unit (6.1.4)

Concept Description: Portable, back-pack crew-carriage type, vacuum device with flexible pick-up hose for collection of food particles and small debris from work counters, food preparation equipment, tables, or general confines of galley and dining area.

Technical Analysis: Acknowledging that vacuuming provides a positive method for retrieval of food particles, an alternate means for general cleaning of larger areas by employment of a back-pack type vacuum device may be considered. While crew encumberance would not be evident in the zero-g environment because of weightlessness conditions, use in a partial-g environment will result in some degree of crew encumberance which may or may not be significant. In considering crew safety aspects and probable psychological rejection of such "strap-on" equipment, the concept was discarded during the initial study phase.

e. Concept: Central Vacuum Cleaner System (6.1.5)

Concept Description: Central vacuum system with plug-in, portable, flexible pick-up hose for collection of food particles and small debris from work counters, food preparation equipment, tables, or general confines of galley and dining area.

Technical Analysis: Although the vacuuming method provides a positive method for retrieval of food particles and a central vacuum system is feasible, this concept would involve excessive built-in ducting and sealing requirements. Also, the flexible pick-up hoses become excessively long, imposing problems in their inherent need for freedom of movement during use. For these reasons, the concept was discarded during the initial study phase.

f. Concept: Automatic Vacuum Retrieval System (6.1.6)

Concept Description: Automatic built-in ducted vacuum collection system for immediate retrieval of food particles and small debris from work counters or tables of galley and dining area. This "controlled-spillage" concept would employ a plenum chamber of appropriate size with orifices suitably located for ingestion of crumbs, liquid droplets, etc. Induced air current within the chamber provides directional movement of air for retrieval and transport to a retainer for subsequent disposal. The plenum chamber would include provisions for sanitizing by an appropriately effective method.

Technical Analysis: Although it is expected that progress will be made in the development of space-oriented prepared foods with minimal tendencies for crumbling, the adeptness of the crew in techniques for preparation of meals and/or dining in the zero-g environment will govern the introduction of free-floating food particles. A means for automatic immediate retrieval precludes more laborious clean-up procedures; however, high mass-air flows are necessary for positive retrieval under all possible situations of escaping food particles. Also, difficulties exist for sanitizing a large plenum chamber and duct. In consideration of design and sanitation problems, the built-in concept was discarded during the initial study phase, even though a selection rationale score of 9.6 was achieved. As a module, however, as described in paragraph 3.9, the concept has validity.

g. Concept: Hand Cleaning With Impregnated Disposable Wipes (6.1.7)

Concept Description: Washing and sanitizing of work counters, food preparation equipment, tables, or general confines of galley and dining area by hand, using appropriately impregnated disposable wipes.

Technical Analysis: Sociological and psychological reasons dictate apparent cleanliness of the galley/dining areas which makes removal of stains and debris necessary, whereas medical reasons mandate stringent sanitation requirements. Impregnated disposable wipes offer a simple means of accomplishing this purpose.

h. Concept: Hand Cleaning With Impregnated Reusable Wipes (6.1.8)

Concept Description: Washing and sanitizing of work counters, food preparation equipment, tables, or general confines of galley and dining area by hand, using appropriately impregnated reusable wipes.

Technical Analysis: Acknowledging the sociological, psychological, and medical reasons for cleanliness and sanitation, impregnated reusable wipes offer a simple means of accomplishing this purpose.

i. Concept: Hand-Held Scrubber Cleaning Unit (6.1.9)

Concept Description: Hand-held powered device imparting oscillatory or rotary motion to facilitate washing and sanitizing of work counters, food preparation equipment, tables, or general confines of galley and dining areas. The device will include provisions for the retention and replacement of appropriately impregnated disposable or reusable wipes.

Technical Analysis: To satisfy the sociological, psychological, and medical reasons for cleanliness and sanitation, the use of a powered device for imparting motion to impregnated wipes would appear to reduce crew fatigue and time for accomplishing the clean-up function. However, a reassessment of this concept resulted in its being discarded during the interim study phase. Paradoxically, its major deficiency is excessive crew time and effort in continual changing of wipes in order to maintain some degree of dampness and bactericide effectiveness for washing and sanitizing. It is also considered unsuitable for small curved surfaces.

j. Concept: Guided Transport "ASTROVAC" Cleaning Unit (6.1.10)

Concept Description: Portable, restrained guidance, cleaning device of the "Astrovac" concept as developed by FH/RAD for washing and sanitizing of work counters, food preparation equipment, tables, or general confines of galley and dining areas. The self-contained "Astrovac" will permit washing, with water and other solutions having detergent or disinfectant properties, in a zero-g environment and will recover the fluids on the surfaces of application. A small hand-held component of the device will deliver a controlled amount of fluid through a sponge layer or head and also reabsorb the fluid by suction. Multi-purpose interchangeable, reusable and flexible heads will allow a diversity of use, and accessibility to corners and curved surfaces.

Technical Analysis: Acknowledging the need for cleanliness and sanitation, the "Astrovac" cleaning device would be more suitable for combined cleansing and sanitizing of larger areas. The zero-g restraint for this piece of equipment would be adapted to a common restrained-guidance system for serving carts or other transportable units within/or between the galley and dining areas.

k. Concept: Back-Pack "ASTROVAC" Cleaning Unit (6.1.11)

Concept Description: Portable, back-pack crew-carriage type cleaning device of the FH/RAD "Astrovac" concept described in Concept 6.1.10 for washing and sanitizing of work counters, food preparation equipment, tables, or general confines of galley and dining areas.

Technical Analysis: To meet requirements for cleanliness and sanitation, and suitability of the "Astrovac" concept for this purpose, a back-pack version of the device may be considered. While crew encumberance would not be evident in the zero-g environment because of weightlessness conditions, use in a partial-g environment will result in some degree of crew encumberance which may or may not be significant. In considering crew safety aspects and probable psychological rejection of such "strap-on" equipment, the concept was discarded during the initial study phase.

l. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-30 below, with the rating numbers and "study/discard" decisions as derived from the Selection Rationale Sheets in Data Book - Book III.

TABLE III-30

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 6.1	SUB-FUNCTION TITLE: Galley and Dining Area Clean-Up	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
6.1.1	Hand-Brushing or Sweeping of Food Particles	7.9	X				
6.1.2	Hand-Held Vacuum Unit	11.4		X			X
6.1.3	Guided Transport Vacuum Cleaner Unit	11.2		X			X
6.1.4	Back-Pack Vacuum Cleaner Unit	8.2	X				
6.1.5	Central Vacuum Cleaner System	8.4	X				
6.1.6	Automatic Vacuum Retrieval System	(9.6)	X				
6.1.7	Hand Cleaning With Impregnated Disposable Wipes	13.8		X			X
6.1.8	Hand Cleaning With Reusable Impregnated Disposable Wipes	15.8		X			X
6.1.9	Hand-Held Scrubber Cleaning Unit	13.4		X		X	
6.1.10	Guided Transport "Astrovac" Cleaning Unit	10.0		X			X
6.1.11	Back-Pack "Astrovac" Cleaning Unit	8.0	X				

For each of the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Hand-Held Vacuum Unit (6.1.2)

In concept, the hand-held vacuum unit is similar to commercially available inexpensive devices widely marketed for consumer use in vacuum cleaning of automobile interiors, or other confined areas. An equivalent size unit for use aboard a space vehicle would be designed for efficient operation in a zero-g environment, and in addition, for collection of wet or dry materials. It is anticipated that the small hand-held unit would be applicable to the Food System primarily as a convenience device for immediate retrieval of solid or liquid food particles, in which case it should be readily accessible and operationally ready at all times. By absence of a lengthy pick-up hose, it is also ideally suitable for the collection of vomitus enabling quick disposal of a small collector bag and expeditious cleansing of only a relatively small pick-up nozzle. Suggestively, it may be desirous to have several units aboard at discrete locations for immediate use. Interface is required with space vehicle electrical power system, and general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.1.2.1 through 6.1.2.3 and 6.1.2.5 through 6.1.2.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

2) Technical Data - Guided Transport Vacuum Cleaner Unit (6.1.3)

The conceptual vacuum cleaner unit for use aboard a space vehicle would be designed for efficient operation in a zero-g environment and for collection of both wet and dry materials. It is more appropriately described as a "mobile" unit rather than a "portable" unit since it is not carried, but moved to various positions along a suitably designed track system which enables controlled guidance and zero-g restraint. The unit is a modified version of the "portable" vacuum cleaning device presently being fabricated by FH/RAD for the SKYLAB under sub-contract to McDonnell Douglas Astronautics Company. It is applicable to the Food System for general vacuuming of the galley and dining areas for retrieval of solid or liquid foods and small debris. Interface is required with space vehicle electrical power system, structural design, and general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.1.3.1 through 6.1.3.3 and 6.1.3.5 through 6.1.3.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

3) Technical Data - Hand Cleaning/Impregnated Disposable Wipes (6.1.7)

In concept, the disposable wipes are similar to commercially available Wash'n Dri® Towelettes in individually sealed packets, but impregnated with a specially developed detergent/germicidal solution suitable for use in the space vehicle. They are applicable to the Food System in providing a means for maintaining a sanitary environment in the galley and dining areas, through combined stain removal (washing) and sanitizing of confining surfaces and installed equipment, by hand-rubbing process. Interface is required with space vehicle environmental control system and general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.1.7.1 through 6.1.7.6 and back-up information is contained in Data Book - Book II. Additional technical data in the form of a comparison of mission requirements for disposable wipes versus reusable wipes for trade-off considerations, are provided in paragraph 6) hereinafter.

4) Technical Data - Hand Cleaning/Impregnated Reusable Wipes (6.1.8)

The reusable wipes are anticipated to be similar to commonly used household type "wash-cloths" or "dish-rags" which would be dampened (impregnated) repetitiously with a specially developed detergent/germicidal solution suitable for use in the space vehicle. They are applicable to the Food System in providing a means for maintaining a sanitary environment in the galley and dining areas, through combined stain removal (washing) and sanitizing of confining surfaces and installed equipment, by hand-rubbing process. Soiled wipes would be laundered and continuously reused until deteriorated. Interface is required with space vehicle environmental control system, and water reclamation system associated with a laundry facility.

Detailed data plus mission oriented data are contained on Element Data Sheets 6.1.8.1 through 6.1.8.6 in Data Book - Book I, and back-up information is contained in Data Book - Book II. Additional technical data in the form of a comparison of mission requirements for reusable wipes versus disposable wipes for trade-off considerations are provided in paragraph 6) hereinafter.

5) Technical Data - Guided Transport "ASTROVAC" Cleaning Unit (6.1.10)

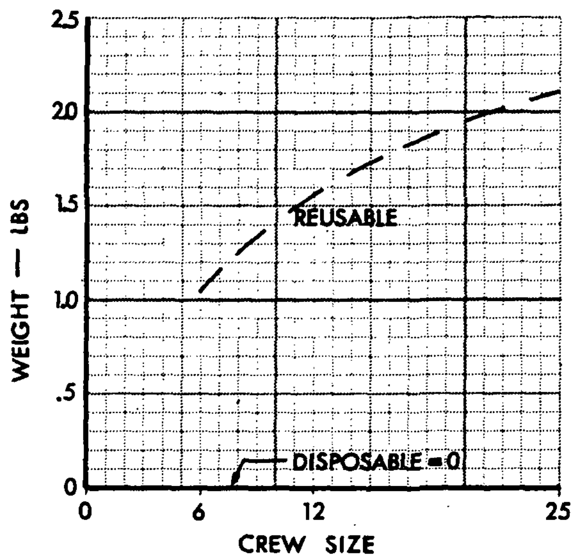
The conceptual cleaning unit is a modified version of the "ASTROVAC" personal hygiene (body-wash) equipment developed by FH/RAD for use in a zero-g environment aboard the Manned Orbiting Laboratory (MOL). The unit would be a "mobile" type, moved to various positions along a suitably designed track system which enables controlled guidance and zero-g restraint. A specially developed detergent/germicidal solution suitable for use in the space vehicle would be employed in operation of the unit. It is applicable to the Food System in providing a means for maintaining a sanitary environment in the galley and dining areas, through combined washing and sanitizing of confining surfaces and installed equipment. Interface is required with space vehicle electrical power system, environmental control system, water reclamation system, structural design, and general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.1.10.1 through 6.1.10.6 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

6) Comparison of Requirements for Disposable versus Reusable Wipes for Cleaning Galley and Dining Area by Hand (6.1.7 versus 6.1.8)

There are some distinct advantages and disadvantages to both disposable and reusable wipes on space missions of extended duration, and any decisions as to preference can only be related to trade studies. It is obvious that the disposable type will impose penalties in increasing the amount of debris generated, processing, and storage until eventually removed at the next scheduled resupply mission. While this problem will not exist with the use of reusable wipes, other penalties are imposed in mandating laundering facilities with consequential increase in electrical energy and water reclamation requirements.

Figure III-96 provides a comparison of installation or initial launch requirements (reference Data Books I and II). It is apparent that disposables appear advantageous, but this is only because of a study premise that there would be no expendables or consumables aboard on initial launch:



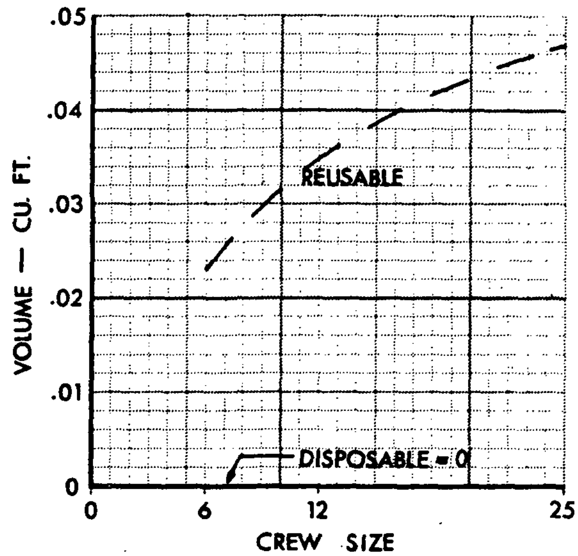


Figure III-96. Weight and Volume of Disposable versus Reusable Wipes - Installation or Initial Launch Requirements for Galley and Dining Area

The following curves provide a comparison of Resupply (14- and 90-day) requirements (reference Data Books I and II). It would appear that disposables have the advantage; however, the average resupply weight and volume of reusable wipes is actually insignificant relative to resupply of pre-mixed cleaning fluid used therewith:

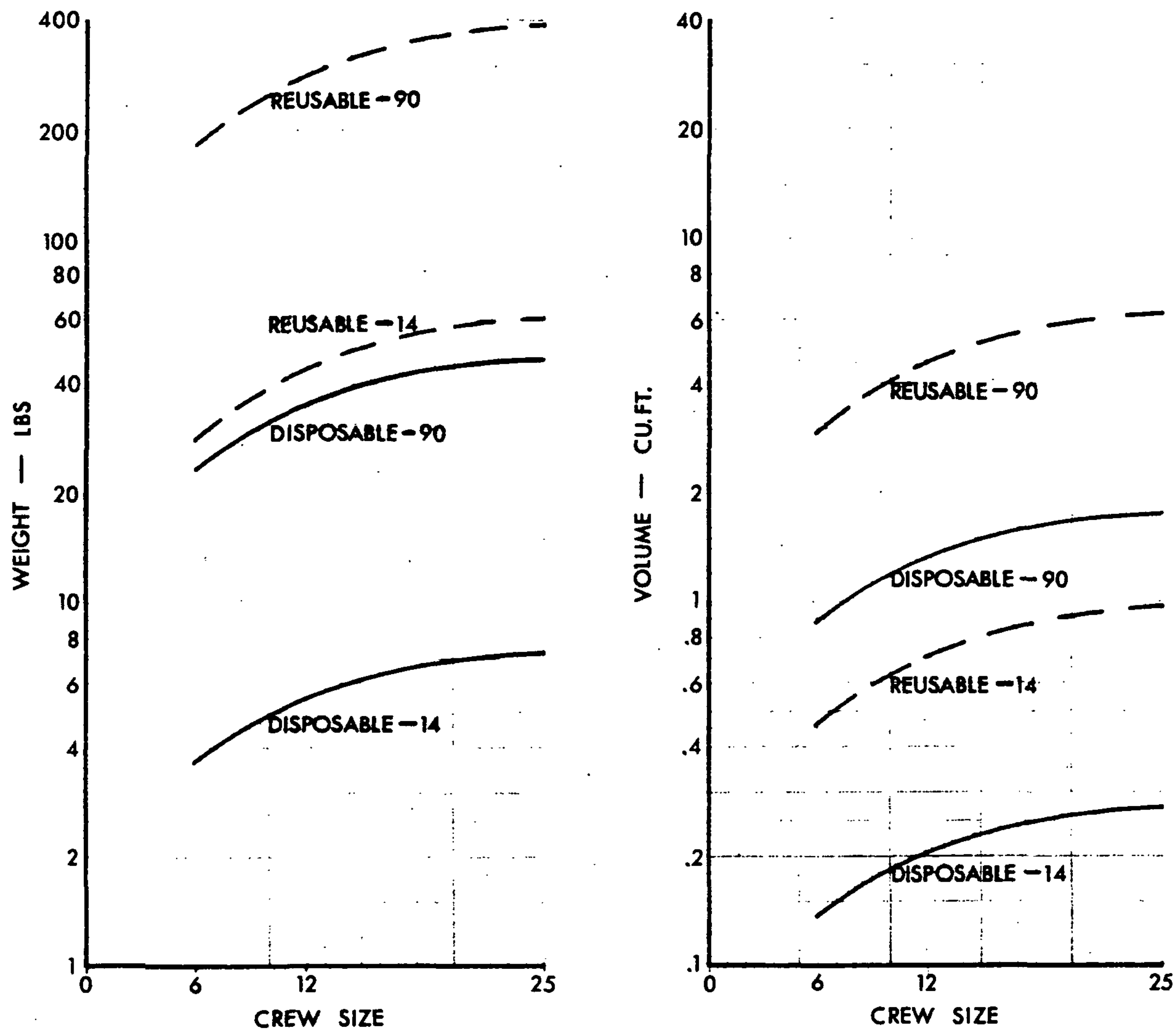


Figure III-97. Weight and Volume of Disposable versus Reusable Wipes - Resupply Requirements for Galley and Dining Area

Figure III-98 provides a comparison of associated (laundering) requirements (reference Data Books I and II).

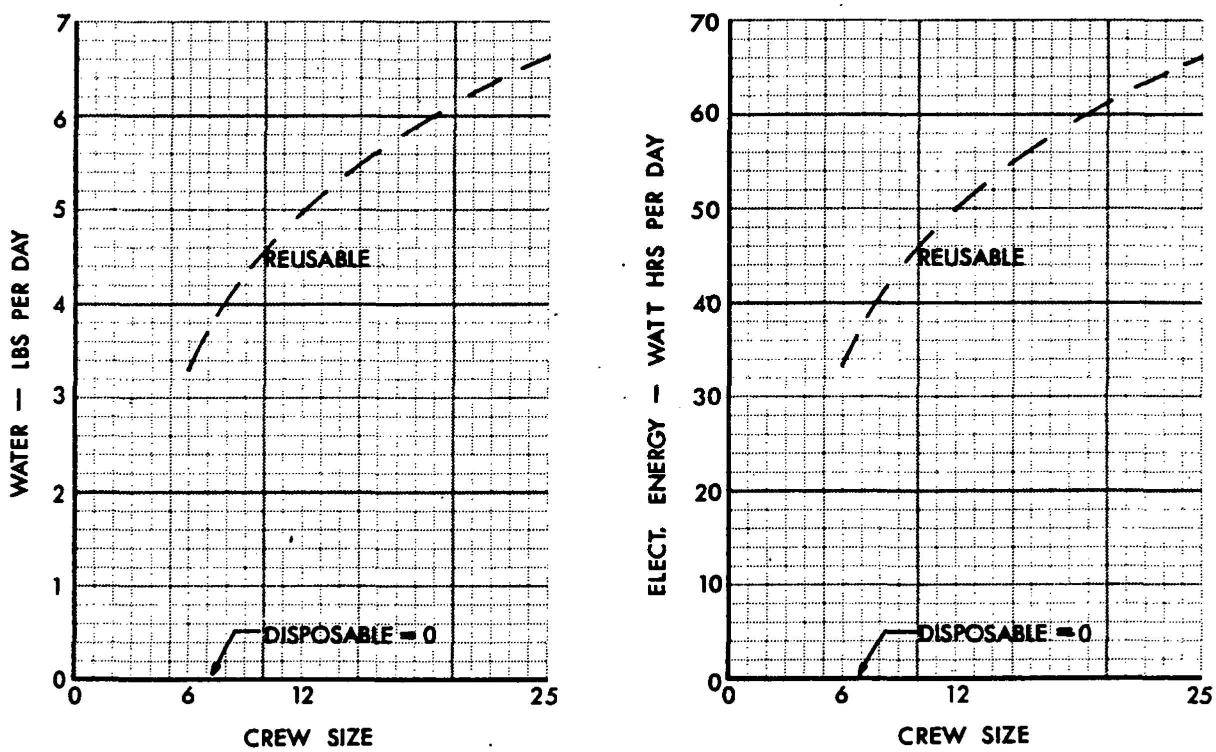


Figure III-98. Laundering Requirements for Disposable Versus Reusable Wipes - Galley and Dining Area

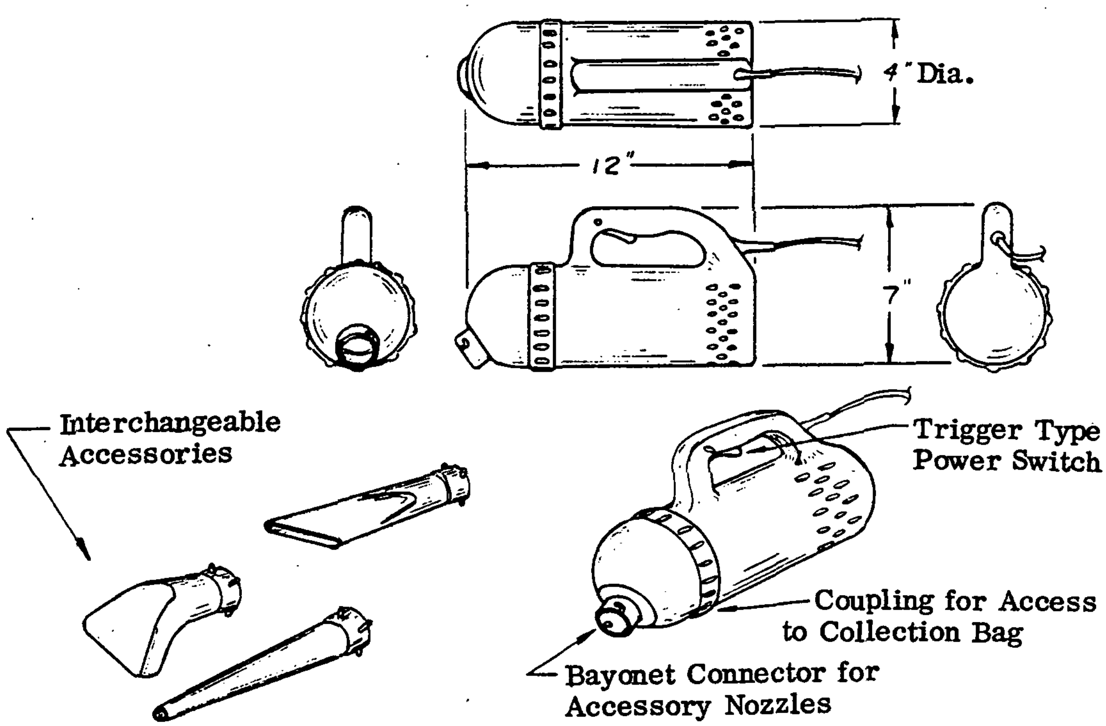
It should be noted that reusable wipes would, in reality, only be resupplied on an attrition basis, replacing those that have been deteriorated and would only contribute an insignificant or negligible part of the generated debris. The quantity of debris generated through use of disposable wipes would be equivalent to the resupply weight and volume thereof as shown in previous comparison curves.

m. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above:

FOOD SYSTEM STUDY SKETCH

Title: Hand-Held Vacuum Cleaner Unit



Hand-vacuum device collection of food particles from work counters, food preparation equipment, tables, or general confines of galley and dining area can be performed through the use of hand-held vacuum device.

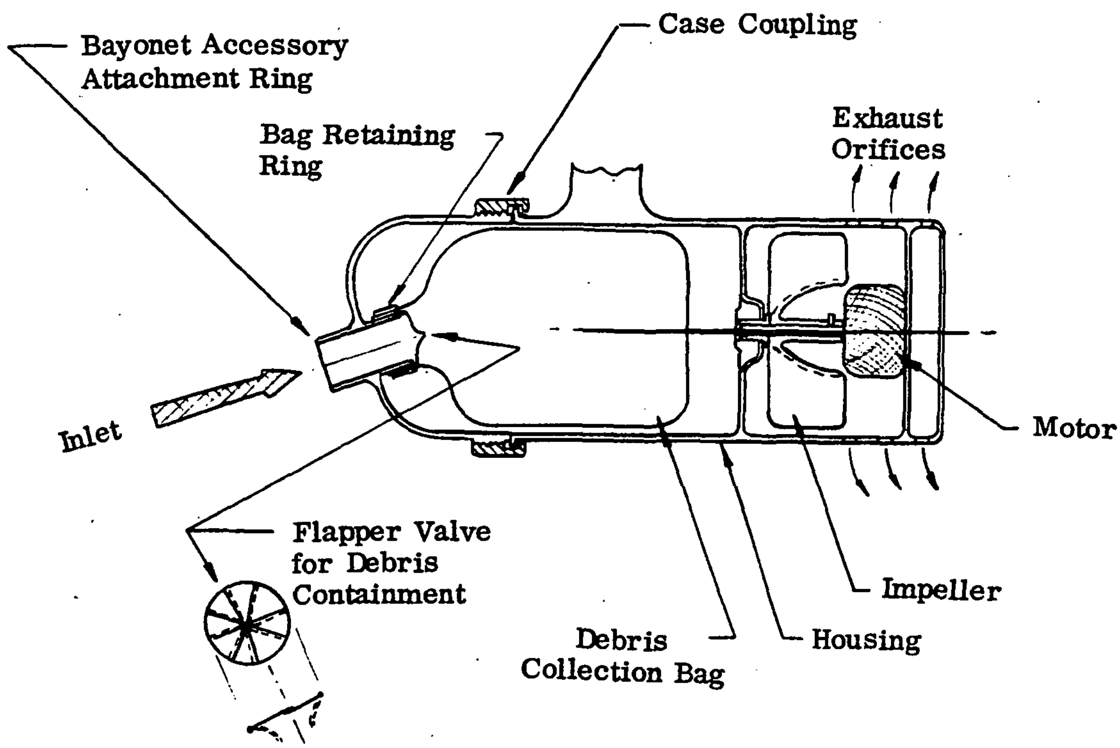
Vacuuming provides a positive method for retrieval of dry or wet food particles, whether static (at rest) or dynamic (free floating) in the zero-g environment as well as under partial-g conditions. The use of a hand vacuum device may have distinct advantages for immediate cleaning of small areas.

D– 6.1.2

(Sheet 1 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Hand-Held Vacuum Unit

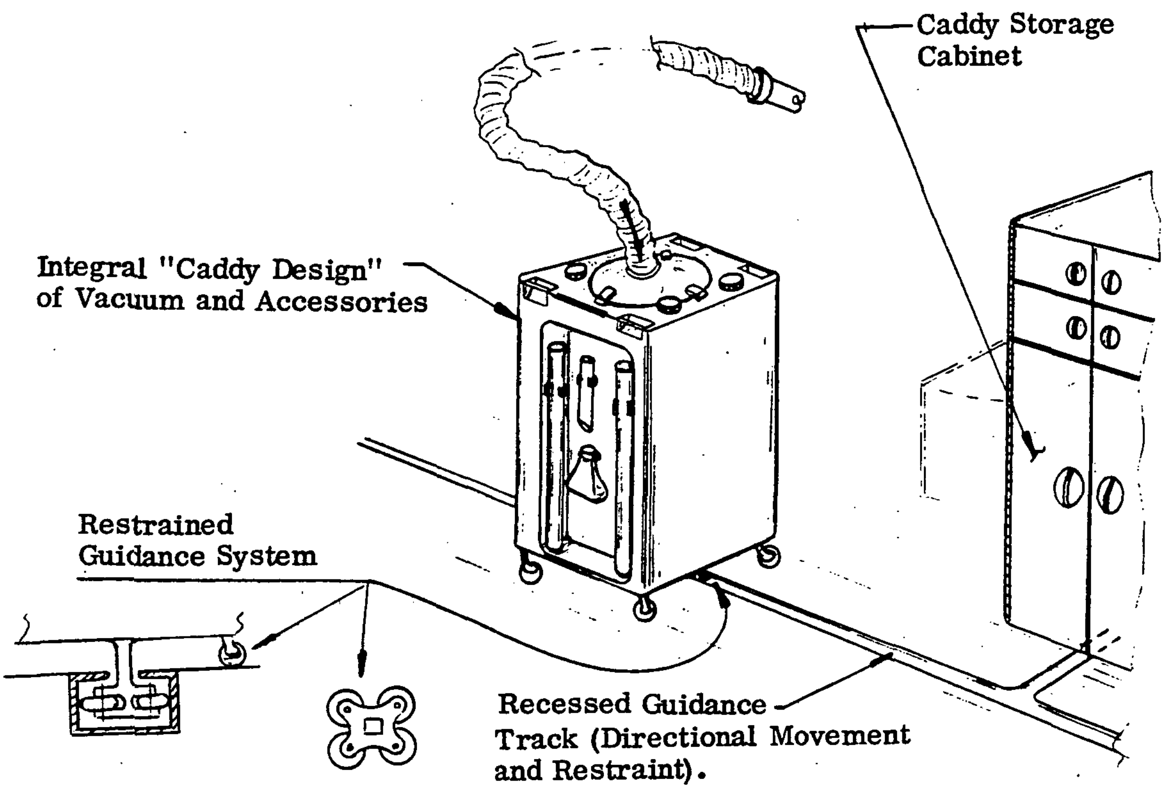


D— 6.1.2

(Sheet 2 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Guided Transport Vacuum Cleaner Unit



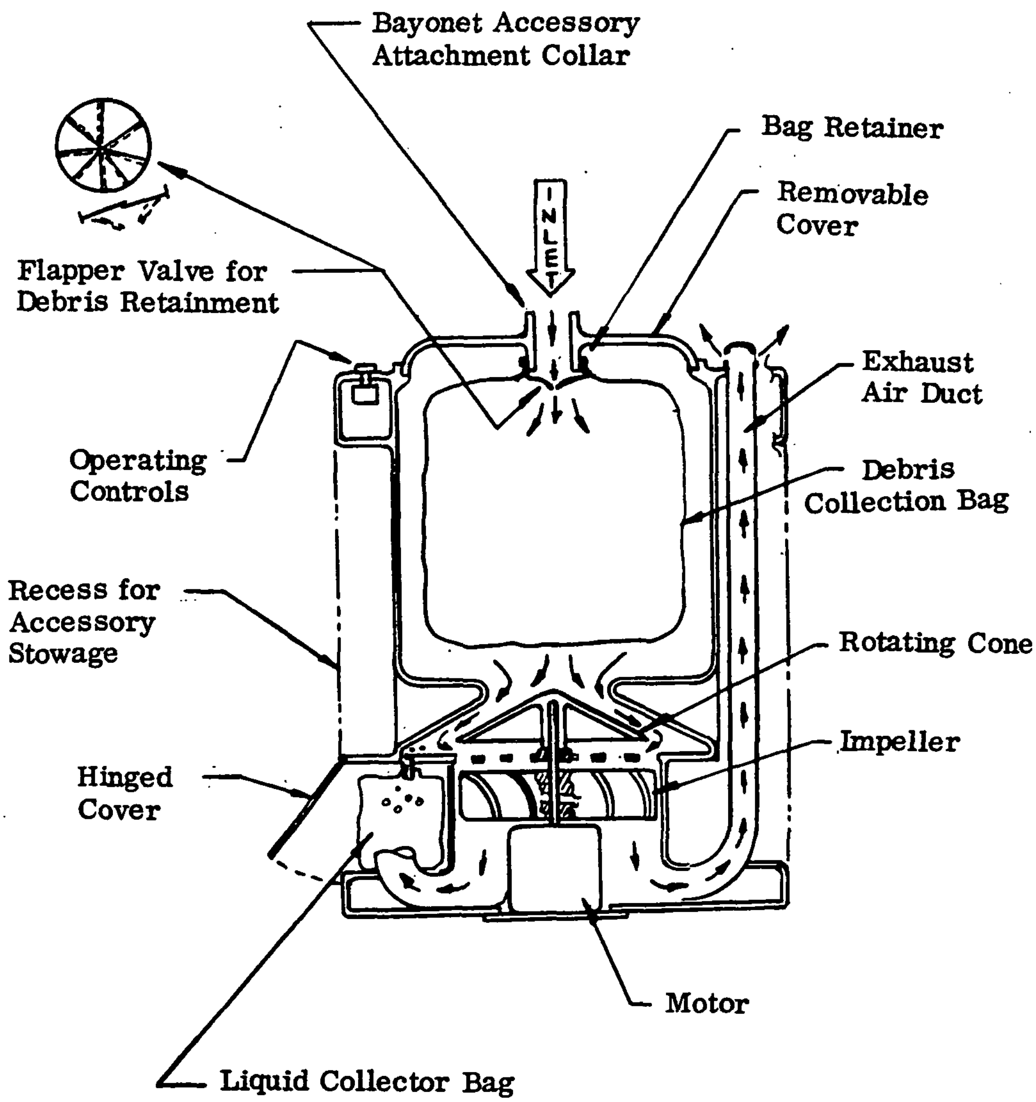
This concept is a self-contained vacuum cleaning device with a disposable internal collector bag for wet or dry debris. Rectangular aluminum housing has integral stowage provisions for accessory pick-up nozzles and hose. Handles facilitate maneuvering using either a recessed floor guidance and ball-type casters for zero-g stability, or side rails for support and guidance.

D— 6.1.3

(Sheet 1 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Guided Transport Vacuum Cleaner Unit

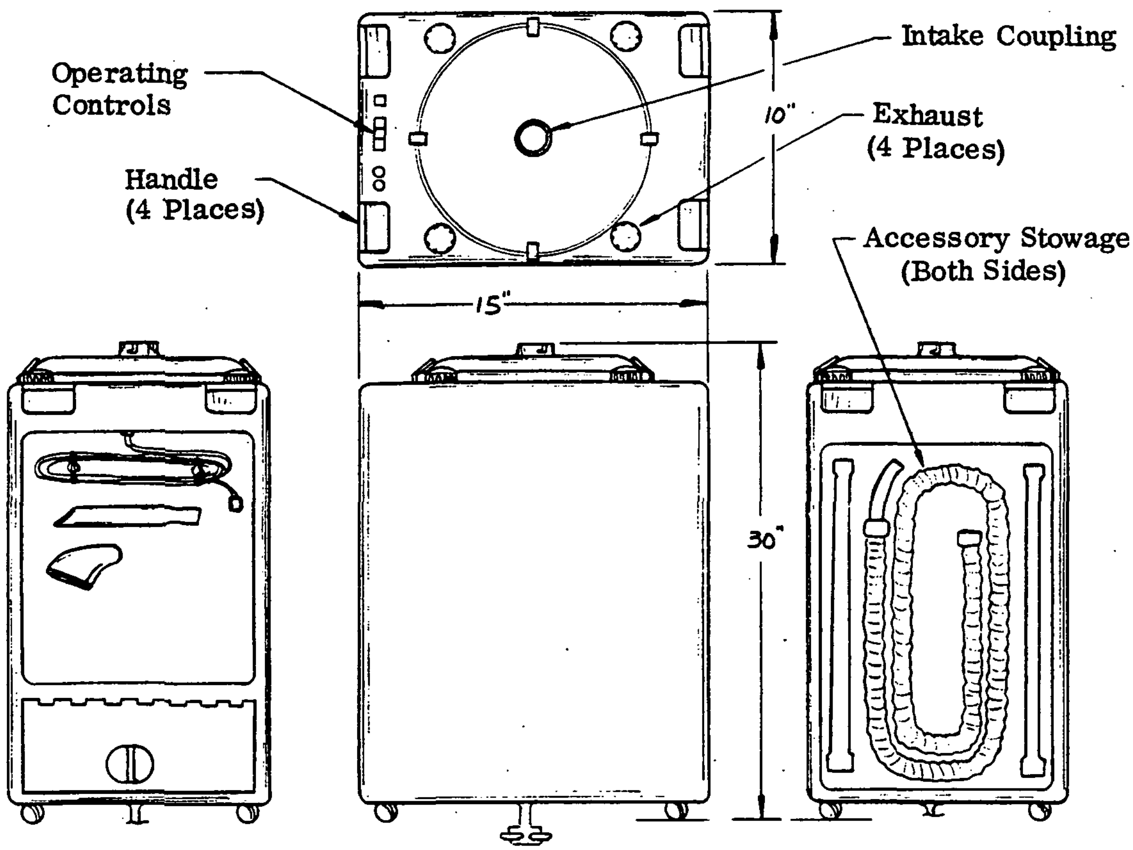


D— 6.1.3

(Sheet 2 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Guided Transport Vacuum Cleaner Unit

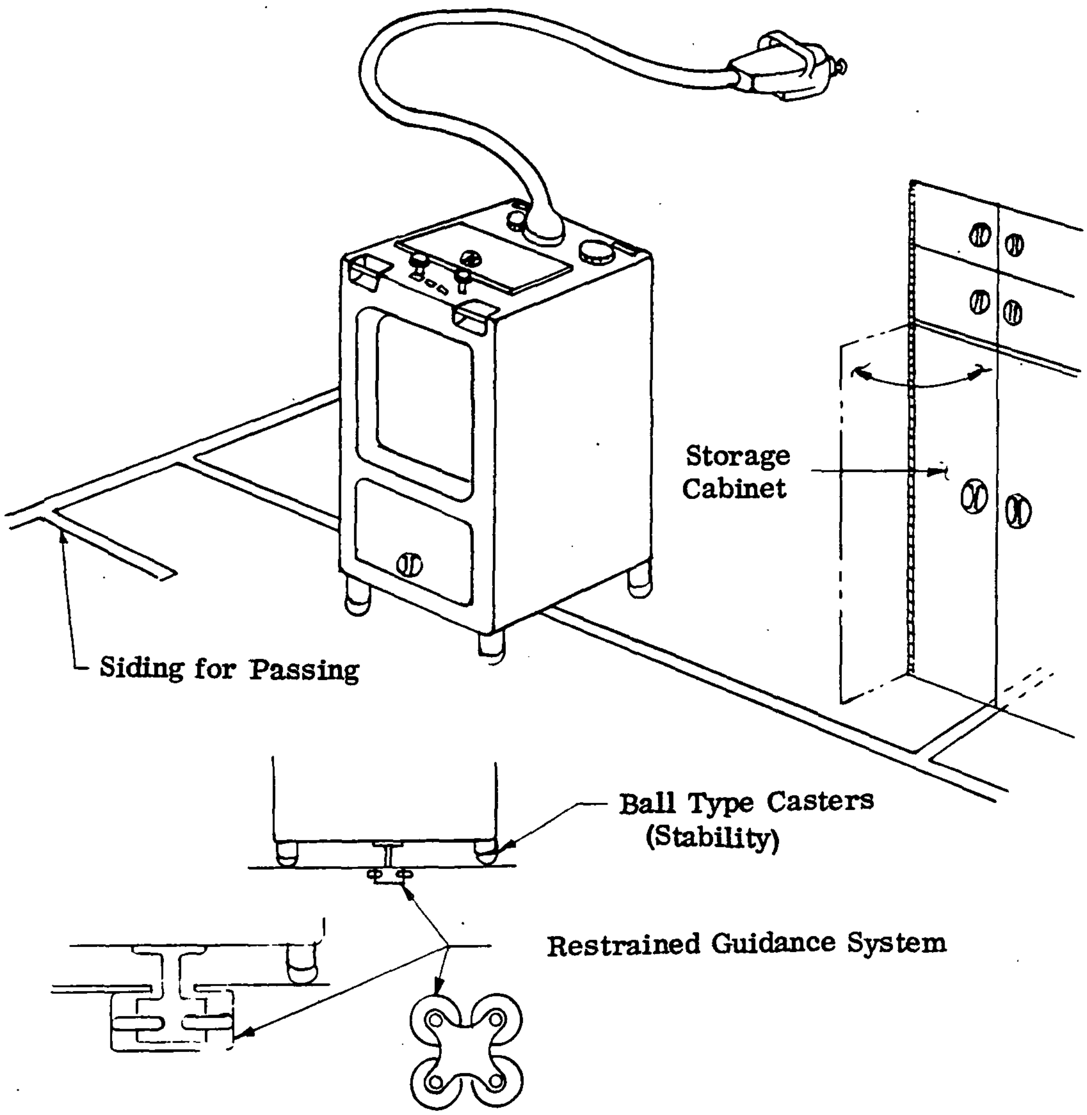


D— 6.1.3

(Sheet 3 of 3)

FOOD SYSTEM STUDY SKETCH

Title: Guided Transport "ASTROVAC" Cleaning Unit

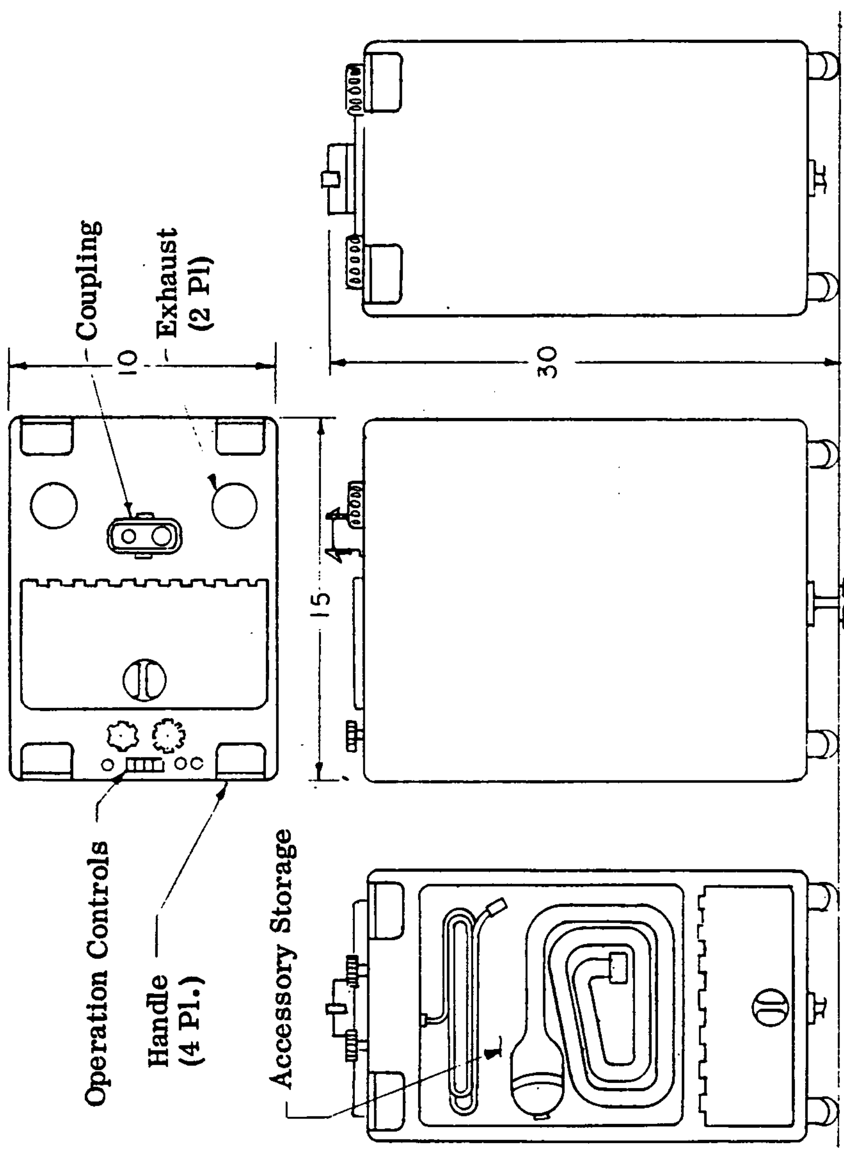


This concept is a portable, restrained guidance, cleaning "Astrovac" device as developed by FH/RAD for washing and sanitizing work counters, food preparation equipment, tables, or general confines of galley and dining areas. The self-contained "Astrovac" will permit washing, with water and other solutions having detergent or disinfectant properties, and will recover the fluids on the surfaces of application. A small hand-held component will deliver a controlled amount of fluid through a sponge layer or head and also reabsorb the fluid by suction.

The zero-g restraint for this equipment would be adapted to a common restrained-guidance system for serving carts or other transportable units within or between the galley and dining areas.

FOOD SYSTEM STUDY SKETCH

Title: Guided Transport "Astrovac" Cleaning Unit

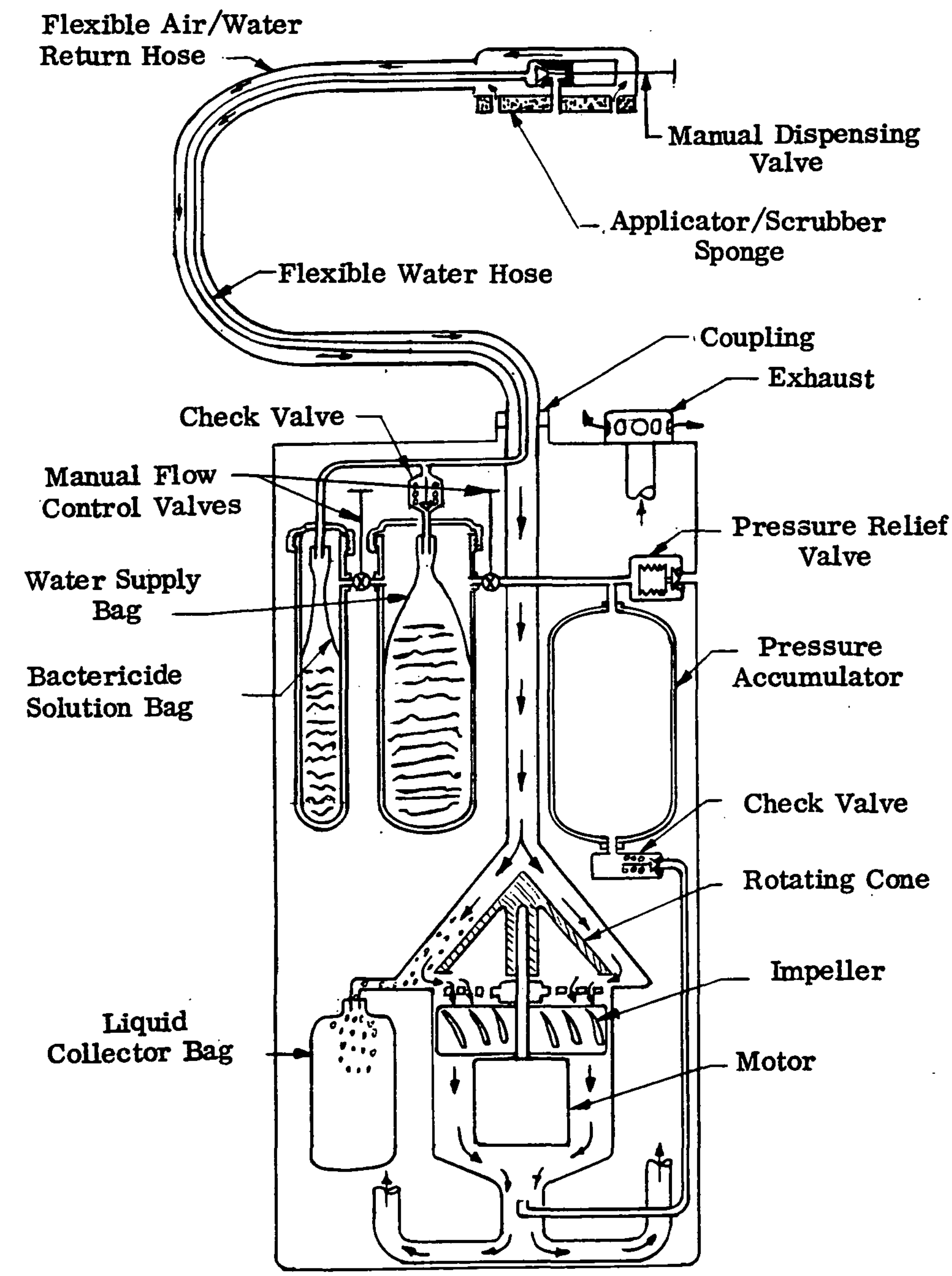


D— 6.1.10

(Sheet 2 of 4)

FOOD SYSTEM STUDY SKETCH

Title: Guided Transport "Astrovac" Cleaning Unit

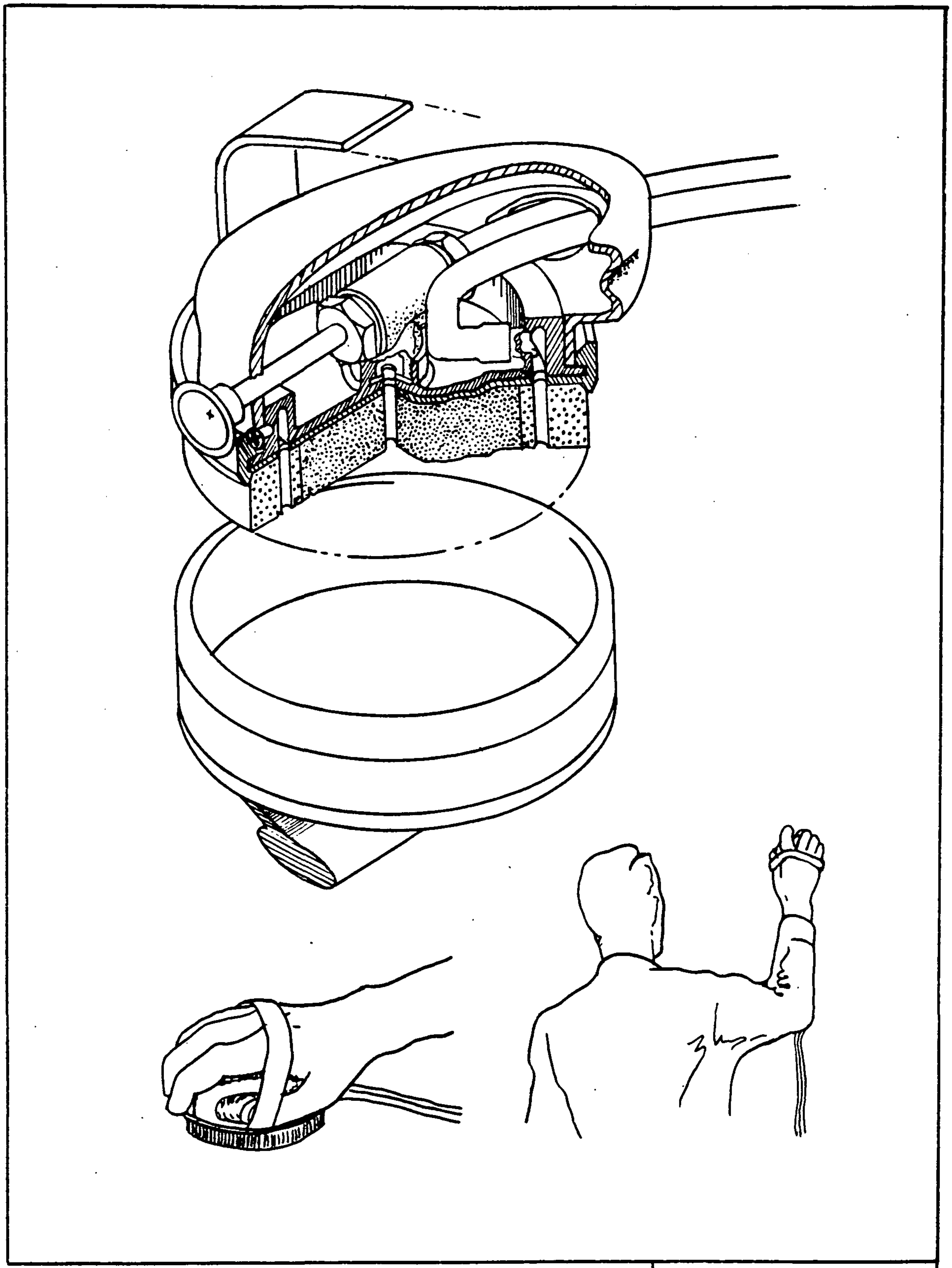


D— 6.1.10

(Sheet 3 of 4)

FOOD SYSTEM STUDY SKETCH

Title: Guided Transport "Astrovac" Cleaning Unit



D— 6.1.10

(Sheet 4 of 4)

6.2 Candidate Dining Area Clean-Up Techniques

a. Concept: Dispenser For Disposable Personal Wipes (6.2.1)

Concept Description: Dispenser for disposable personal wipes or napkins in dining area.

Technical Analysis: Personal hygienic requirements and habits compel provisions for wiping of mouth or fingers during and subsequent to eating. Disposable napkins are a suitable method.

b. Concept: Dispenser For Reusable Personal Wipes (6.2.2)

Concept Description: Dispenser for reusable personal wipes or napkins in dining area.

Technical Analysis: Personal hygienic requirements and habits compel provisions for wiping of mouth or fingers during and subsequent to eating. Reusable napkins are a suitable method if laundering facilities are available.

c. Concept: Dispenser For Impregnated Personal Cleansing Wipes (6.2.3)

Concept Description: Dispenser for disposable individual packet-type impregnated personal cleansing wipes in dining area.

Technical Analysis: For personal hygienic purposes, the use of damp wipes, equivalent to commercially available Wash'n Dri® Towelettes, are ideally suitable for superficial cleaning of mouth and fingers, and/or face and hands after eating. This serves to minimize crew time expended at lavatories and reduce water reclamation requirements.

d. Concept: Receptacle For Temporary Retention of Soiled Wipes (6.2.4)

Concept Description: Appropriately designed receptacles in close proximity to dining positions for temporary retention of soiled wipes, either disposable or reusable type, prior to more complete clean-up procedures.

Technical Analysis: Unpredictable circumstances may require the use of several wipes during the process of dining in which case sociological and aesthetic reasons would make immediate convenient removal from sight desirable.

e. Concept: Disposable Covers For Dining Tables (6.2.5)

Concept Description: Use of disposable coverings for dining tables to reduce clean-up work load.

Technical Analysis: This concept would represent a simple means to reduce table clean-up requirements in a partial-g environment and offers some psychological and/or aesthetic value. In a zero-g environment, the concept is less valid and is considered an unnecessary luxury imposing penalties on waste disposal facilities, for which reasons it was discarded during the initial study phase even though a selection rationale score of 12.5 was achieved.

f. Concept: Reusable Covers For Dining Tables (6.2.6)

Concept Description: Use of reusable coverings for dining tables to reduce clean-up work load.

Technical Analysis: This concept would represent a simple means to reduce table clean-up requirements in a partial-g environment and offers some psychological and/or aesthetic value. In a zero-g environment, the concept is less valid and is considered an unnecessary luxury imposing penalties on laundering facilities (if available), for which reasons it was discarded during the initial study phase even though a selection rationale score of 14.8 was achieved.

g. Concept: Retainer For Residues of After-Dinner Smoking (6.2.7)

Concept Description: Appropriately designed receptacles to accommodate residues of possible after-dinner smoking.

Technical Analysis: Non-valid concept since smoking has been and is expected to be prohibited on future space missions; therefore, it was discarded during the initial study phase with no attempt to achieve a selection rationale score.

h. Concept: Hand Carriage For Return of Meal Trays (6.2.8)

Concept Description: Hand-carriage of covered meal trays with dining aids (dishes, cups, utensils), unconsumed food, etc. to a temporary retention rack within or in proximity to the galley for subsequent cleaning and disposal functions as applicable.

Technical Analysis: This is considered to be a simple-feasible stage of the overall clean-up procedure which could be effectively accomplished by each crewman as he departs the dining area.

i. Concept: <u>Meal Tray Guided Return Rail System</u> (6.2.9)

Concept Description: Restrained guidance transport system providing for the return of covered meal trays with dining aids (dishes, cups, utensils), unconsumed food, etc., to the galley area in the same manner as delivered therefrom.

Technical Analysis: This is considered to be an appropriate stage of the overall cleaning procedure, if the same serving method is employed.

j. Concept: <u>Meal Tray Guided Return Carrier Unit</u> (6.2.10)

Concept Description: Portable, restrained guidance, rack-type conveyance unit (cart equivalent) providing for the return of covered meal trays with dining aids (dishes, cups, utensils), unconsumed food, etc., to the galley area in the same manner delivered therefrom.

Technical Analysis: This is considered to be an appropriate stage of the overall cleaning procedure, if the same serving method is employed. The zero-g restraint for this piece of equipment would be adapted to a common restrained-guidance system for other transportable units within/or between the galley and dining areas.

k. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-31 below, with the rating numbers and "study/discard" decisions as derived from the Selection Rationale Sheets in Data Book - Book III.

TABLE III- 31

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 6.2 TITLE: Dining Area Clean-Up		INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
6.2.1	Dispenser For Disposable Personal Wipes	16.5		X			X
6.2.2	Dispenser For Reusable Personal Wipes	18.8		X			X
6.2.3	Dispenser For Disposable Impregnated Personal Cleansing Wipes	16.5		X			X
6.2.4	Receptacle For Temporary Retention Of Soiled Wipes	15.6		X			X
6.2.5	Disposable Covers For Dining Tables	(12.5)	X				
6.2.6	Reusable Covers For Dining Tables	(14.8)	X				
6.2.7	Receptacle For Residues Of After Dining Smoking	-	X				
6.2.8	Hand-Carriage For Return Of Meal Trays	12.5		X			X
6.2.9	Meal Tray Guided Return Rail System	12.7		X			X
6.2.10	Meal Tray Guided Return Carrier Unit	12.1		X			X

For each of the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Dispenser/Disposable Personal Wipes (6.2.1)

The disposable personal wipes are identical to commercially available pre-folded paper napkins, such as the "MARATHON #170 JUNIOR - STANDARD WEIGHT - COMPACT" type marketed by Marathon Division of American Can Company, which are commonly used in luncheonette or cafeteria-type dining establishments. The dispenser would be similar to the commercial unit which accommodates the aforementioned napkins, but modified in design for use of corrosion resistant materials and to be compatible with installation requirements in a zero-g environment of the space vehicle. The napkins are applicable to the Food System in providing for habitual wiping practices (mouth/fingers, etc.) and social amenities. Interface is required with space vehicle general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.2.1.1 through 6.2.1.3 and 6.2.1.5 through 6.2.1.7 in

Data Book - Book I, and back-up information is contained in Data Book - Book II. Additional technical data in the form of a comparison of mission requirements for disposable wipes versus reusable wipes for trade-off considerations, are provided in paragraph 8) hereinafter.

2) Technical Data - Dispenser/Reusable Personal Wipes (6.2.2)

The reusable personal wipes are anticipated to be similar to commonly used formal dining-type cloth napkins used in the household or better restaurant type dining establishments. In concept, the dispenser is merely a drawer-type container, with integral zero-g retention devices for the contents, conveniently located in proximity to each dining position. Although the possibility exists for inclusion of a napkin, along with dining utensils, on each meal tray as it is being prepared, theoretically negating the need for the conceptual dispensers at the dining positions, additional napkins should be readily accessible to each diner (crewman) should the need warrant. The napkins are applicable to the Food System in providing for habitual wiping practices (mouth/fingers, etc.) and social amenities. Soiled wipes would be laundered and continually reused until deteriorated. Interface is required with space vehicle water reclamation system as associated with a laundry facility.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.2.2.1 through 6.2.2.3 and 6.2.2.5 through 6.2.2.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II. Additional technical data in the form of a comparison of mission requirements for disposable wipes versus reusable wipes for trade-off considerations, are provided in paragraph 8) hereinafter.

3) Technical Data - Dispenser/Disposable Impregnated Personal Wipes (6.2.3)

In concept, the disposable personal wet-type wipes, are similar to commercially available Wash'n Dri® Towelettes in individually sealed packets, but impregnated with a specially developed cleaning solution suitable for use in the space vehicle. The conceptual dispenser would be designed to hold a supply of the packets, enabling singular removal thereof, and be compatible with installation requirements in a zero-g environment of the space vehicle. The possibility exists for inclusion of a sealed packet, along with other dining accessories, on each meal tray as it is being prepared, thereby negating the need for the conceptual dispensers at the dining positions. The impregnated towelettes are applicable to the Food System in providing a means for satisfaction of minimal personal hygienic needs immediately after dining. Interface is required with space vehicle general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.2.3.1 through 6.2.3.3 and 6.2.3.5 through 6.2.3.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

4) Technical Data - Receptacle/Temporary Retention Soiled Wipes (6.2.4)

The conceptual receptacle is a simple container for zero-g retention of a small quantity of discarded soiled wipes, intended to be located in proximity to each dining position. The design should be coordinated with general design of the dining facilities. The receptacles are applicable to the Food System in providing a means for immediate although temporary disposal of soiled wipes during the process of dining, particularly where unpredictable circumstances compel a diner (crewman) to employ several wipes. Interface is required with space vehicle general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.2.4.1 through 6.2.4.6 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

5) Technical Data - Hand Return of Meal Trays (6.2.8)

The concept of each crewmember carrying his own soiled meal tray and utensils back to a depository rack after completion of dining is applicable to the Food System only insofar as it represents a phase in the "clean-up" function. It is correlated to serving Concept 4.2.1, using the same equipment described therefor.

Detailed data are contained on Element Concept Data Sheets 4.2.1.1 through 4.2.1.3 and mission oriented data are contained on Element Concept Data Sheets 6.2.8.1 through 6.2.8.3 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

6) Technical Data - Meal Tray Guided Return Rail (6.2.9)

Employment of a guided return rail system, for random transport of soiled meal trays and utensils back to the galley after completion of dining, is applicable to the Food System in that it facilitates a phase of the "clean-up" function. The concept is correlated to serving concept 4.1.3, using the same equipment described therefor.

Detailed data are contained on Element Concept Data Sheets 4.1.3.1 through 4.1.3.3 and mission oriented data are contained on Element Concept Data Sheets 6.2.9.1 through 6.2.9.3 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

7) Technical Data - Meal Tray Guided Return Carrier Unit (6.2.10)

Employment of a guided return carrier unit, for collection of all soiled meal trays and utensils after completion of dining and for transport of such articles back to the galley, is applicable to the Food System as a means to facilitate phases of the "clean-up" function. The concept is correlated to serving concept 4.1.7, using the same equipment described therefor.

Detailed data are contained on Element Concept Data Sheets 4.1.7.1 through 4.1.7.3 and mission oriented data are contained on Element Concept Data Sheets 6.2.10.1 through 6.2.10.3 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

8) Comparison of Requirements for Disposable versus Reusable Personal Cleaning Wipes or Napkins (6.2.1 versus 6.2.2)

There are some distinct advantages and disadvantages to both disposable and reusable napkins on space missions of extended duration, and any decisions as to preference can only be related to trade studies. It is obvious that disposable type will impose penalties in increasing the amount of debris generated, processing, and storage until eventually removed at the next scheduled resupply mission. While this problem will not exist with the use of reusable napkins, other penalties are imposed in mandating laundering facilities with consequential increase in electrical energy and water reclamation requirements.

Figure III-99 provides a comparison of installation or initial launch requirements (reference Data Books I and II). It is apparent that disposables have the advantage, but this is only because of a study premise that there would be no expendables or consumables aboard on initial launch.

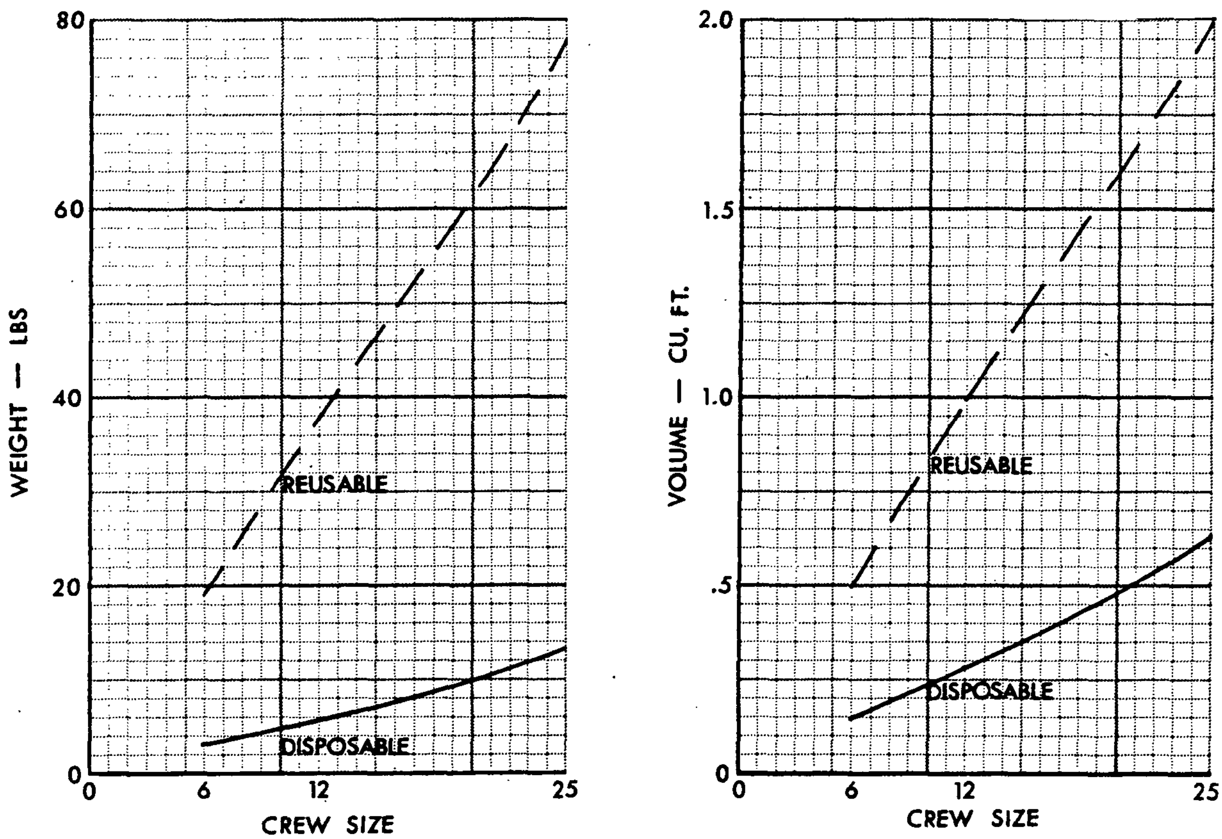


Figure III-99. Weight and Volume of Disposable Versus Reusable Personal Napkins - Installation or Initial Launch Requirements

Figure III-100 provides a comparison of Resupply (14- and 90-day) requirements (reference Data Books I and II). It is obvious that reusable napkins have the advantage with the average resupply weights and volumes thereof being relatively insignificant:

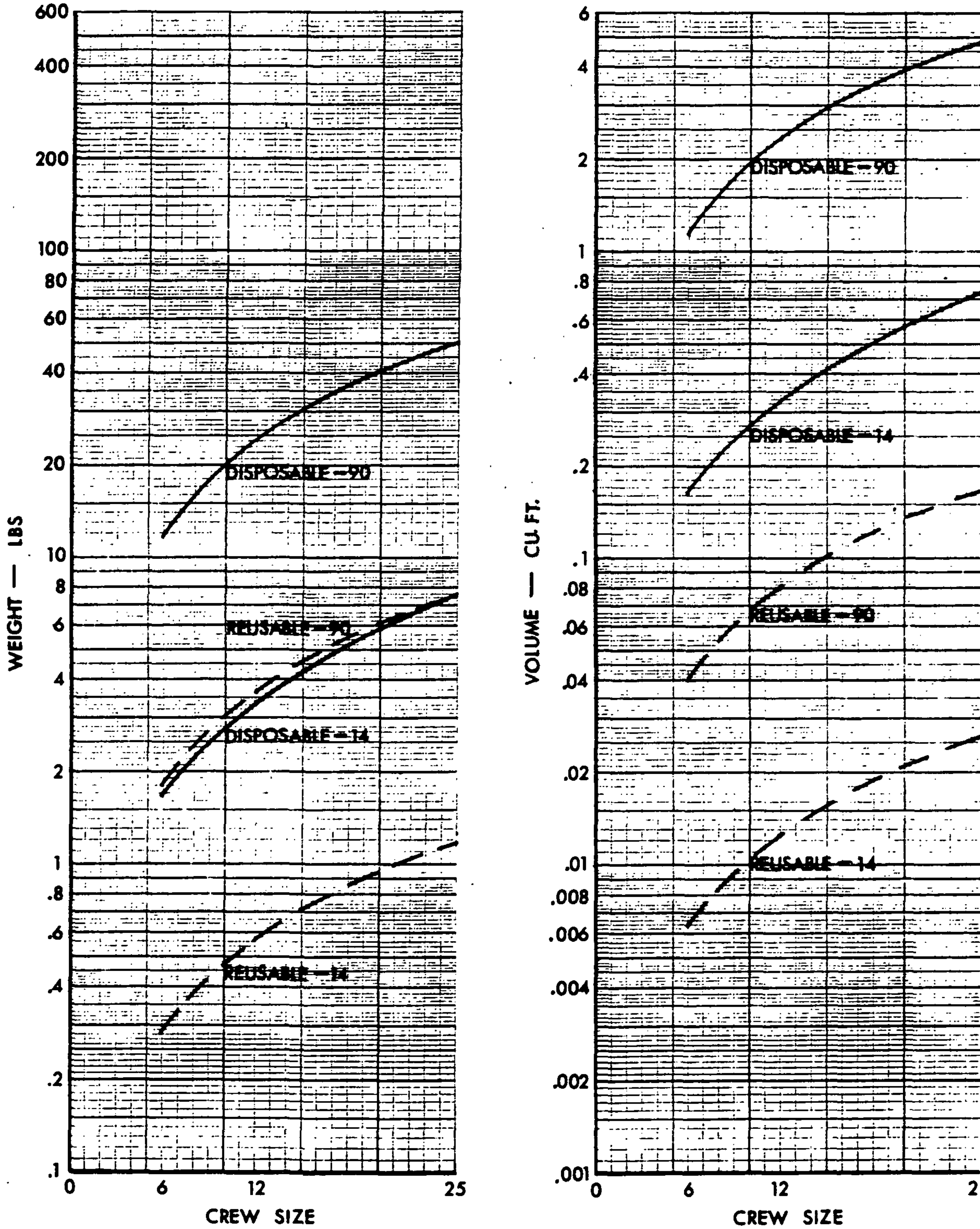


Figure III-100. Weight and Volume of Disposable Versus Reusable Personal Napkins - Resupply Requirements

Figure III-101 provides a comparison of associated (laundering) requirements (reference Data Books I and II):

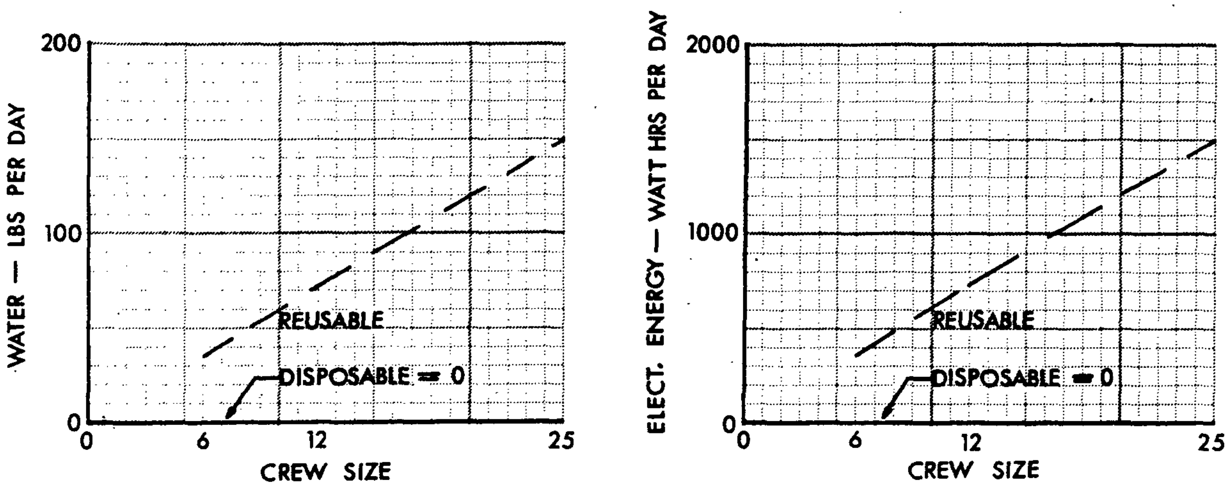


Figure III-101. Laundering Requirements For Disposable Versus Reusable Personal Napkins

It should be noted that reusable napkins would, in reality, only be resupplied on an attrition basis, replacing those that have been deteriorated and would only contribute an insignificant or negligible part of the generated debris. The quantity of debris generated through use of disposable napkins would be equivalent to the resupply weight and volume thereof as shown in previous comparison curves.

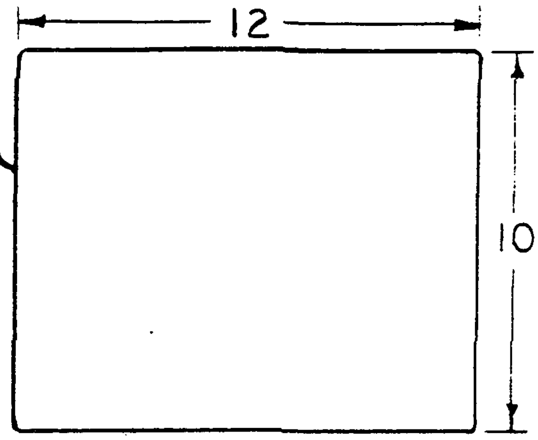
1. Applicable Sketches

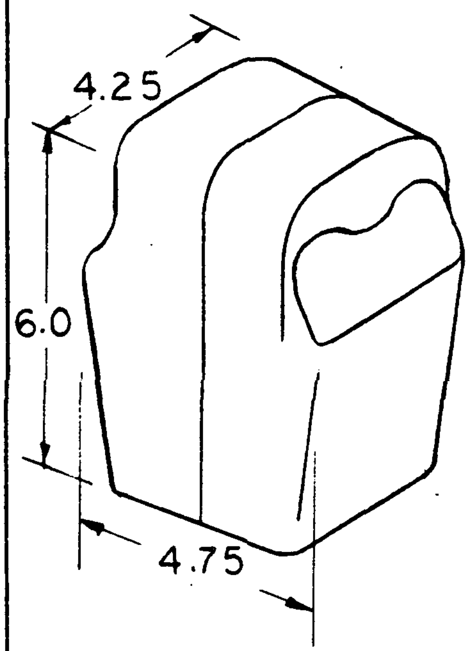
The following sketches depict equipment concepts for the techniques described above:

FOOD SYSTEM STUDY SKETCH

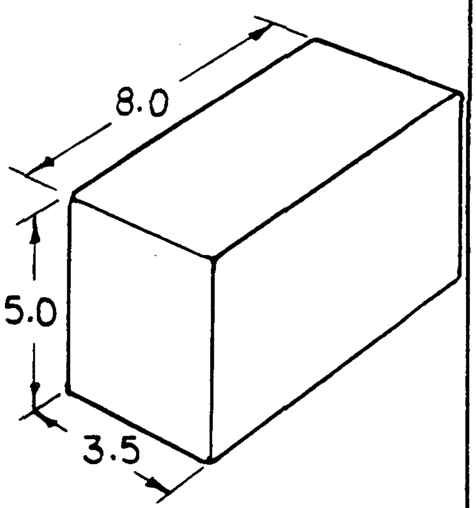
Title: Dispenser For Disposable Personal Wipes

Single Wipe





Dispenser



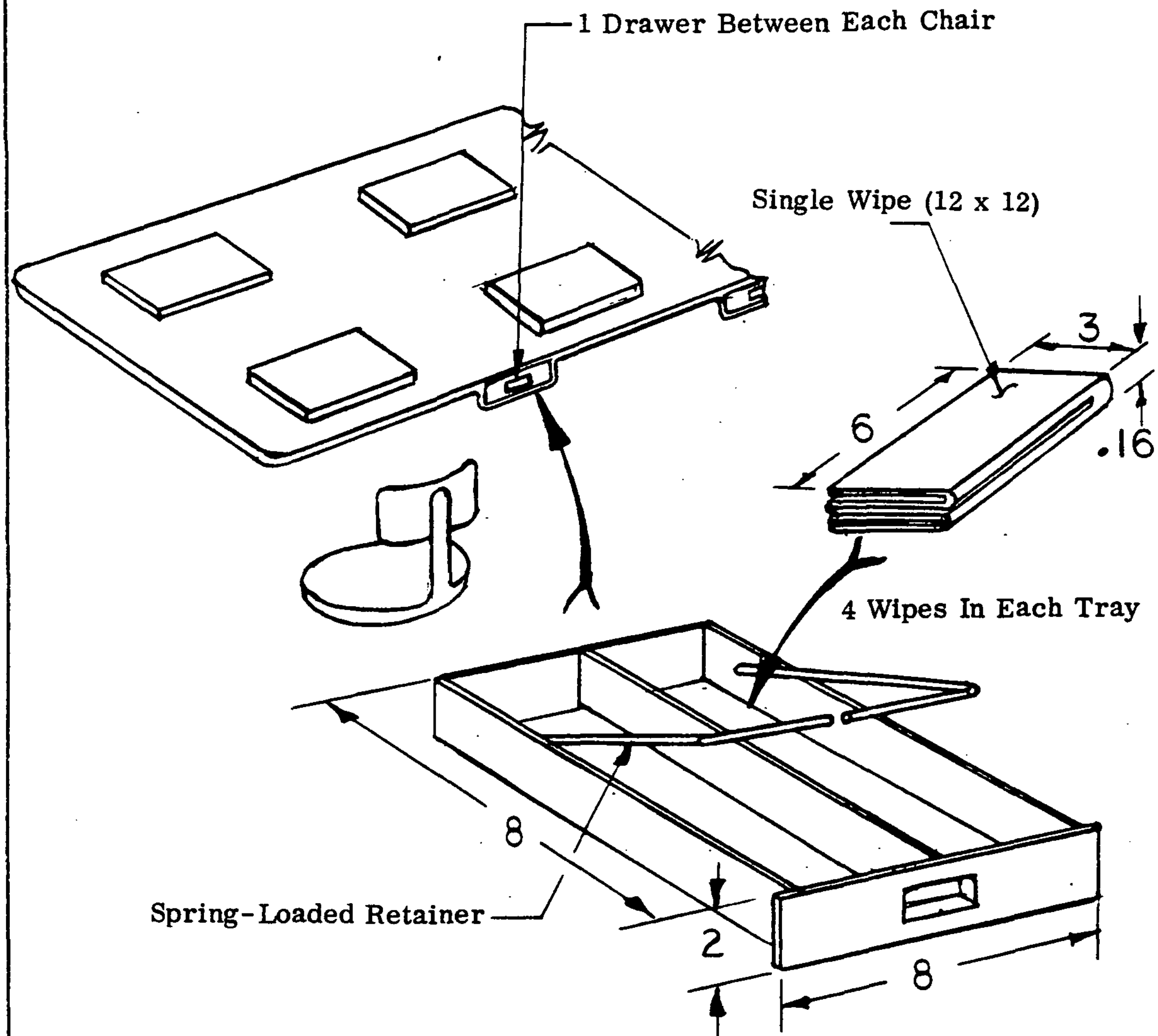
300 Packaged Wipes

This unit is similar to a standard earth-type napkin dispenser. It will be of aluminum construction having provisions for internal retention and dispensing of disposable, absorbent paper napkins.

This unit will be applicable for zero-g and one-g usage.

FOOD SYSTEM STUDY SKETCH

Title: Dispenser For Reusable Personal Wipes



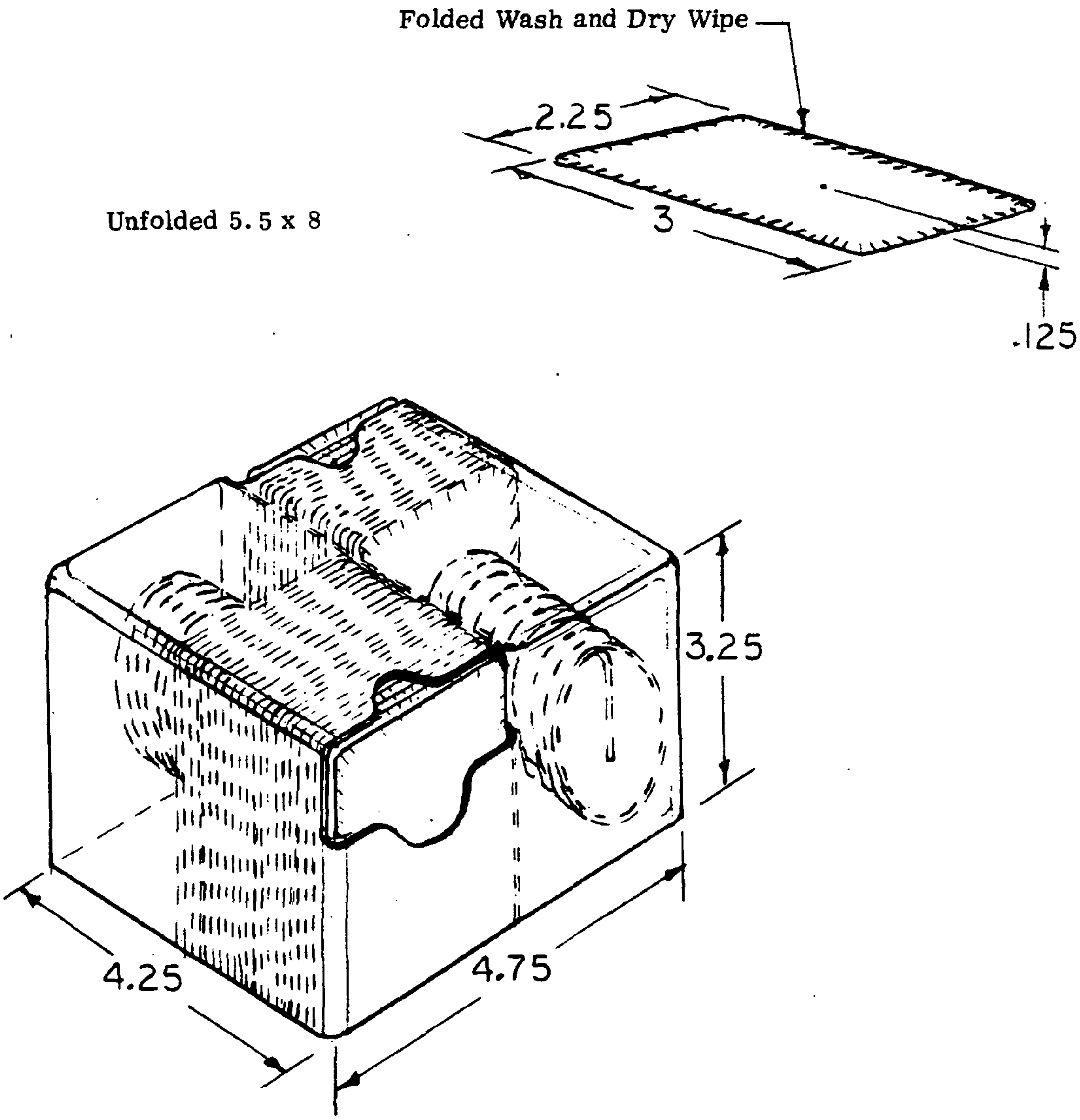
This is a compartmented drawer which has a spring-loaded device for the retention of reusable personal napkins. This drawer has a recessed, finger-actuated, light spring force, latching device for positive retention in its closed position.

This concept is applicable for zero- and one-g usage.

D— 6.2.2

FOOD SYSTEM STUDY SKETCH

Title: Dispenser For Disposable Impregnated Personal Cleansing Wipes



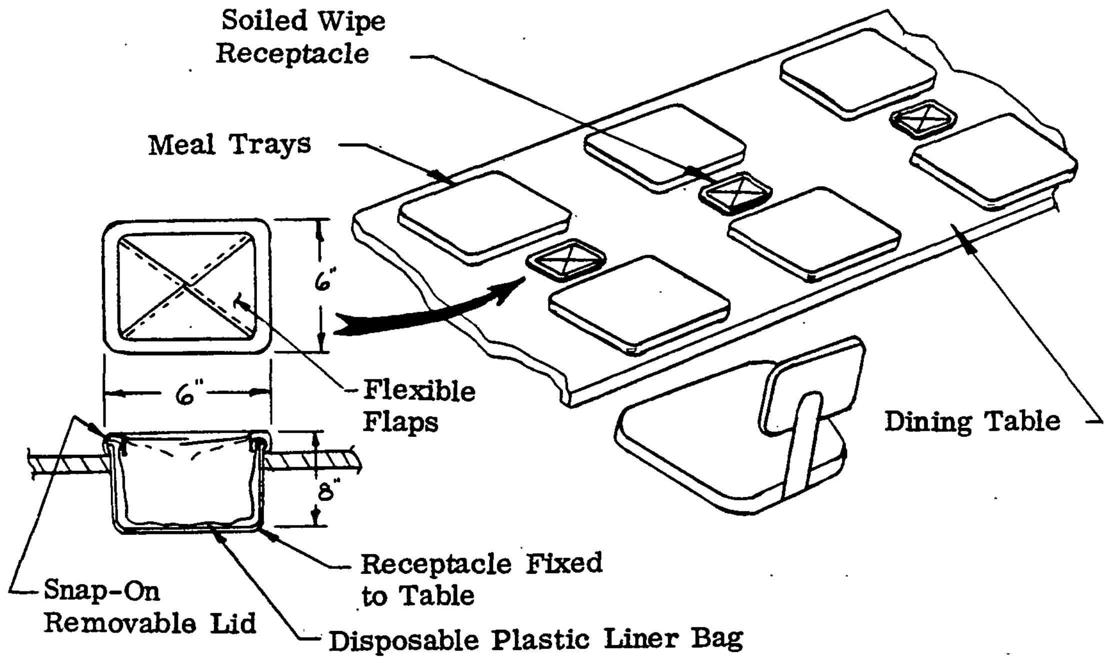
This is a box-type enclosure of aluminum construction having provisions for internal retention and dispensing of disposable impregnated cleansing towelettes in individual packet form.

This method provides a means for superficial cleansing of hands and face immediately after completion of the meal which will minimize crew time at lavatory and water reclamation demands.

D— 6.2.3

FOOD SYSTEM STUDY SKETCH

Title: Receptacle For Temporary Retention of Soiled Wipes



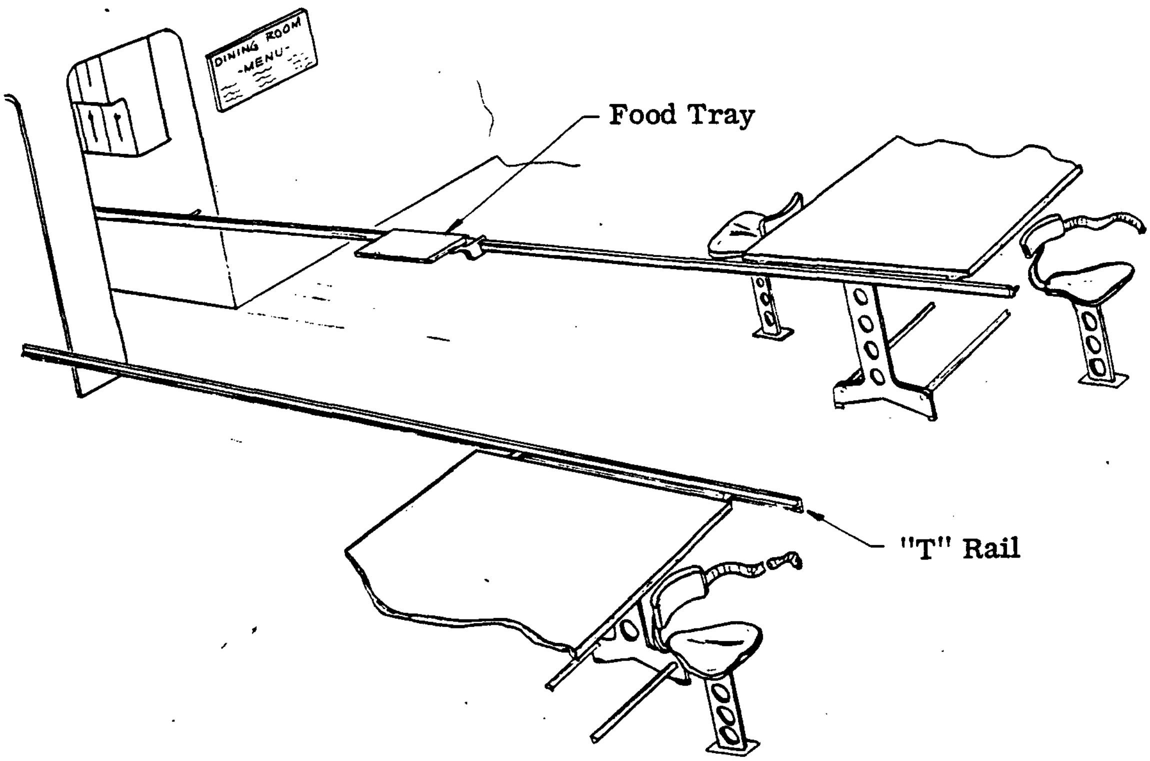
This concept consists of a dining table flush-mounted container for temporary retention of soiled wipes and debris. It consists of a fixed receptacle, which may be of sheetmetal or wire mesh construction, and a removable flap-type cover which also serves to retain the thin film plastic bag which is disposed of along with the contained waste matter.

This concept is applicable for both zero-g and one-g usage.

D— 6.2.4

FOOD SYSTEM STUDY SKETCH

Title: Meal Tray Guided Return Rail System



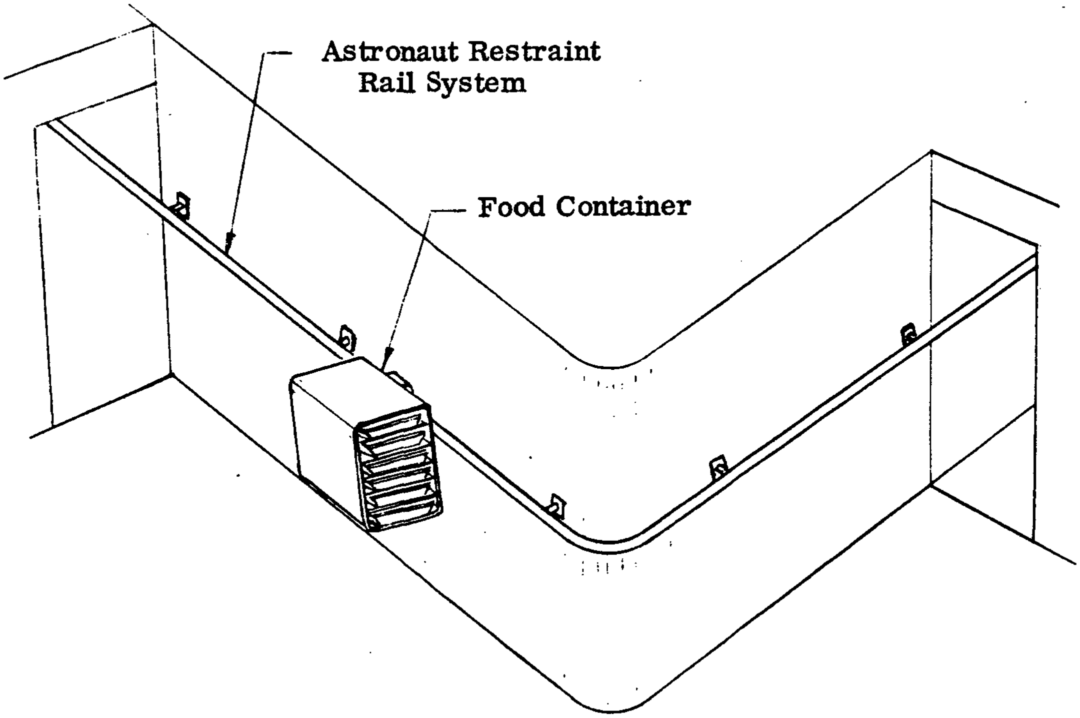
This system utilizes a slotted tray with a guide rail running from the preparation area to the consumption area. It would be used for the transport of prepared meals to the seated crewman in zero-g. It may also be used for the return of the soiled tray to the galley for clean-up after the meal. This system may be mechanically propelled or manually propelled.

A minimum of further development would be needed to perfect this system which would be used basically in zero-g dining.

D— 6.2.9

FOOD SYSTEM STUDY SKETCH

Title: Meal Tray Guided Return Rail System



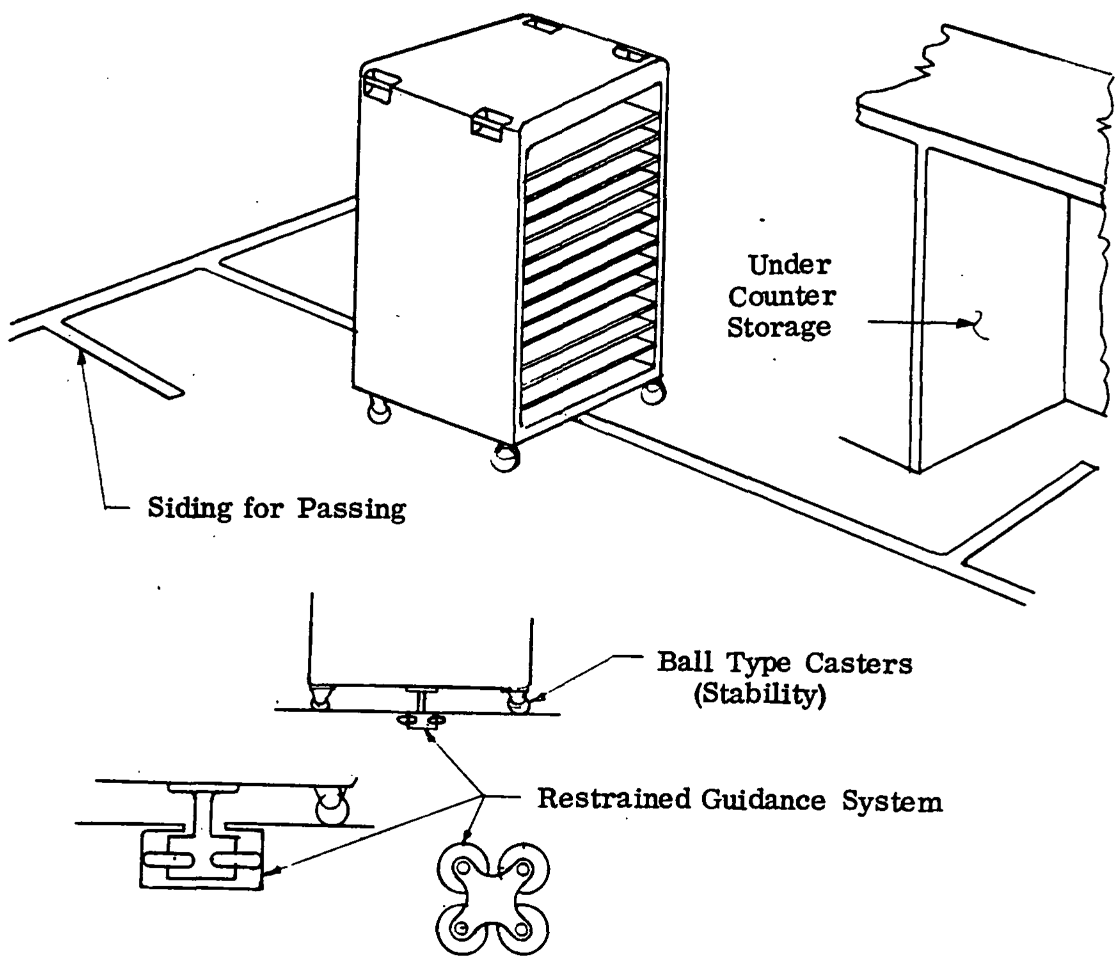
This tray container has been designed to attach to the astronaut restraint rail. This rail is used for guiding containers loaded with trays of food to the dining area and for returning used trays to the cleaning area. It is propelled along the rail.

A minimum amount of further design is needed to perfect this system for zero- and one-g application.

D— 6.2.10 A

FOOD SYSTEM STUDY SKETCH

Title: Meal Tray Guided Return Carrier Unit



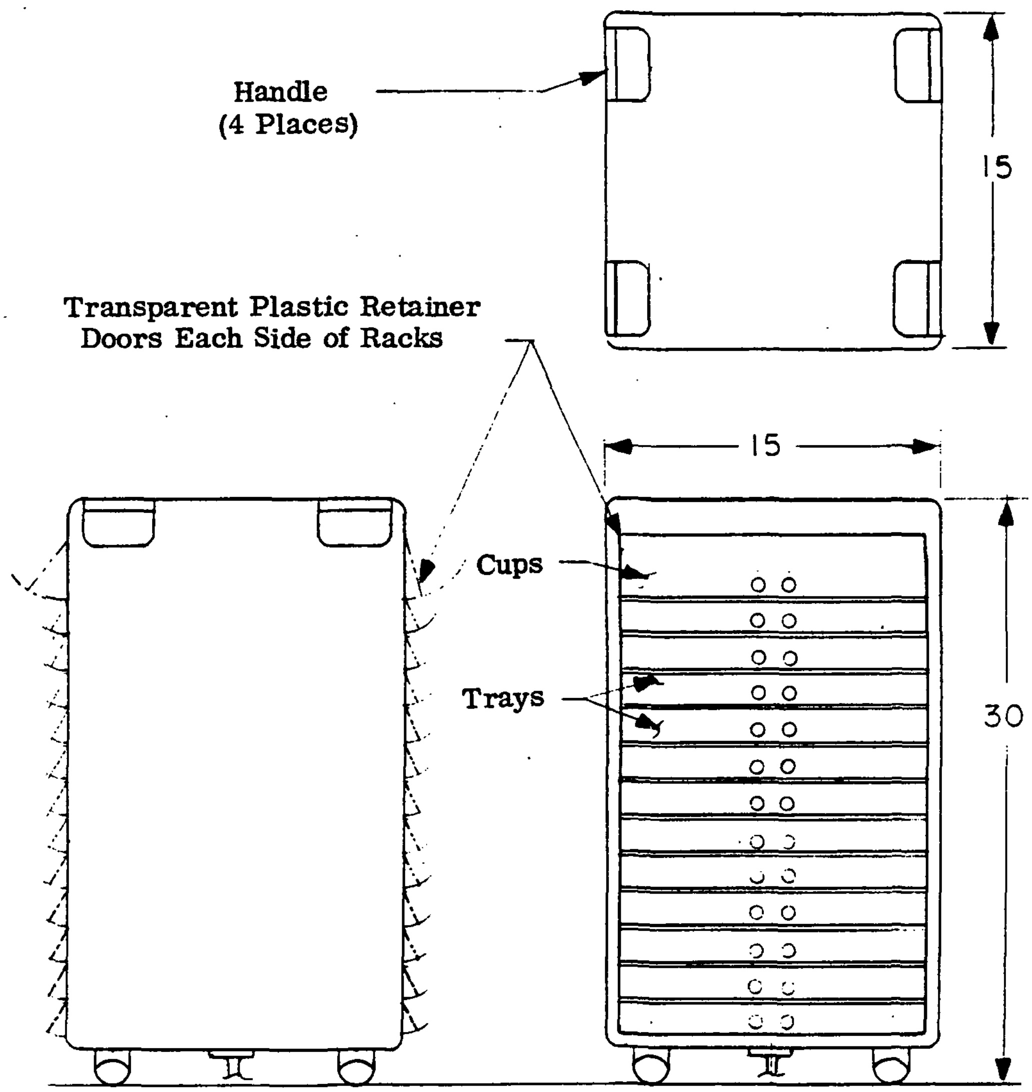
This concept is a rack-type cabinet used to stow soiled trays, cups, utensils, etc. and to transport them to the clean-up area. This unit will be constructed of lightweight aluminum propelled on ball-type casters. A recessed floor track will guide and restrain the carrier in zero- and one-g usage. The casters will provide stability in zero-g and mobility in one-g.

D— 6.2.10 B

(Sheet 1 of 4)

FOOD SYSTEM STUDY SKETCH

Title: Meal Tray Guided Return Carrier Unit

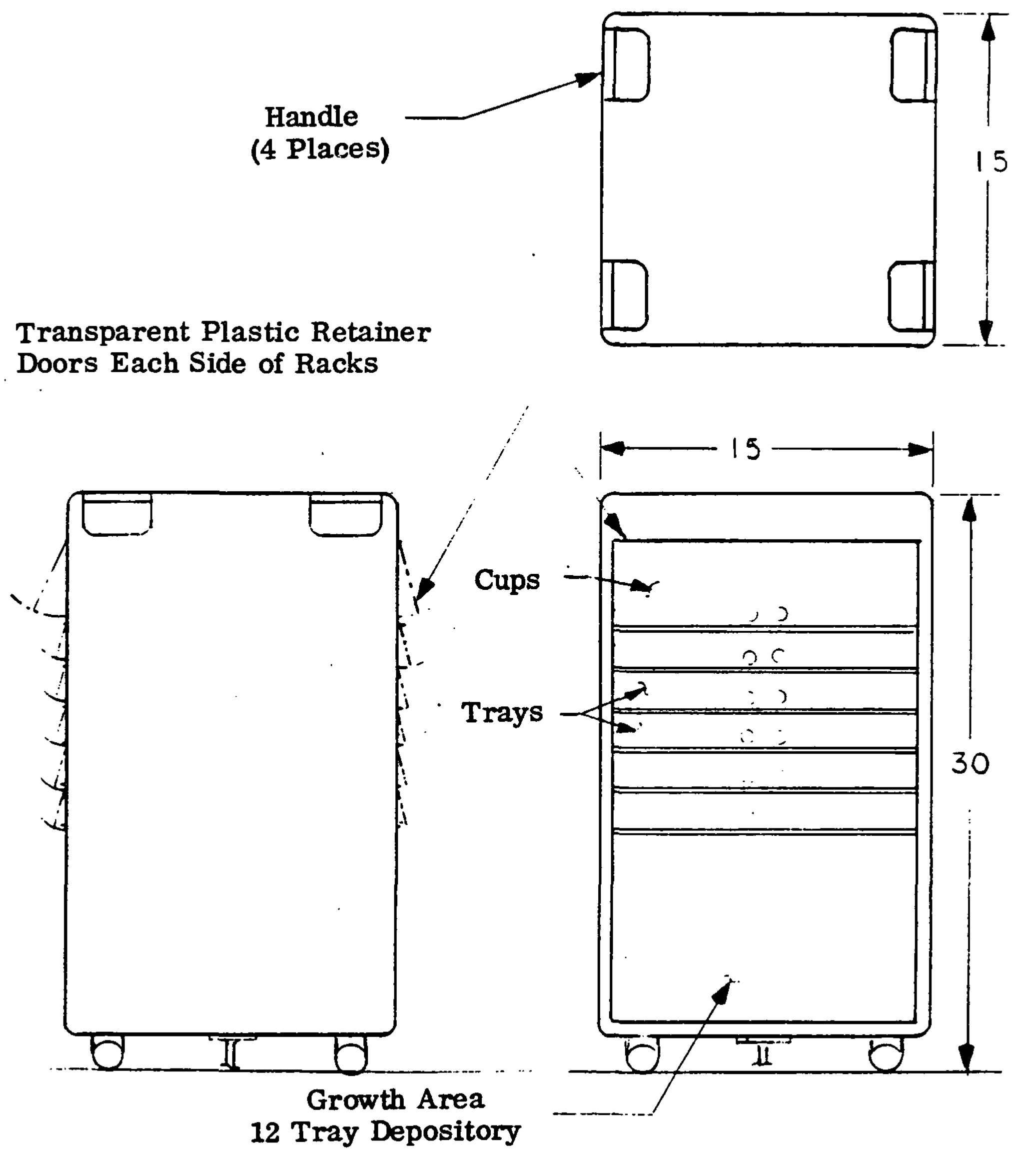


D— 6.2.10 B

(Sheet 2 of 4)

FOOD SYSTEM STUDY SKETCH

Title: Meal Tray Guided Return Carrier Unit

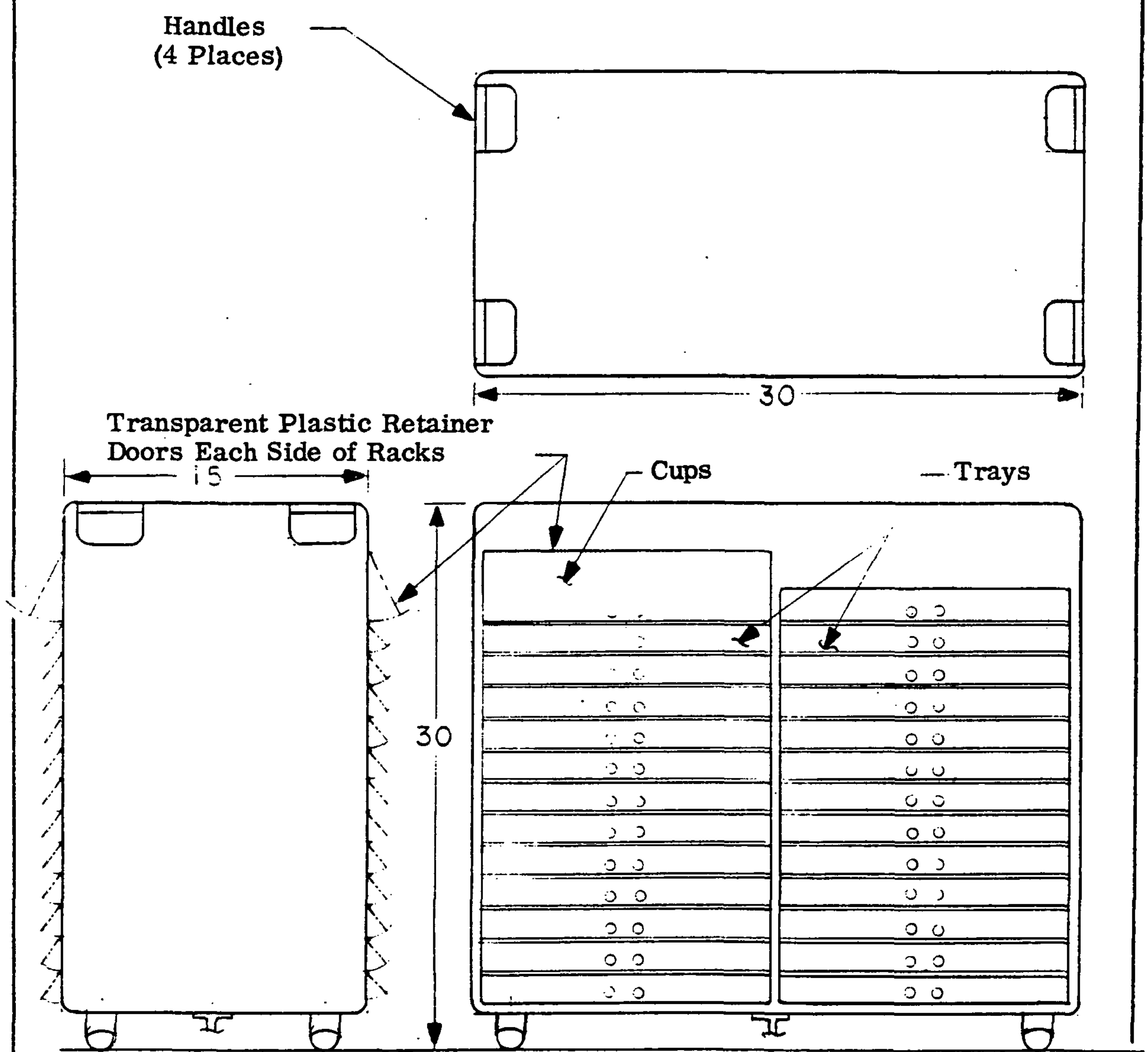


D— 6.2.10 B

(Sheet 3 of 4)

FOOD SYSTEM STUDY SKETCH

Title: Meal Tray Guided Return Carrier Unit

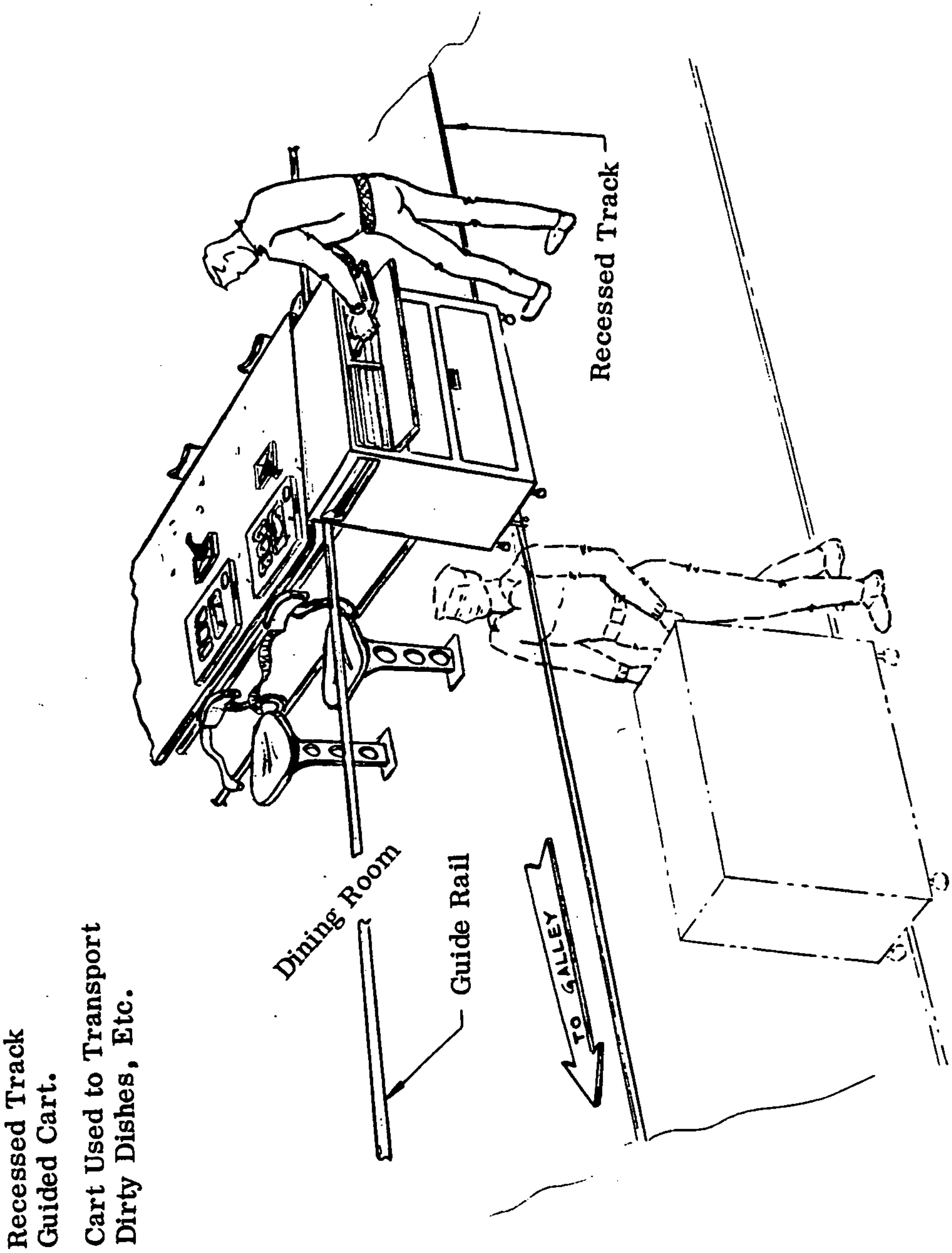


D— 6.2.10 B

(Sheet 4 of 4)

FOOD SYSTEM STUDY SKETCH

Title: Meal Tray Guided Return Carrier Unit



This concept is similar to 6.2.10B except that the cart that is used by the steward to serve the meal, which will be stationed at the dining table, will also be used to store and transport the soiled trays, cups, utensils, etc. to the clean-up area. The cart may be attached to either a hand rail or a recessed floor track.

D— 6.2.10 C

6.3 Candidate Galley Clean-Up Techniques

a. Concept: Temporary Reusable Soiled Wipes Storage Unit (6.3.1)

Concept Description: Appropriately designed receptacle for temporary retention of soiled reusable wipes for subsequent delivery to a laundry facility within the space vehicle.

Technical Analysis: Collection and storage of soiled reusable wipes, if used, will be necessary.

b. Concept: Temporary Debris Collection/Storage Unit (6.3.2)

Concept Description: Appropriately designed temporary waste collection storage unit, intended for hand-placement of debris (soiled disposable wipes, food wraps or containers, unconsumed food, disposable dining aids, etc.) into a removable impervious bag-type liner.

Technical Analysis: This is considered to be a simple-feasible stage of the overall clean-up procedure, with subsequent removal from the galley via some means of transport, to a general space vehicle waste disposal facility.

c. Concept: Combination Debris Collector/Shredder (6.3.3)

Concept Description: Appropriately designed debris collector/ shredder device for reducing bulk volume of waste material prior to transport to a remote general disposal area within the space vehicle. The device would include a removable impervious bag-type liner and provisions for sanitizing by an appropriately effective method.

Technical Analysis: A debris shredder may be advantageous for partial reduction of the volume of waste material, facilitating subsequent disposal requirements; however, compaction is still considered mandatory and the need for pre-shredding becomes questionable. A reassessment of this concept resulted in its being discarded during the interim study phase. Major cause for rejection is superfluous crew time and effort, unwarranted weight, and power consumption to perform a function of dubious value. Removal of waste material from the galley area suffices for area "clean-up"; subsequent disposal techniques were not considered to be within the scope of this Food System Study.

d. Concept: Combination Debris Collector/Compactor (6.3.4)

Concept Description: Appropriately designed debris collector/compactor device to reduce bulk volume of waste material prior to transport to a remote general disposal area within the space vehicle. The device would include a removable impervious bag-type liner and provisions for sanitizing by an appropriately effective method.

Technical Analysis: Compaction of debris generated within the galley and dining areas appears to be a desirable procedure for reduction of the volume of waste material, facilitating subsequent disposal requirements. However, it would seem logical to assume that a debris compactor would be located at a remote general disposal area for reduction of the bulk of waste from all work, residential, recreational, or medical stations, etc., within the space vehicle. A reassessment of this concept resulted in its being discarded during the interim study phase. Major cause for rejection is superfluous crew time and effort, unwarranted weight, and power consumption to perform a redundant function. A compactor is essential, but installed in a general disposal area for all space vehicle waste. Removal of waste material from the galley suffices for area "clean-up"; subsequent disposal techniques are not considered to be within the scope of this Food System Study.

e. Concept: Combination Debris Collector/Shredder/Compactor (6.3.5)

Concept Description: Appropriately designed debris collector/shredder/compactor device for reducing bulk volume of waste material prior to transport to a remote general disposal area within the space vehicle. The device would include a removable impervious bag-type liner and provisions for sanitizing by an appropriately effective method.

Technical Analysis: Theoretically, a preparatory stage process of shredding disposable waste material should increase the efficiency of compacting, resulting in greater reduction of the bulk volume; however, the density of compacted debris is determined by the compression force exerted. For the type of galley/dining debris expected, compaction only, without the additional complexity of a shredding function, was considered adequate, for which reason this concept was discarded during the initial study phase. (NOTE: See Concept 6.3.4 for comment on compaction).

f. Concept: Hand Carriage For Transport of Debris (6.3.6)

Concept Description: Manual carriage of soiled wipe containments and galley debris containments, respectively, to remote laundry and general disposal areas within the space vehicle.

Technical Analysis: This is considered to be a simple feasible means of transport with no space vehicle penalties or interfacing requirements, and is equally suitable for zero-g or partial-g environments.

g. Concept: Manual Movement of Debris Transporter (6.3.7)

Concept Description: Portable, restrained guidance, debris collection and conveyance unit (cart equivalent) with removable impervious bag-type liners, manually moved to either remote laundry or remote general disposal areas within the space vehicle.

Technical Analysis: This can be considered a more convenient means of transport, more applicable to a zero-g environment where personnel movement without some means of restraint (hand-hold) is difficult.

h. Concept: Automatic Movement of Debris Transporter (6.3.8)

Concept Description: Appropriately designed transportable debris collection and conveyance unit with impervious bag-type liners, automatically moved to either remote laundry or remote general disposal areas within the space vehicle.

Technical Analysis: This can be considered a more sophisticated means of transport, the design of which can be made adaptable to either zero-g or partial-g environment. The interface penalties to the space vehicle airframe and associated maintainability aspects are minimal, however, since transport can be accomplished manually, this concept was discarded during the initial study phase even though a selection rationale score of 12.1 was achieved.

i. Concept: Automatic Debris Collector/Shredder/Disposer (6.3.9)

Concept Description: Appropriately designed debris collector/ shredder device with vacuum system for automatic delivery of waste material to a remote general disposal area within the space vehicle. This concept would employ a plenum chamber of appropriate size in which induced air current provides directional movement of air and debris to the disposal facility. The plenum chamber would include provisions for sanitizing by an appropriately effective method.

Technical Analysis: This can be considered as the most sophisticated method of eliminating waste from the galley area, and is obviously the most convenient with respect to galley crew task accomplishment. However, complex space vehicle structural interface requirements are evident, and high mass-air flows are necessary. Also, inherent difficulties exist for sanitizing the plenum chamber. In consideration of design and sanitation problems, the concept was discarded during the initial study phase.

j. Concept: Hand-Washing Sink in Galley (6.3.10)

Concept Description: Hand-washer or sink designed for zero-g application (and adaptable for use in partial-g environment) consisting of a fixed lower section and hinged upper enclosure section having arm insertion ports and a viewing port. Water flow and dispensing of detergents is controlled from the interior. Induced air current within the chamber provides appropriate directional water movement toward a drain port for subsequent reclamation.

Technical Analysis: Hygienic reasons mandate provisions in the galley for hand-washing prior to, during, and subsequent to food handling; however, this concept was discarded during the initial study phase even though a selection rationale score of 11.8 was achieved, only in favor of a multi-purpose galley sink unit per Concept 6.3.11 which provides the same capability.

k. Concept: Combination Galley Sink For Hand and Utensil Washing (6.3.11)

Concept Description: Combination sink unit for washing of hands and/or handwashing of galley/dining reusable utensils (dishes, trays, etc.). Designed for zero-g application (and adaptable for use in partial-g environment), consisting of a fixed lower section sized to accommodate the largest food preparation utensils employed, and a hinged upper enclosure section permitting insertion and/or removal of utensils. The upper enclosure section would have arm-insertion ports and a viewing port. Water flow and dispensing of detergents is controlled from the interior. Induced air current within the chamber provides appropriate directional water movement toward a drain port for subsequent reclamation.

Technical Analysis: Hygienic reasons mandate provisions in the galley for hand-washing prior to, during, and subsequent to food handling. In addition, it is probable that washing of reusable utensils or other small equipment, by hand, will be necessary under certain spontaneous conditions. (NOTE: Washing of all reusable utensils, etc., by hand, is considered unrealistic and unacceptable except for infrequent unusual circumstances.)

l. Concept: Hand-Drying of Reusable Utensils (6.3.12)

Concept Description: Drying of galley/dining reusable utensils (dishes, trays, etc.) by hand, employing suitable wipes, either disposable or reusable type.

Technical Analysis: This is considered a simple feasible method for drying utensils and, although psychologically unacceptable and time-consuming, the concept was retained for further study consideration even though a selection rationale score of 8.7 was achieved during the initial study phase. A re-assessment of this concept resulted in its being discarded, during the interim study phase, as a sole means for accomplishing part of the "clean-up" function because of excessive crew time and effort. However, it is probable that drying (after washing) of reusable utensils or other equipment, by hand, will be necessary under certain spontaneous conditions. (NOTE: Drying of all reusable utensils, etc., by hand, is considered unrealistic and unacceptable except for infrequent unusual circumstances.)

m. Concept: Combination Automatic Dishwasher/Dryer (6.3.13)

Concept Description: Combination washer/dryer unit for automatic cleaning of galley/dining reusable utensils (dishes, trays, etc.), designed for zero-g application (and adaptable for use in partial-g environment). The unit may employ ultrasonic cleaning in addition to washing with water/detergent solutions. A positive method of solvent injection and recovery will be provided, and a trap to collect particulate matter will be included. Suitable retention racks will be included in the cleaning chamber for the items to be cleaned. A heating device is included to elevate the water temperature sufficiently for washing and sterilization, and to provide hot-air drying. After completion of washing and rinse cycles, the water is pumped through a liquid-gas separator for subsequent reclamation.

Technical Analysis: An automatic means for cleansing and sanitizing a large quantity of galley/dining reusable utensils is considered mandatory to reduce galley crew work load and duration of time to perform function.

n. Concept: Dispenser For Disposable Galley Utility Wipes (6.3.14)

Concept Description: Dispenser for disposable utility wipes conveniently located in galley area.

Technical Analysis: Such provisions appear warranted for general wiping purposes; disposable wipes are considered suitable.

o. Concept: Dispenser For Reusable Galley Utility Wipes (6.3.15)

Concept Description: Dispenser for reusable utility wipes conveniently located in galley area.

Technical Analysis: Such provisions appear warranted for general wiping purposes; reusable wipes are considered suitable if laundering facilities are available.

p. Concept: Stowage of Cleaning Equipment (6.3.16)

Concept Description: Stowage compartment or compartments for cleaning equipment, detergents, disinfectants, wipes, etc. incorporating suitable retention provisions compatible with form-factors of the stored items.

Technical Analysis: Suitable stowage provisions for equipment which is not of a fixed-installation type is considered mandatory, particularly in a zero-g environment.

q. Concept Evaluation Summary and Technical Data

The concepts described above are summarized in Table III-32 below, with the rating numbers and "study/discard" decisions as derived from the Selection Rationale Sheets in Data Book - Book III.

TABLE III-32

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM NO.: 6.3 SUB-FUNCTION TITLE: Galley Clean-Up

CONCEPT NUMBER	CONCEPT TITLE	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
		RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
6.3.1	Temporary Reusable Soiled Wipes Storage Unit	14.7		X			X
6.3.2	Temporary Debris Collection/Storage Unit	14.4		X			X
6.3.3	Debris Collector/Shredder	9.0		X		X	
6.3.4	Debris Collector/Compactor	10.5		X		X	
6.3.5	Debris Collector/Shredder/Compactor	8.4	X				
6.3.6	Hand-Carriage For Transport of Debris	13.5		X			X
6.3.7	Manual Movement Of Debris Transporter	12.4		X			X
6.3.8	Automatic Movement Debris Transporter	(12.1)	X				
6.3.9	Automatic Debris Collector/Shredder/Dispenser	8.1	X				
6.3.10	Hand-Washing Sink in Galley	(11.8)	X				
6.3.11	Combination Galley Sink For Hand And Utensil Washing	9.0		X			X
6.3.12	Hand-Drying Of Reusable Utensils	(8.7)		X		X	
6.3.13	Combination Automatic Dishwasher/Dryer	9.7		X			X
6.3.14	Dispenser For Disposable Galley Utility Wipes	16.5		X			X
6.3.15	Dispenser For Reusable Galley Utility Wipes	18.8		X			X
6.3.16	Stowage Of Cleaning Equipment	13.5		X			X

For each of the concepts selected for detailed study, technical data are presented below:

1) Technical Data - Temporary Reusable Soiled Wipes Storage Unit (6.3.1)

In concept, the storage unit is a simple container, having a cloth bag liner such as a commonly used "laundry bag", for zero-g retention of a daily quantity of soiled reusable wipes. The design of the unit should be coordinated with general design of the galley facility and located for convenient access. The unit is applicable to the Food System in providing a means for temporary storage of soiled wash cloths, cloth napkins, and cloth utility wipes resulting from various "clean-up" functions. The cloth bag liner would be laundered, along with its contents, and continually reused until deteriorated. Interface is required with space vehicle water reclamation system as associated with a laundry facility.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.1.1 through 6.3.1.3 and 6.3.1.5 through 6.3.1.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

2) Technical Data - Temporary Debris Collection/Storage Unit (6.3.2)

In concept, the storage unit is a simple container, having an impervious disposable liner such as a commonly used "garbage bag", for zero-g retention of debris generated in the galley and dining areas. The design of the unit should be coordinated with general design of the galley facility and located for convenient access. The unit is applicable to the Food System in providing a means for storing collected debris (i.e., food wraps, waste food, soiled disposable wipes, disposable utensils, etc.) resulting from food preparation, dining, and various "clean-up" functions. Interface is required with space vehicle general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.2.1 through 6.3.2.3 and 6.3.2.5 through 6.3.2.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II. Additional technical data, summarizing the Food System debris, are provided in paragraph 6.4 herein.

3) Technical Data - Hand Carriage Transport of Debris (6.3.6)

The concept of a crew member carrying sealed bags of debris, from the galley to some remote general debris processing/disposal facility, or laundry facility, is applicable to the Food System only insofar as it represents a phase in the "clean-up" function. There is no associated equipment involved, nor any space vehicle interfaces.

Only mission oriented data are contained on Element Concept Data Sheets 6.3.6.1 through 6.3.6.3 in Data Book - Book I.

4) Technical Data - Manually Moved Debris Transporter (6.3.7)

The conceptual transporter is a simple unit of "a box-like open-framework" type construction with provisions for retention of contents while being used in a zero-g environment aboard a space vehicle. The unit would be of a "mobile" type, moved to various locations along a suitably designed track system which enables controlled guidance and zero-g restraint. It is applicable to the Food System in providing a means for accomplishing a phase of the "clean-up" function; i.e., the transport of sealed bags of debris from the galley to some remote general debris processing/disposal facility, or laundry facility. Interface is required with space vehicle structural design.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.7.1 through 6.3.7.3 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

5) Technical Data - Combination Galley Sink/Hand and Utensil Washing (6.3.11)

In concept, the unit would be a modified version of the personal hygiene sink developed by FH/RAD for use in a zero-g environment aboard a space vehicle. FH/RAD has accomplished preliminary design and fabricated working-models for demonstration of the principles of operation in a one-g environment; however, zero-g operation has not yet been evaluated. The FH/RAD design has been proposed to McDonnell Douglas for SKYLAB application, and to North American for Space Station/Base application for which full-scale mock-ups were provided for their Phase "B" Space Station mock-up. The conceptual unit would have a somewhat larger wash chamber to enable insertion of utensils up to the size of a small food tray. The galley sink is applicable to the Food System in providing a means for washing hands prior to, during, and subsequent to food handling, and infrequent washing of some utensils. Interface is required with space vehicle electrical power system, structural design, and water reclamation system.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.11.1 through 6.3.11.3 and 6.3.11.5 through 6.3.11.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

6) Technical Data - Combination Automatic Dishwasher/ Dryer (6.3.13)

The conceptual dishwasher/dryer would be a specially developed unit, suitable for use in a zero-g environment aboard a space vehicle. The unit is applicable to the Food System in providing a means for automatic cleansing and sanitizing of soiled food preparation devices, meal trays, cups, dining utensils, etc. to alleviate an obviously laborious and time-consuming manual task. Interface is required with space vehicle electrical power system, structural design, and water reclamation system.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.13.1 through 6.3.13.3 and 6.3.13.5 through 6.3.13.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

7) Technical Data - Dispenser/Disposable Galley Utility Wipes (6.3.14)

The disposable utility wipes are anticipated to be similar to commercially available perforated roll-type paper wipes commonly used in household kitchens and/or lavatories. The dispenser would be similar to the commercial units of an automatic self-advance feed type. The design of the dispenser should assure satisfactory operation in a zero-g environment, and should be coordinated with the general design of the galley facility, being located for convenient access. The disposable wipes are applicable to the Food System in providing a means for accomplishing various "clean-up" functions; i.e., wiping of hands, wiping food residues from soiled trays or utensils, absorption of food spills, or other uses of similar nature. Interface is required with space vehicle general debris processing techniques.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.14.1 through 6.3.14.3 and 6.3.14.5 through 6.3.14.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II. Additional technical data in the form of a comparison of mission requirements for disposable wipes versus reusable wipes for trade-off considerations, are provided in paragraph 10) hereinafter.

8) Technical Data - Dispenser/Reusable Galley Utility Wipes (6.3.15)

The reusable utility wipes are anticipated to be fabricated from a cloth material having suitable absorption characteristics, in a form compatible with the associated dispenser. In concept, the dispenser is a simple "box-like" open container with suitable zero-g retention provisions for the wipes stored therein. The design of the dispenser should be coordinated with the general design of the galley facility, being located for convenient access. The disposable wipes are applicable to the Food System in providing a means for accomplishing various "clean-up" functions; i.e., wiping of hands, wiping food residues from soiled trays or utensils, absorption of food spills, or other uses of similar nature. Soiled wipes would be laundered and continually reused until deteriorated. Interface is required with space vehicle water reclamation system as associated with a laundry facility.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.15.1 through 6.3.15.3 and 6.3.15.5 through 6.3.15.7 in Data Book - Book I, and back-up information is contained in Data Book - Book II. Additional technical data in the form of a comparison of mission requirements for disposable wipes versus reusable wipes for trade-off considerations, are provided in paragraph 10) hereinafter.

9) Technical Data - Stowage of Cleaning Equipment (6.3.16)

Conceptually, an enclosed cabinet extending from floor toward ceiling would be needed for storage of cleaning equipment, with suitable provisions incorporated for retention of contents in a zero-g environment of the space vehicle. The cabinet could include ultraviolet lamps for germicidal effect, the power for which would be removed whenever the doors are opened for stowage or removal of materials. The design of the cabinet should be coordinated with the general design of the galley facility for an efficient layout acknowledging lesser priority for location of the stowage cabinet. The unit is applicable to the Food System only insofar as it is associated with the "clean-up" function, providing a means for convenient access to a weekly supply of materials used for cleaning and storage of other cleaning devices. Interface is required with space vehicle electrical power system, and structural design.

Detailed data plus mission oriented data are contained on Element Concept Data Sheets 6.3.16.1 through 6.3.16.3 in Data Book - Book I, and back-up information is contained in Data Book - Book II.

10) Comparison of Requirements for Disposable versus Reusable Utility Wipes for General Usage in Galley (6.3.14 versus 6.3.15)

There are some distinct advantages and disadvantages to both disposable and reusable utility wipes on space missions of extended duration, and any decisions as to preference can only be related to trade studies. It is obvious that disposable type will impose penalties in increasing the amount of debris generated, processing, and storage until eventually removed at the next scheduled resupply mission. While this problem will not exist with the use of reusable utility wipes, other penalties are imposed in mandating laundering facilities with consequential increase in electrical energy and water reclamation requirements.

Figure III-102 provides a comparison of installation or initial launch requirements (reference Data Books I and II). It is apparent that disposables have the advantage, but this is only because of a study premise that there would be no expendables or consumables aboard on initial launch:

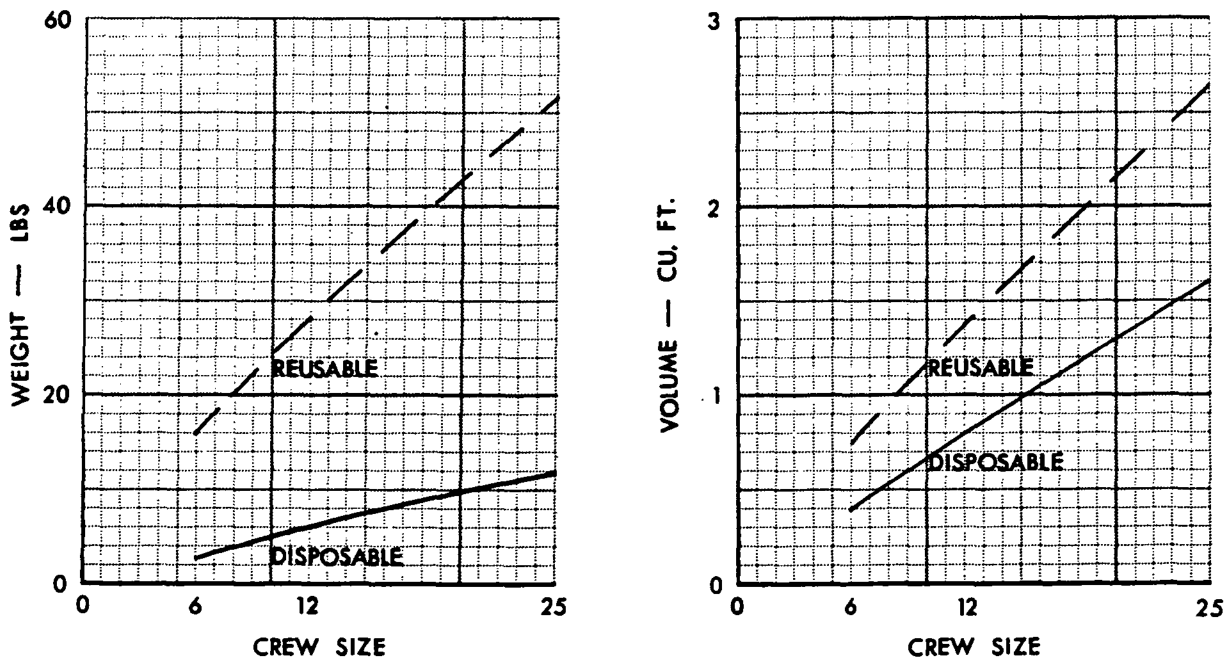


Figure III-102. Weight and Volume of Disposable Versus Reusable Wipes - Installation or Initial Launch Requirements for Galley Only

Figure III-103 provides a comparison of resupply (14- and 90-day) requirements (reference Data Books I and II). It is obvious that reusable utility wipes have the advantage with the average resupply weights and volumes thereof being relatively insignificant.

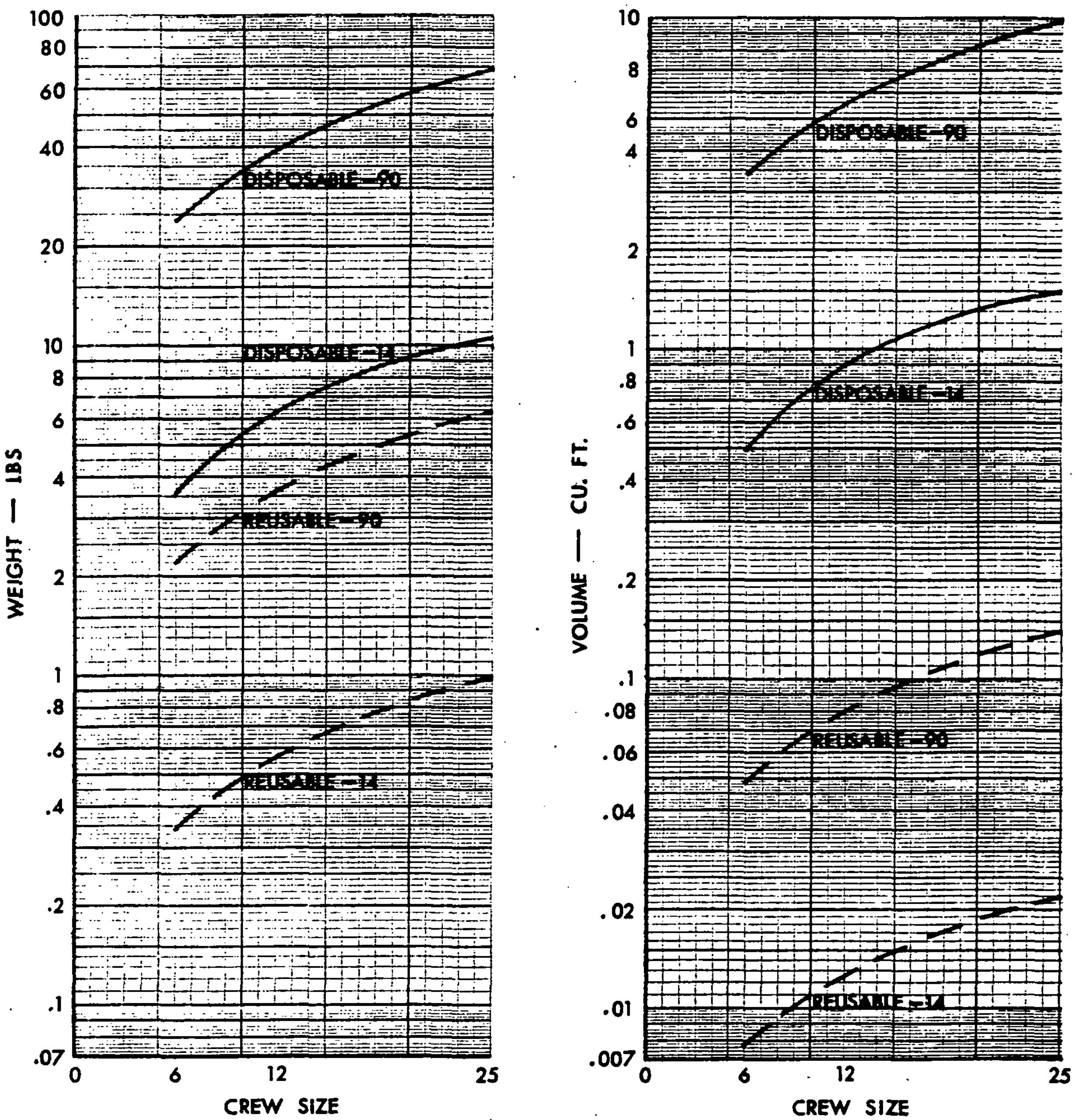


Figure III-103. Weight and Volume of Disposable Versus Reusable Galley Wipes - Resupply Requirements

Figure III-104 provides a comparison of associated (laundering) requirements (reference Data Books I and II).

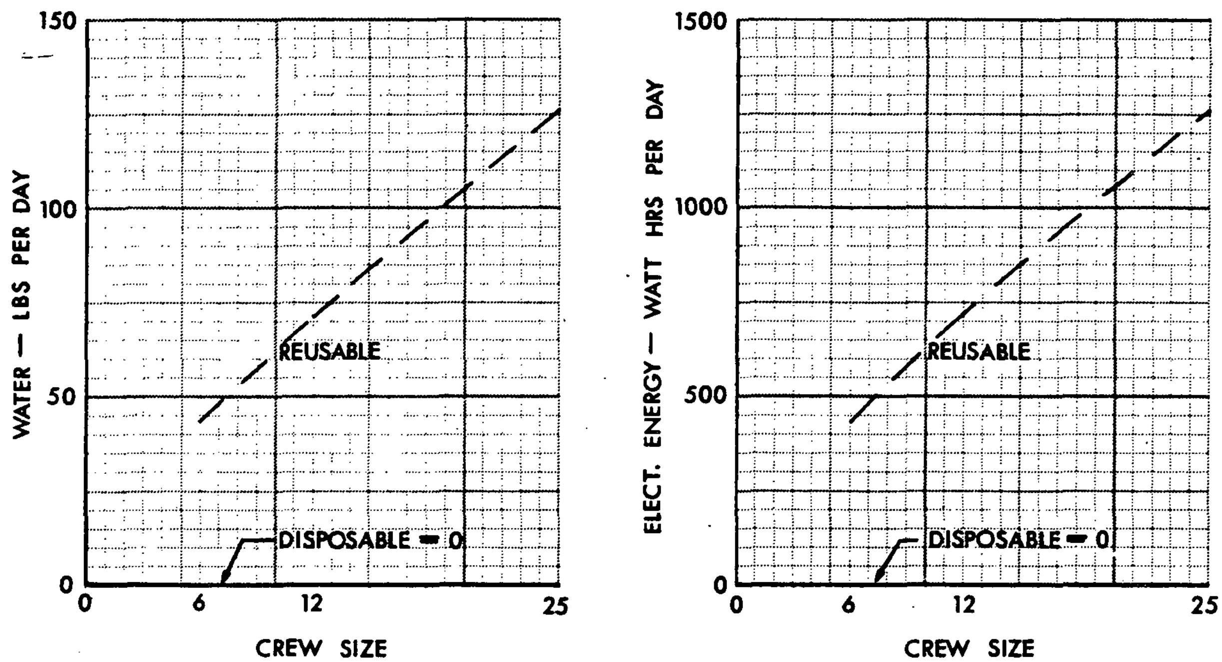


Figure III-104. Laundering Requirements for Disposable Versus Reusable Galley Wipes

It should be noted that reusable utility wipes would, in reality, only be resupplied on an attrition basis, replacing those that have been deteriorated and would only contribute an insignificant or negligible part of the generated debris. The quantity of debris generated through use of disposable utility wipes would be equivalent to the resupply weight and volume thereof as shown in previous comparison curves.

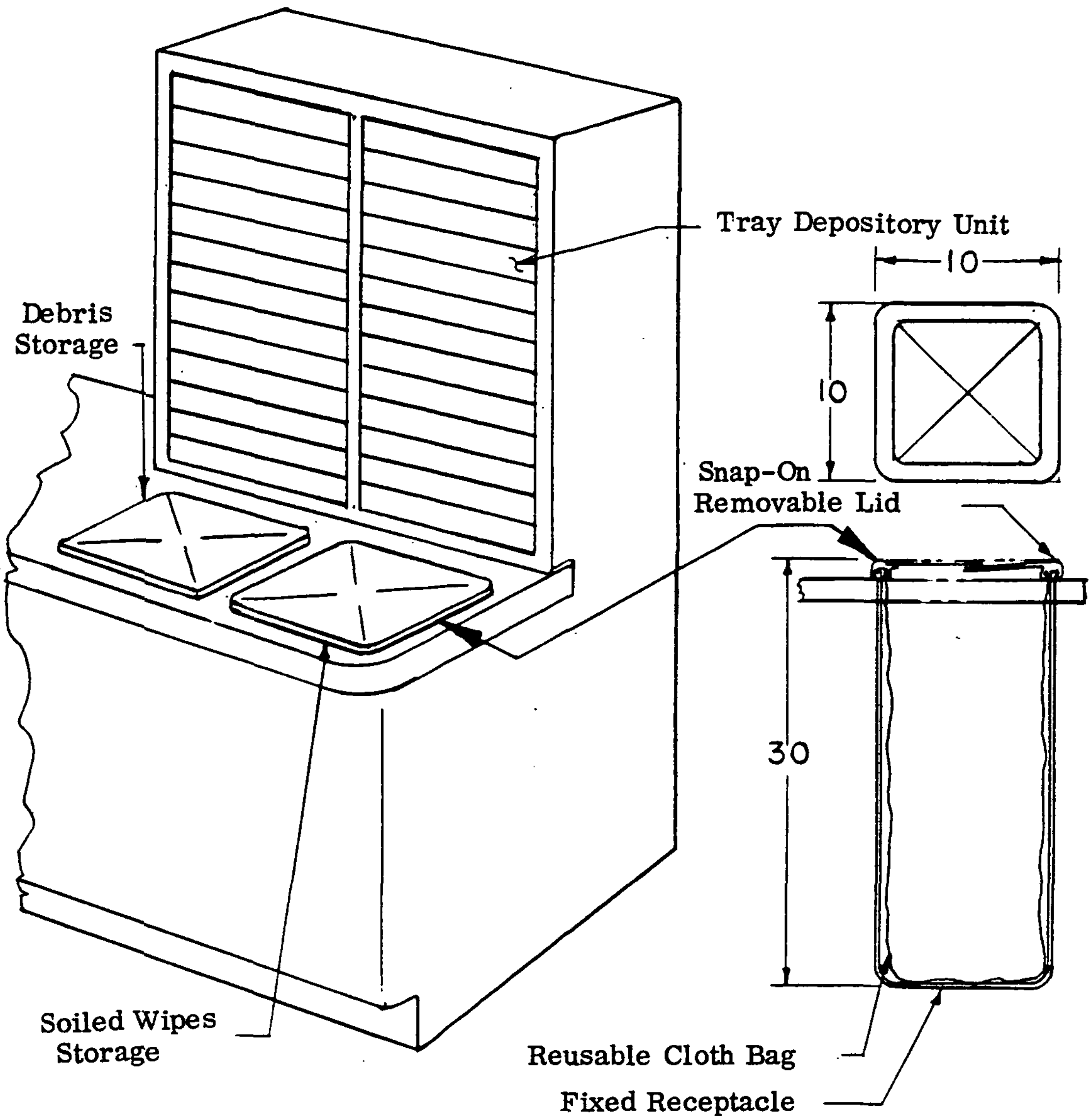
r. Applicable Sketches

The following sketches depict equipment concepts for the techniques described above:

FOOD SYSTEM STUDY SKETCH

Title: Temporary Reusable Soiled Wipes Storage Unit

Each Storage Unit will Weigh Approximately 2.0 Lbs.
Each Cloth Bag Liner will Stow, Clean, in a Space
10 x 5 x 0.5 and will Weigh Approximately 0.2 Lbs.

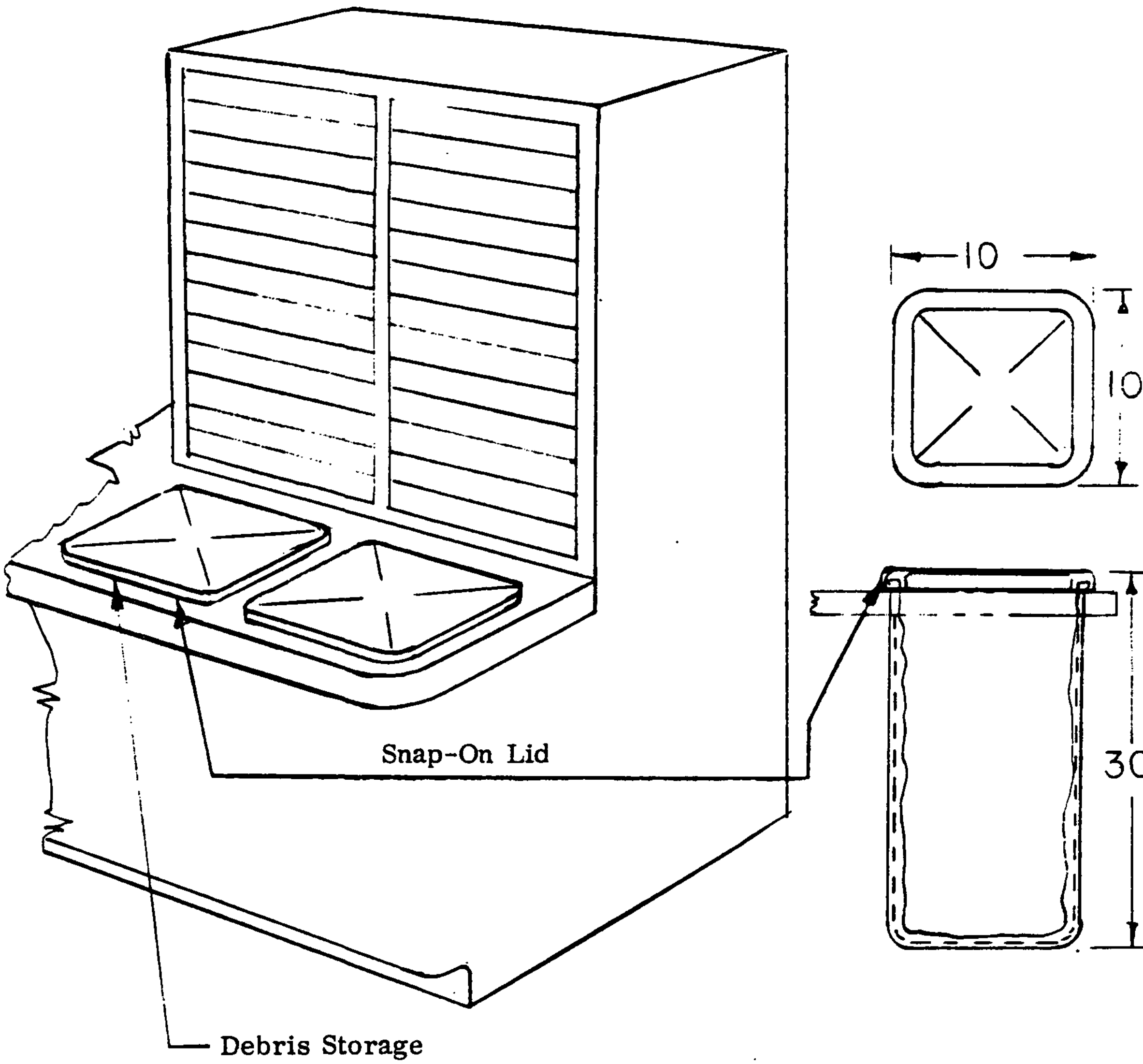


In this concept, the container will consist of a fixed receptacle which may be made of sheetmetal or wire mesh and a removable flap-type cover which also serves to retain the reusable lightweight cloth bag which will be laundered along with the reusable soiled wipes. This concept is applicable for both zero- and one-g usage.

D— 6.3.1

FOOD SYSTEM STUDY SKETCH

Title: Temporary Debris Collection Storage Unit

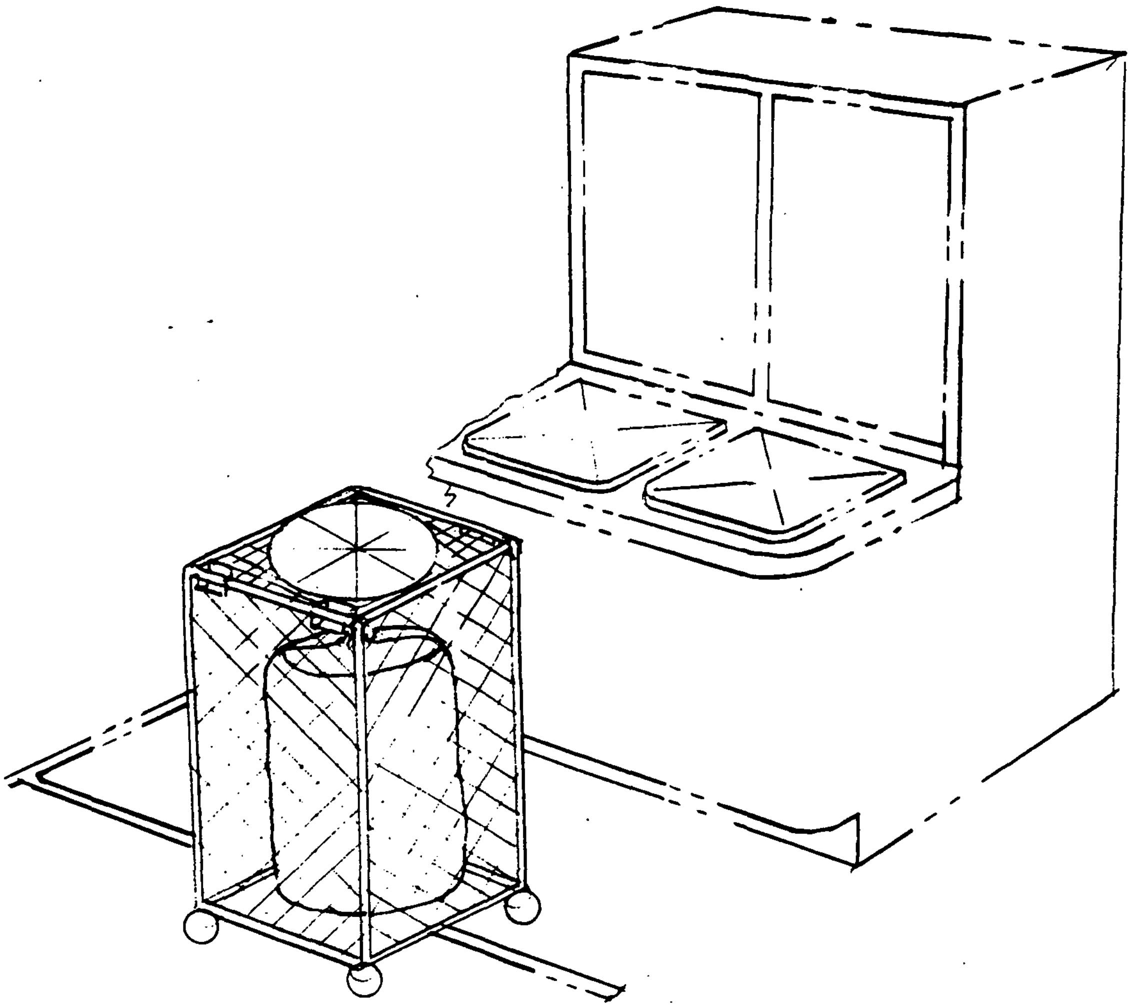


This concept is similar to 6.3.1 except that it is used for temporary storage of debris in the galley using a plastic-type liner to collect the debris, which would be disposed of along with the contained debris. This concept is similar to present day debris collection methods and is applicable for both zero- and one-g usage.

D— 6.3.2

FOOD SYSTEM STUDY SKETCH

Title: Manual Movement of Debris Transporter



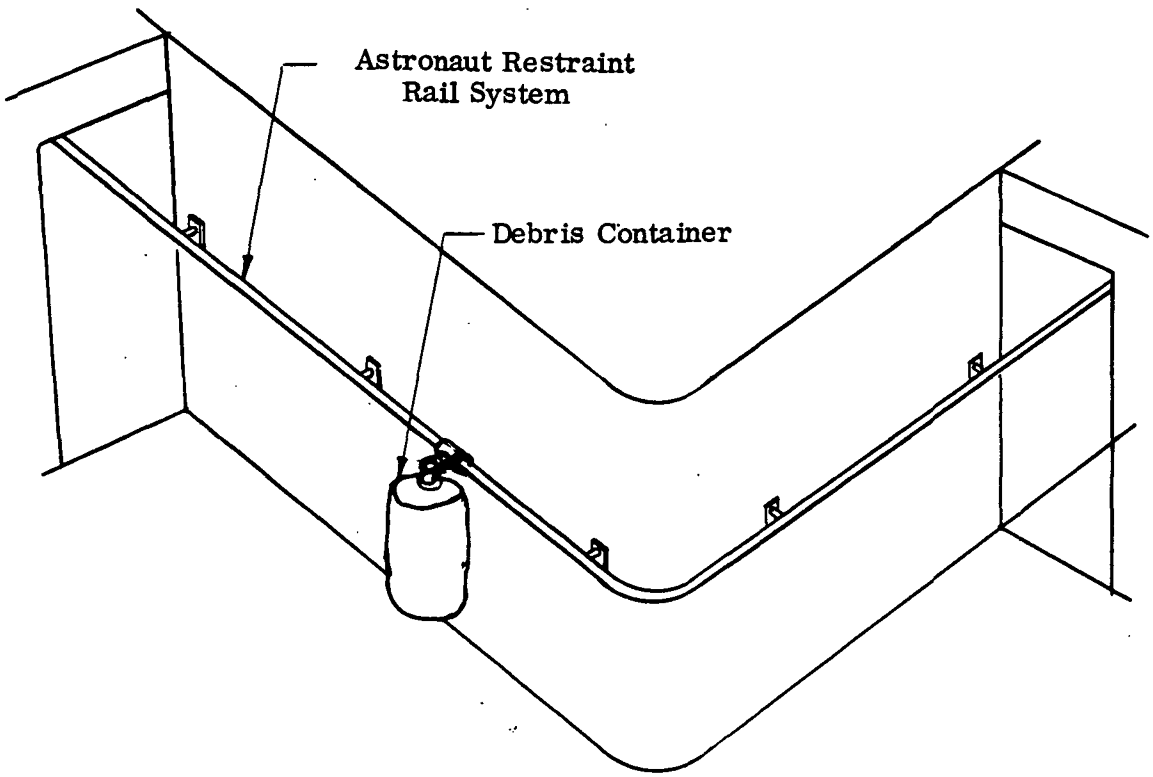
This mobile carrier unit framework is constructed of aluminum having open sides and top which are enclosed with a webbing or net-type closure. It has a single point restraint feature adapter to a floor recessed guidance track for zero-g application. Ball-type casters provide mobility in one-g and stability in zero-g.

This concept is to facilitate the transport of soil wipe containments and various debris containments from the galley to laundry and/or disposal.

D— 6.3.7 A

FOOD SYSTEM STUDY SKETCH

Title: Manual Movement of Debris Transporter



Use Astronaut Restraint Rail System for Debris Transport

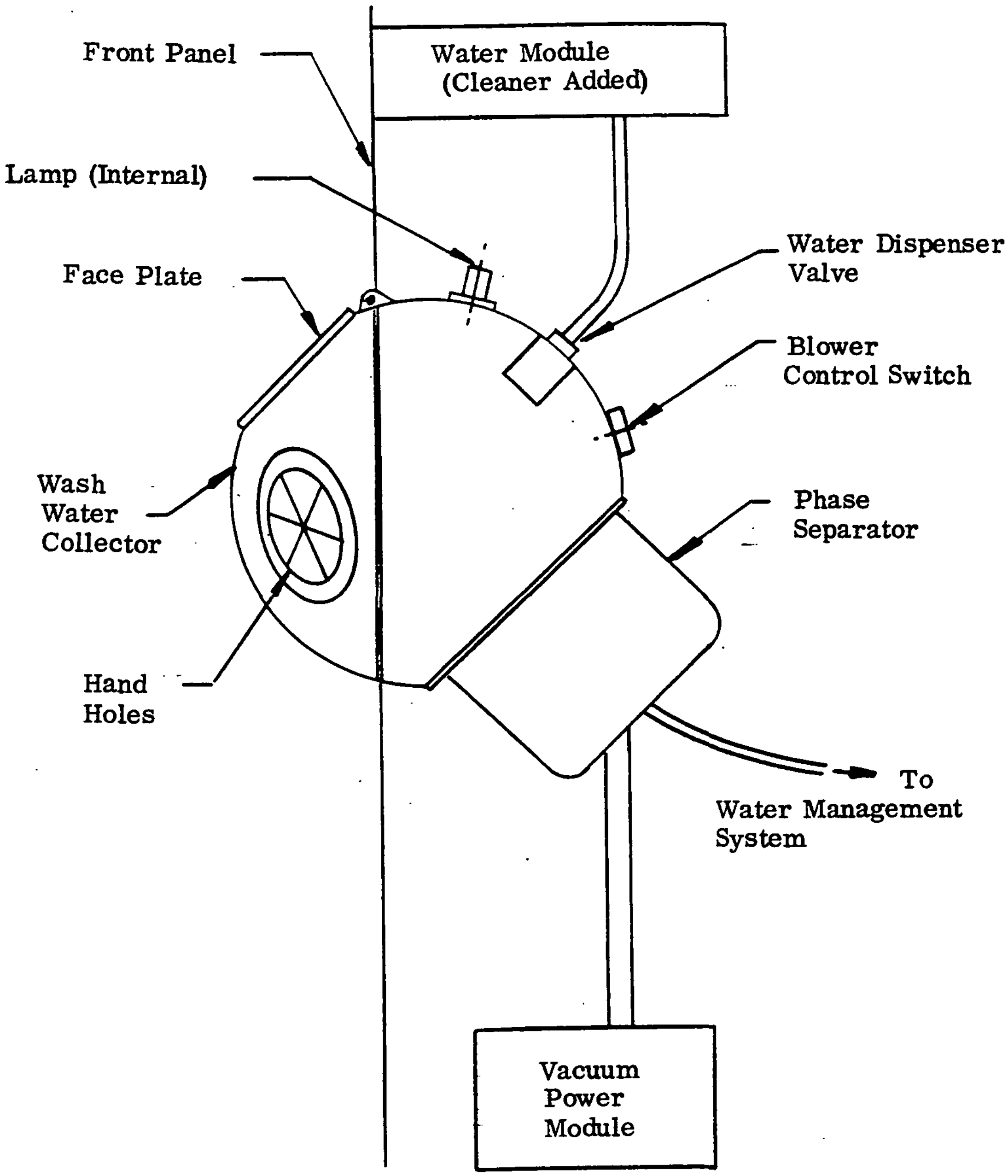
A system of bag transportation using the astronaut restraint rail provides a simple way of transporting debris bags adapted for attachment to the rail.

This concept is mainly used in a zero-g condition.

D— 6.3.7 B

FOOD SYSTEM STUDY SKETCH

Title: Combination Galley Sink for Hand and Utensil Washing

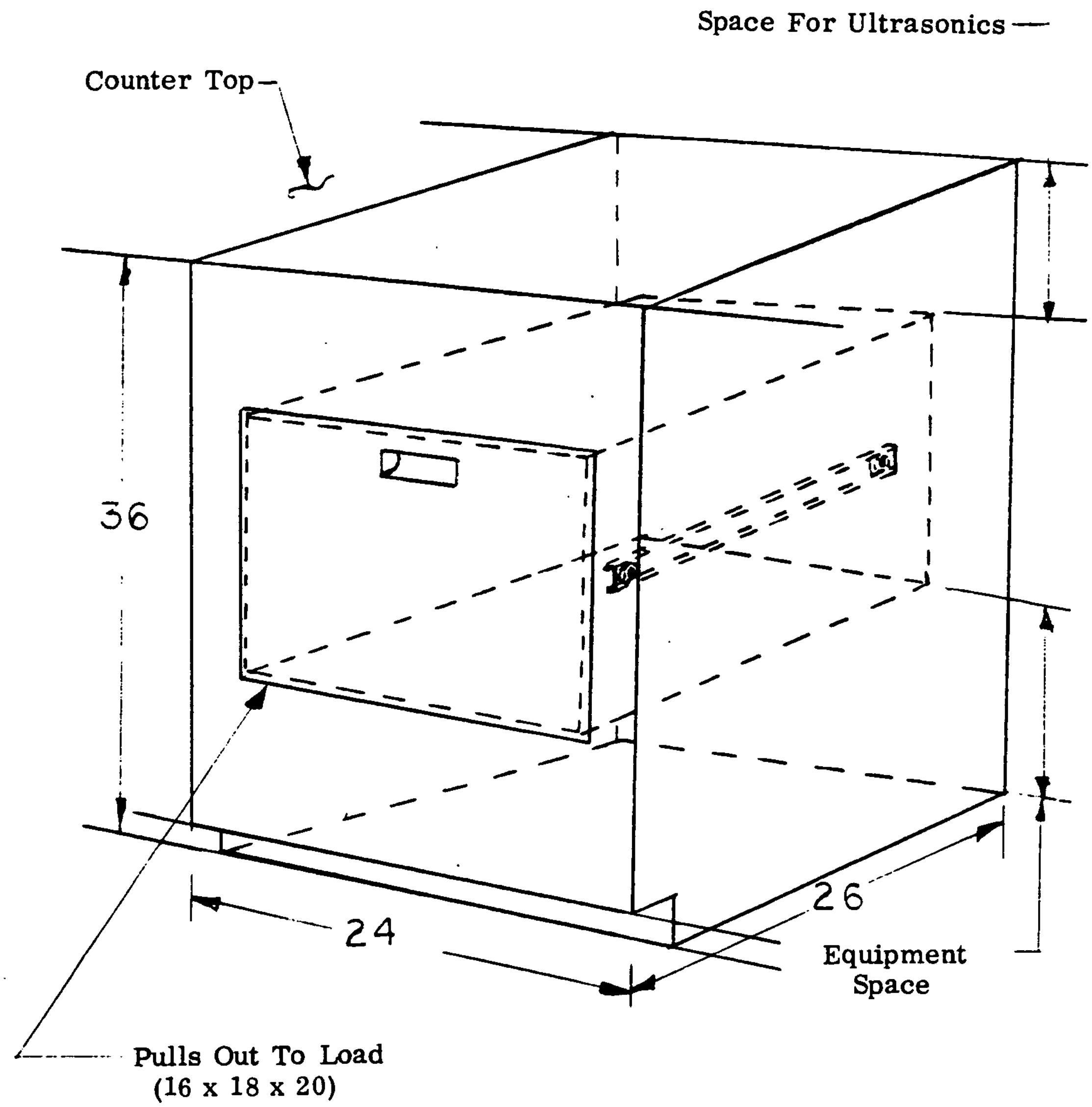


This is a galley sink which will operate in zero- to partial-g. Air is used as the collection and transporting agent for the water. The sink employs an enclosed spherical chamber, the upper half of which is hinged to permit insertion and removal of utensils, and which has hand ports for washing. The lower portion contains the drain and mechanisms for the removal of waste water. Some further development will be necessary to perfect this concept.

D— 6.3.11

FOOD SYSTEM STUDY SKETCH

Title: Combination Automatic Dishwasher/Dryer



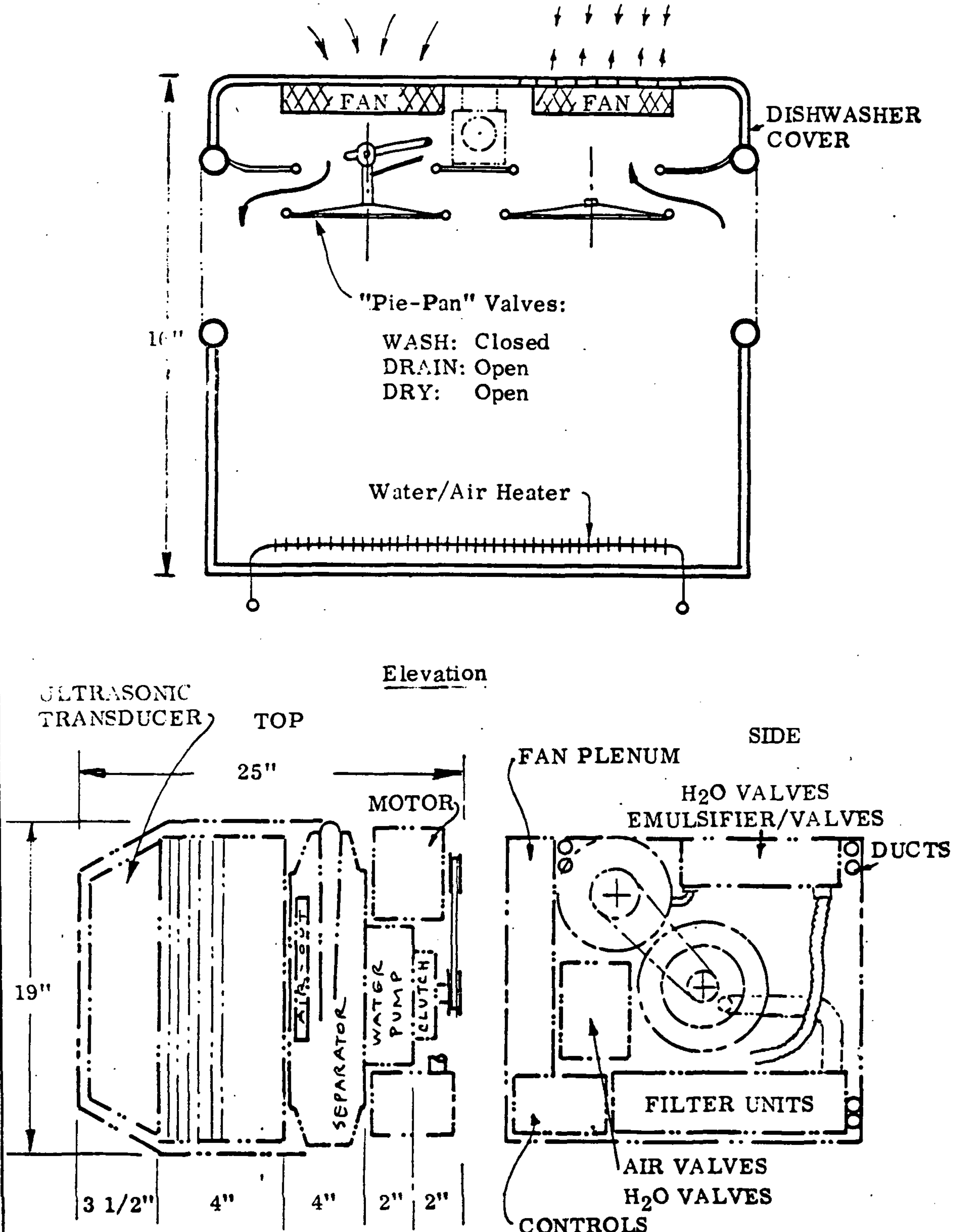
Combination washer/dryer unit for automatic cleaning of galley/dining reusable utensils (dishes, trays, etc.), designed for zero-g application (and adaptable for use in partial-g environment). The unit may employ ultrasonic cleaning in addition to washing with water/detergent solutions. A positive method of solvent injection and recovery will be provided, and a trap to collect particulate matter will be included. Suitable retention racks will be included in the cleaning chamber for the items to be cleaned. A heating device is included to elevate the water temperature sufficiently for washing and sterilization, and to provide hot-air drying. After completion of washing and rinse cycles, the water is pumped through a liquid-gas separator for subsequent reclamation.

D— 6.3.13

(Sheet 1 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Combination Automatic Dishwasher/Dryer

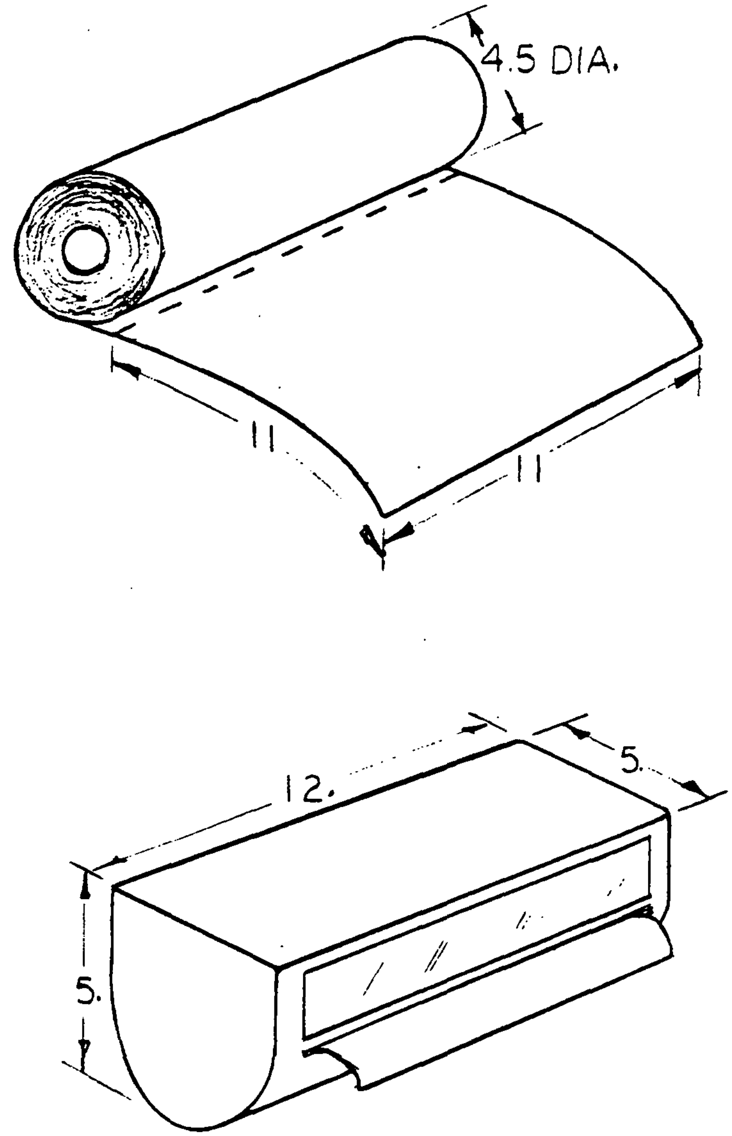


D— 6.3.13

(Sheet 2 of 2)

FOOD SYSTEM STUDY SKETCH

Title: Dispenser-Disposable Galley Utility Wipes



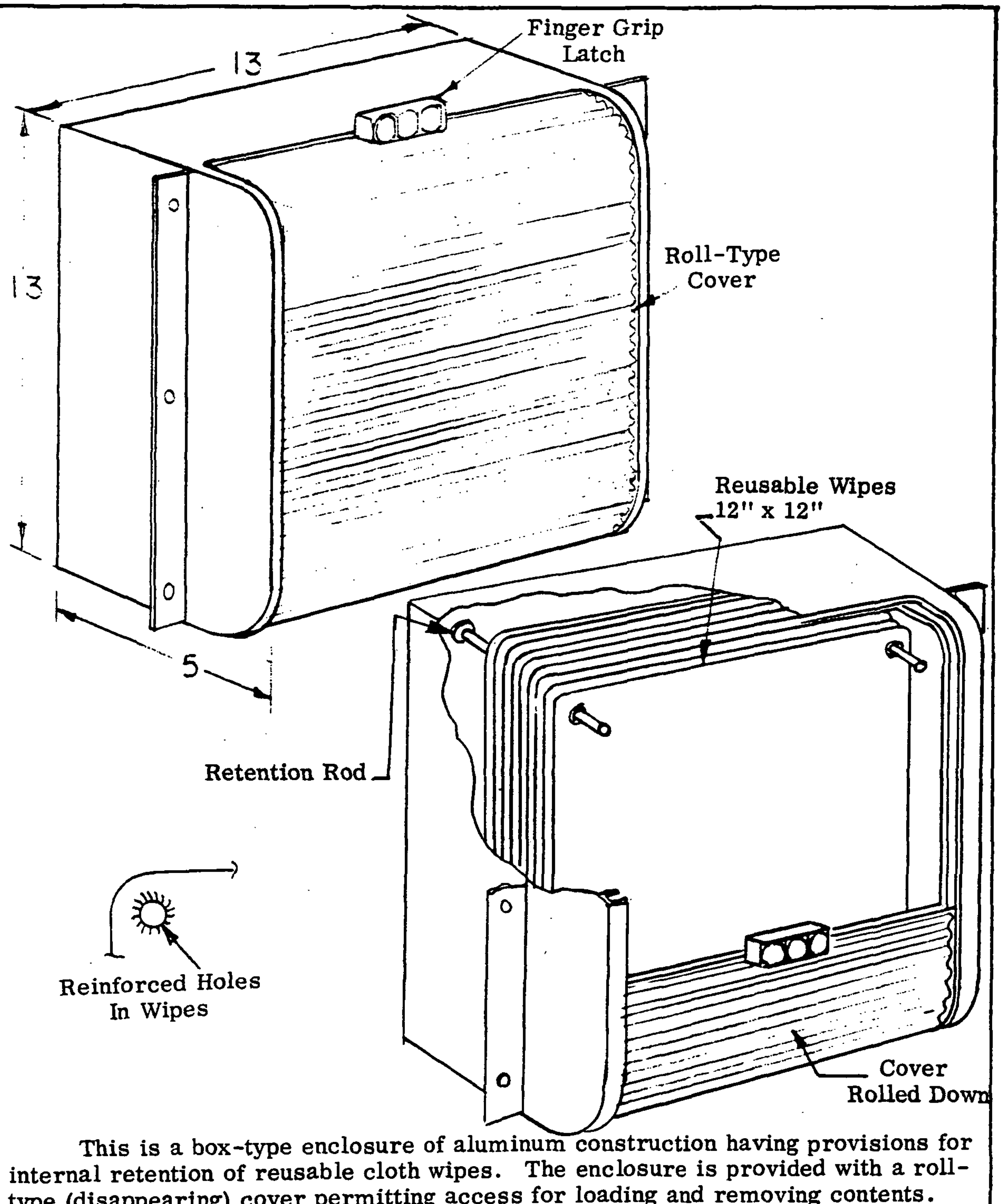
This concept is a lightweight enclosure having provisions for internal retention of disposable-absorbent paper wipes in the form of a continuous roll. The enclosure is provided with a hinged transparent door to permit visual determination of contents supply status.

This concept is similar to present day earth-type equipment and can be used during zero-g or one-g applications.

D— 6.3.14

FOOD SYSTEM STUDY SKETCH

Title: Dispenser For Reusable Galley Utility Wipes



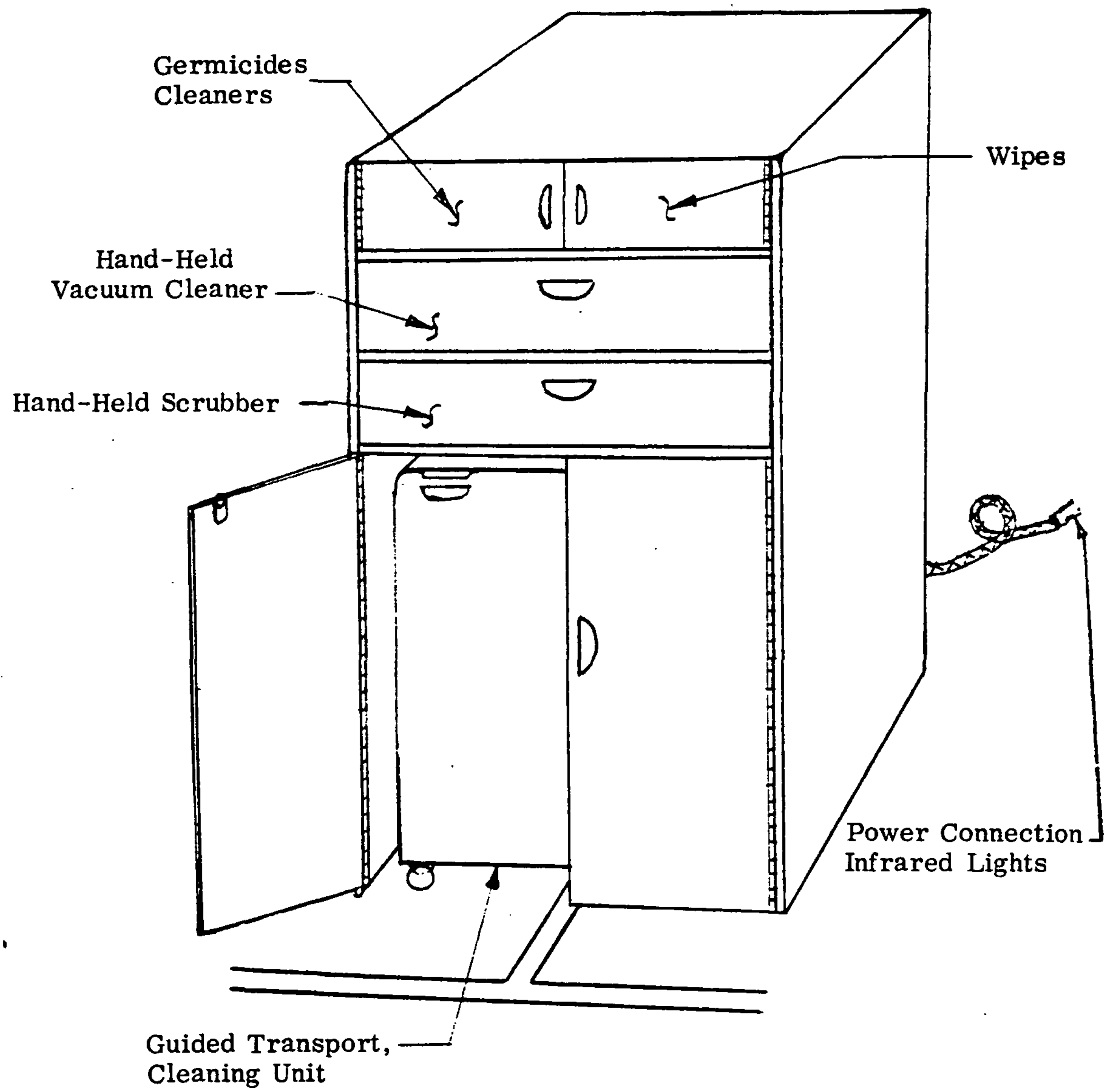
This is a box-type enclosure of aluminum construction having provisions for internal retention of reusable cloth wipes. The enclosure is provided with a roll-type (disappearing) cover permitting access for loading and removing contents. The reusable wipes are of cotton cloth or similar material. The wipes are to be used for drying of hands, wiping spillages, and other miscellaneous clean-up functions in the galley.

This item is for zero- and one-g usage.

D— 6.3.15

FOOD SYSTEM STUDY SKETCH

Title: Stowage of Cleaning Equipment



The storage cabinet provides restrained storage for a guided transport cleaning unit, a hand-held scrubber with attachments, a hand-held vacuum cleaner with attachments, germicides, cleaners, and wipes. Ultraviolet light is provided within the cabinet for its germicidal effects.

D— 6.3.16

6.4 Summary of Galley and Dining Area Debris Generated in the Food System Study Concepts

The debris generated in the galley and dining areas, based on assumptions and/or estimates employed in conduct of the Food System Study (reference Data Books I and II), is provided as a comprehensive list in the following Table III-33. The data is correlated to the study concept numbers where applicable, and is representative of a compacted state. Study Concepts 5.6.4 and 5.6.5 relate to Disposable "Conventional" Utensils and Disposable "Unconventional" Utensils respectively, but do not attempt to suggest preferential usage; however, there appeared to be four logical combinations that may be selected as desirable options, the associated weights and volumes for which are separately included. It should be noted that no other disposable dining aids or utensils were selected for study. There are no applicable study concept numbers for food provisions, therefore, the associated debris is correlated to the study premise combinations of water balance/wet food mix possibilities. In the absence of any authoritative data relating to the new foods, i.e., storage durability, palatability, etc., it is arbitrarily assumed that 10% of the food will be wasted, contributing to the debris generated. The food waste rationale includes food adhering to package material, food spillage or escapement during meal preparation or dining, unconsumed food during dining periods, food spoilage, and/or any indeterminate reason.

Summaries of weights and representative compacted volumes of debris generated per day are provided in a matrix form in Tables III-34A and B, Tables III-35A and B, and Tables III-36A and B following. Each set of tables indicate the sum totals of debris for thirty Food System Study concept combinations; i.e., the six possible food provision premises with associated waste food and package material including "clean-up" debris as a constant, using reusable utensils, or either of four possible combinations of disposable utensils. Tables III-34A and B are applicable to a six-man crew, Tables III-35A and B are applicable to a 12-man crew, and Tables III-36A and B are applicable to a 25-man crew.

TABLE III-33

DETERMINATION OF DEBRIS GENERATED PER DAY

Study Reference	Debris	(6) Weight (lbs)	(6) Volume (cu ft)	(12) Weight (lbs)	(12) Volume (cu ft)	(25) Weight (lbs)	(25) Volume (cu ft)
Disposable Utensils Comb. "A"	18 Forks @ .0055 lbs	.099					
	Forks @ .0035 cu ft		.063				
	18 Spoons @ .0059 lbs	.106					
	Spoons @ .0035 cu ft		.063				
	18 Knives @ .0066 lbs	.119					
	Knives @ .0006 cu ft		.011				
	36 Forks @ .0055 lbs			.198			
	Forks @ .0035 cu ft				.126		
	36 Spoons @ .0059 lbs			.212			
	Spoons @ .0035 cu ft				.126		
	36 Knives @ .0066 lbs			.237			
	Knives @ .0006 cu ft				.022		
	75 Forks @ .0055 lbs					.416	
	Forks @ .0035 cu ft						.2625
	75 Spoons @ .0059 lbs					.443	
	Spoons @ .0035 cu ft						.2625
	75 Knives @ .0066 lbs					.495	
	Knives @ .0006 cu ft						.0450
Sub-Total:		.324	.137	.647	.274	1.354	.5700
Disposable Utensils Comb. "B"	18 Forks @ .0055 lbs	.099					
	Forks @ .0035 cu ft		.063				
	18 Spoons @ .0059 lbs	.106					
	Spoons @ .0035 cu ft		.063				
	36 Forks @ .0055 lbs			.198			
	Forks @ .0035 cu ft				.126		
	36 Spoons @ .0059 lbs			.212			
	Spoons @ .0035 cu ft				.126		
	75 Forks @ .0055 lbs					.416	
	Forks @ .0035 cu ft						.2625
	75 Spoons @ .0059 lbs					.443	
	Spoons @ .0035 cu ft						.2625
Sub-Total:		.205	.126	.410	.252	.859	.5250

TABLE III-33. DETERMINATION OF DEBRIS GENERATED PER DAY (cont'd)

Study Reference	Debris	(6) Weight (lbs)	(6) Volume (cu ft)	(12) Weight (lbs)	(12) Volume (cu ft)	(25) Weight (lbs)	(25) Volume (cu ft)
Disposable Utensils Comb. "C"	18 Knives @ .0066 lbs	.119					
	Knives @ .0006 cu ft		.011				
	18 Sporks @ .0057 lbs	.103					
	Sporks @ .0035 cu ft		.063				
	36 Knives @ .0066 lbs			.237			
	Knives @ .0006 cu ft				.022		
	36 Sporks @ .0057 lbs			.205			
	Sporks @ .0035 cu ft				.126		
	75 Knives @ .0066 lbs					.495	
	Knives @ .0006 cu ft						.0450
	75 Sporks @ .0057 lbs					.428	
	Sporks @ .0035 cu ft						.2625
Sub-Total:		.222	.074	.442	.148	.923	.3075
Disposable Utensils Comb. "D"	18 Spoons @ .0059 lbs	.106					
	Spoons @ .0035 cu ft		.063				
	18 Knife/Fork/Tongs @ .0088 lbs	.158					
	Knife/Fork/Tongs @ .0060 cu ft		.108				
	36 Spoons @ .0059 lbs			.212			
	Spoons @ .0035 cu ft				.126		
	36 Knife/Fork/Tongs @ .0088 lbs			.317			
	Knife/Fork/Tongs @ .0060 cu ft				.216		
	75 Spoons @ .0059 lbs					.443	
	Spoons @ .0035 cu ft						.2625
	75 Knife/Fork/Tongs @ .0088 lbs					.660	
	Knife/Fork/Tongs @ .0060 cu ft						.4500
Sub-Total:		.264	.171	.529	.342	1.103	.7125

TABLE III-33. DETERMINATION OF DEBRIS GENERATED PER DAY (cont'd)

Study Reference	Debris	(6) Weight (lbs)	(6) Volume (cu ft)	(12) Weight (lbs)	(12) Volume (cu ft)	(25) Weight (lbs)	(25) Volume (cu ft)
Food Packaging 20/80 Mix B	6 x Pkg Matl @ .469 lbs Pkg Matl @ .121 cu ft 12 x Pkg Matl @ .469 lbs Pkg Matl @ .121 cu ft 25 x Pkg Matl @ .469 lbs Pkg Matl @ .121 cu ft	2.814	.726	5.628	1.452	11.725	3.025
Food Packaging 20/80 Mix C	6 x Pkg Matl @ .710 lbs Pkg Matl @ .078 cu ft 12 x Pkg Matl @ .710 lbs Pkg Matl @ .078 cu ft 25 x Pkg Matl @ .710 lbs Pkg Matl @ .078 cu ft	4.260	.468	8.520	.936	17.750	1.950
Food Packaging 60/40 Mix B	6 x Pkg Matl @ .336 lbs Pkg Matl @ .077 cu ft 12 x Pkg Matl @ .336 lbs Pkg Matl @ .077 cu ft 25 x Pkg Matl @ .336 lbs Pkg Matl @ .077 cu ft	2.016	.462	4.032	.924	8.400	1.925
Food Packaging 60/40 Mix C	6 x Pkg Matl @ .452 lbs Pkg Matl @ .055 cu ft 12 x Pkg Matl @ .452 lbs Pkg Matl @ .055 cu ft 25 x Pkg Matl @ .452 lbs Pkg Matl @ .055 cu ft	2.712	.330	5.424	.660	11.300	1.375
Food Packaging 85/15 Mix B	6 x Pkg Matl @ .253 lbs Pkg Matl @ .049 cu ft 12 x Pkg Matl @ .253 lbs Pkg Matl @ .049 cu ft 25 x Pkg Matl @ .253 lbs Pkg Matl @ .049 cu ft	1.518	.294	3.036	.588	6.325	1.225

TABLE III-33. DETERMINATION OF DEBRIS GENERATED PER DAY (cont'd)

Study Reference	Debris	(6) Weight (lbs)	(6) Volume (cu ft)	(12) Weight (lbs)	(12) Volume (cu ft)	(25) Weight (lbs)	(25) Volume (cu ft)
Food Packaging 85/15 Mix C	6 x Pkg Matl @ .297 lbs Pkg Matl @ .041 cu ft 12 x Pkg Matl @ .297 lbs Pkg Matl @ .041 cu ft 25 x Pkg Matl @ .297 lbs Pkg Matl @ .041 cu ft	1.782	.246	3.564	.492	7.425	1.025
Food Prov. 20/80 Mix B	6 x Waste Food @ .371 lbs Waste Food @ .009 cu ft 12 x Waste Food @ .371 lbs Waste Food @ .009 cu ft 25 x Waste Food @ .371 lbs Waste Food @ .009 cu ft	2.226	.054	4.452	.108	9.275	.225
Food Prov. 20/80 Mix C	6 x Waste Food @ .379 lbs Waste Food @ .0086 cu ft 12 x Waste Food @ .379 lbs Waste Food @ .0086 cu ft 25 x Waste Food @ .379 lbs Waste Food @ .0086 cu ft	2.274	.0516	4.548	.1032	9.475	.2150
Food Prov. 60/40 Mix B	6 x Waste Food @ .264 lbs Waste Food @ .0076 cu ft 12 x Waste Food @ .264 lbs Waste Food @ .0076 cu ft 25 x Waste Food @ .264 lbs Waste Food @ .0076 cu ft	1.584	.0456	3.168	.0912	6.600	.1900
Food Prov. 60/40 Mix C	6 x Waste Food @ .268 lbs Waste Food @ .0074 cu ft 12 x Waste Food @ .268 lbs Waste Food @ .0074 cu ft 25 x Waste Food @ .268 lbs Waste Food @ .0074 cu ft	1.608	.0444	3.216	.0888	6.700	.1850

TABLE III-33. DETERMINATION OF DEBRIS GENERATED PER DAY (cont'd)

		(6)		(12)		(25)	
Study Reference	Debris	Weight (lbs)	Volume (cu ft)	Weight (lbs)	Volume (cu ft)	Weight (lbs)	Volume (cu ft)
Food Prov. 85/15 Mix B	6 x Waste Food @ .197 lbs	1.182					
	Waste Food @ .0068 cu ft		.0408				
	12 x Waste Food @ .197 lbs			2.364			
	Waste Food @ .0068 cu ft				.0816		
	25 x Waste Food @ .197 lbs					4.925	.1700
	Waste Food @ .0068 cu ft						
Food Prov. 85/15 Mix C	6 x Waste Food @ .198 lbs	1.188					
	Waste Food @ .0067 cu ft		.0402				
	12 x Waste Food @ .198 lbs			2.376			
	Waste Food @ .0067 cu ft				.0804		
	25 x Waste Food @ .198 lbs					4.950	
	Waste Food @ .0067 cu ft						.1675
Concept 6.1.2	1.5 bags @ .05 lbs	.075		.075			
	bags @ .002 cu ft		.004		.004		
	3 bags @ .05 lbs					.150	
	bags @ .002 cu ft						.006
	Estimated debris collected by vacuuming (food particles, vomitus, etc.)	.075	.006	.150	.012	.300	.024
Concept 6.1.3	1.5 bags @ .10 lbs	.150		.150		.150	
	bags @ .008 cu ft		.012		.012		.012
	Estimated debris collected by vacuuming (food particles, escaped packaging material, wipe scraps, etc.)	.225	.018	.450	.036	.900	.072
Concept 6.1.7	20 towelettes @ .013 lbs	.260					
	towelettes @ .0004884 cu ft		.0098				
	30 towelettes @ .013 lbs			.390			
	towelettes @ .0004884 cu ft				.0147		
	40 towelettes @ .013 lbs					.520	
	towelettes @ .0004884 cu ft						.0196

TABLE III-33. DETERMINATION OF DEBRIS GENERATED PER DAY (cont'd)

		(6)		(12)		(25)	
Study Reference	Debris	Weight (lbs)	Volume (cu ft)	Weight (lbs)	Volume (cu ft)	Weight (lbs)	Volume (cu ft)
Concept 6.1.10	.33 sponge @ .02 lbs	.007					
	sponge @ .000309 cu ft		.0001				
	.50 sponge @ .02 lbs			.010			
	sponge @ .000309 cu ft				.0002		
	1 sponge @ .02 lbs					.020	
	sponge @ .000309 cu ft						.0003
Concept 6.2.1	48 napkins @ .0036 lbs	.173					
	napkins @ .00027 cu ft		.0130				
	96 napkins @ .0036 lbs			.346			
	napkins @ .00027 cu ft				.0260		
	200 napkins @ .0036 lbs					.720	
	napkins @ .00027 cu ft						.0540
Concept 6.2.3	18 towelettes @ .013 lbs	.234					
	towelettes @ .0004884 cu ft		.0088				
	36 towelettes @ .013 lbs			.468			
	towelettes @ .0004884 cu ft				.0176		
	75 towelettes @ .013 lbs					.975	
	towelettes @ .0004884 cu ft						.0366
Concept 6.2.4	9 bags @ .001 lbs	.009					
	bags @ .000156 cu ft		.0014				
	18 bags @ .001 lbs			.018			
	bags @ .000156 cu ft				.0028		
	39 bags @ .001 lbs					.039	
	bags @ .000156 cu ft						.0061
Concept 6.3.2	3 bags @ .02 lbs	.060		.060			
	bags @ .00289 cu ft		.0087		.0087		
	6 bags @ .02 lbs					.120	
	bags @ .00289 cu ft						.0173

TABLE III-33. DETERMINATION OF DEBRIS GENERATED PER DAY (concluded)

Study Reference	Debris	(6) Weight (lbs)	(6) Volume (cu ft)	(12) Weight (lbs)	(12) Volume (cu ft)	(25) Weight (lbs)	(25) Volume (cu ft)
Concept 6.3.14	29 wipes @ .0082 lbs	.238					
	wipes @ .00116 cu ft		.0336				
	48 wipes @ .0082 lbs			.394			
	wipes @ .00116 cu ft				.0557		
	84 wipes @ .0082 lbs					.689	
	wipes @ .00116 cu ft						.0974
	Sub-Totals:	1.506	.1154	2.511	.1897	4.583	.3453

TABLE III-34A. DEBRIS WEIGHT PER DAY FOR 6-MAN CREW

Total Weight (Pounds) Including Clean-Up Debris As A Constant		With Waste Food and Package Material of Either					
		20/80 Mix B	20/80 Mix C	60/40 Mix B	60/40 Mix C	85/15 Mix B	85/15 Mix C
Without Disposable Utensils		6.546	8.040	5.106	5.826	4.206	4.476
With Disposable Utensils of Either	Comb. "A"	6.870	8.364	5.430	6.150	4.530	4.800
	Comb. "B"	6.751	8.245	5.311	6.031	4.411	4.681
	Comb. "C"	6.768	8.262	5.328	6.048	4.428	4.698
	Comb. "D"	6.810	8.304	5.370	6.090	4.470	4.740

TABLE III-34B. DEBRIS VOLUME PER DAY FOR 6-MAN CREW

Total Volume (Cu. Ft.) Including Clean-Up Debris As A Constant		With Waste Food and Package Material of Either					
		20/80 Mix B	20/80 Mix C	60/40 Mix B	60/40 Mix C	85/15 Mix B	85/15 Mix C
Without Disposable Utensils		.8954	.6350	.6230	.4898	.4502	.4016
With Disposable Utensils of Either	Comb. "A"	1.0324	.7720	.7590	.6268	.5872	.5386
	Comb. "B"	1.0214	.7610	.7490	.6158	.5762	.5276
	Comb. "C"	.9694	.7090	.6970	.5638	.5242	.4756
	Comb. "D"	1.0664	.8060	.7940	.6608	.6212	.5726

TABLE III-35A. DEBRIS WEIGHT PER DAY FOR 12-MAN CREW

Total Weight (Pounds) Including Clean-Up Debris As A Constant		With Waste Food and Package Material of Either					
		20/80 Mix B	20/80 Mix C	60/40 Mix B	60/40 Mix C	85/15 Mix B	85/15 Mix C
Without Disposable Utensils		12.591	15.579	9.711	11.151	7.911	8.451
With Disposable Utensils of Either	Comb."A"	12.238	16.226	10.358	11.798	8.558	9.098
	Comb."B"	13.001	15.989	10.121	11.561	8.321	8.861
	Comb."C"	13.033	16.021	10.153	11.593	8.353	8.893
	Comb."D"	13.120	16.108	10.240	11.680	8.440	8.980

TABLE III-35B. DEBRIS VOLUME PER DAY FOR 12-MAN CREW

Total Volume (Cu. Ft.) Including Clean-Up Debris As A Constant		With Waste Food and Package Material of Either					
		20/80 Mix B	20/80 Mix C	60/40 Mix B	60/40 Mix C	85/15 Mix B	85/15 Mix C
Without Disposable Utensils		1.7497	1.2289	1.2049	.9385	.8593	.7621
With Disposable Utensils of Either	Comb."A"	2.0237	1.5029	1.4789	1.2125	1.1333	1.0361
	Comb."B"	2.0017	1.4809	1.4569	1.1905	1.1113	1.0141
	Comb."C"	1.8977	1.3769	1.3529	1.0865	1.0073	.9101
	Comb."D"	2.0917	1.5709	1.5469	1.2805	1.2013	1.1041

TABLE III-36A. DEBRIS WEIGHT PER DAY FOR 25-MAN CREW

Total Weight (Pounds) Including Clean-Up Debris As A Constant		With Waste Food and Package Material of Either					
		20/80 Mix B	20/80 Mix C	60/40 Mix B	60/40 Mix C	85/15 Mix B	85/15 Mix C
Without Disposable Utensils		25.583	31.808	19.583	22.583	15.833	16.958
With Disposable Utensils of Either	Comb. "A"	26.937	33.162	20.937	23.937	17.187	18.312
	Comb. "B"	26.442	32.667	20.442	23.442	16.692	17.817
	Comb. "C"	26.506	32.731	20.506	23.506	16.756	17.881
	Comb. "D"	26.686	32.911	20.686	23.686	16.936	18.061

TABLE III-36B. DEBRIS VOLUME PER DAY FOR 25-MAN CREW

Total Volume (Cu. Ft.) Including Clean-Up Debris As A Constant		With Waste Food and Package Material of Either					
		20/80 Mix B	20/80 Mix C	60/40 Mix B	60/40 Mix C	85/15 Mix B	85/15 Mix C
Without Disposable Utensils		3.5953	2.5103	2.4603	1.9053	1.7403	1.5378
With Disposable Utensils of Either	Comb. "A"	4.1653	3.0803	3.0303	2.4753	2.3103	2.1078
	Comb. "B"	4.1203	3.0353	2.9853	2.4303	2.2653	2.0628
	Comb. "C"	3.9028	2.8178	2.7678	2.2128	2.0478	1.8453
	Comb. "D"	4.3078	3.2228	3.1728	2.6178	2.4528	2.2503

7.0 Provide For Recording of Food

The recording of food should be initiated at the time that a detailed menu selection is established defining the specific food items, their combinations, and recipes which are to be included in the prescribed 2800 K Cal/man-day dietary regime. Initial impetus for these choices will probably be provided by the U.S. Army Natick Laboratories "Space Food Prototype Production Guides" which contains the requirements for producing a variety of acceptable dehydrated, bite-sized intermediate moisture, and freeze dehydrated food items. Additionally, the microbiological requirements as specified in this document should be utilized as a universal guide to mission food supply safety. In order to provide the most acceptable food mix, a similar production guide or at least a listing of constraints with end item inspection for conformance conducted by the Government should be included in any provisioning subcontract for those food items which may be classified as commercially available and used regularly in the normal earth environment.

No engineering data sheets have been prepared for the system concepts since Fairchild Hiller's instructions were to not propose specific items of equipment, but only define techniques and requirements which will integrate with, as yet undefined, onboard systems.

7.1 Candidate Recording Techniques

a. Concept: Record Gross Amounts of Food (7.1.1)

Concept Description: The recording of the gross amounts of food packaged for trans-shipment to the spacecraft or shuttle would occur at the various food suppliers. Essentially, the first inventory should describe the quantity, portion or bulk package size, the source of the ingredients, recipes, processes, nutritional characteristics, packaging, shipping and storage criteria, and ultimate utilization criteria.

Located within pertinent areas of the spacecraft freezer, refrigerator, dehydrated and shelf stable food storage, a master log should be maintained to ascertain the total quantity, type of food, and time withdrawal from each storage area for every meal. The methods which may be utilized to record such data include written records, preprinted checklists, voice recording, or computer time sharing via a patch line to the galley from the spacecraft master console.

Technical Analysis: Figure III-105, "Food Inventory Record" has been prepared to illustrate a written recording technique which may be used by crewmen aboard a spacecraft to collect the necessary information.

An initial requirement would be the numerical identification of each food package by the food suppliers. The designations for each food type could be arranged in the following manner:

Food Type	Series
Frozen	100
Dehydrated	200
Shelf Stable	300
Intermediate Moisture	400
Perishable	500
Beverage	600

The food supplies could be packaged in appropriate man meal increments within each number series. In the example shown in Figure III-105, a 6-man 14-day resupply mission was assumed. In actual practice, the food supply would consist of preselected, 6 man/meal packages, consecutively numbered, and stored in each of the applicable storage areas.

For the preparation of any meal during a mission, the menu plan would be consulted; the indicated meal packages would be withdrawn from storage; and corresponding entries would be made on the inventory record.

The record sheet could be either a continuing inventory for the entire mission duration, or could consist of only two columns; one showing the previous day's balance, the other the current tally. This type of written data could be video transmitted to the ground station on a daily basis and, in the latter case, erased to provide a new space for the following day's record.

The data acquired from this type of log would provide a daily tally of the amount of food withdrawn from stores to aid in maintaining real time information on the gross quantities of food available within the spacecraft versus mission duration. This data would be important in planning mission resupply periods, mission alternatives, and emergency situations.

Mission Day	1					2					3					4				
Meal	A	B	C	Out	BAL	A	B	C	Out	BAL	A	B	C	Out	BAL	A	B	C	Out	BAL
(101-184) Frozen	191		102	2	82			103	1	81	104		105	2	79		106		1	78
(201-236) Dehydrated					36	201			1	35					35					35
(301-372) Shelf Stable					72					72		301	302	2	70			303	1	69
(401-436) Intermediate Moisture		401		1	35					35					35	401			1	34
(501-524) Perishable					24		501		1	23			502	1	22					22
(601-672) Beverage	601	602	603	3	69	604	605	606	3	66	607	608	609	3	63	610	611	612	3	60

Figure III-105. Food Inventory Record Concept For 6 Men, 14 Day Resupply

b. Concept: Record Unconsumed Food (7.1.2)

Concept Description: Relatively close estimates (within several percentage points) of the amount of food served versus the amount of food consumed should be maintained for each crewman at every meal. This data will assist in correlating the following: (1) Long- and short-term appetite factor; (2) Estimate of general physiological and psychological conditions; (3) Crew acceptability of food types, their quality, menu plans, and recipies; (4) Overall conditions which may suggest improvements or modifications to the general dining habitat; (5) Nutritional balance of each crewman; and (6) Water balance of each crewman.

Technical Analysis: In order to aid in the collection of the above data, a technique similar to that of the inventory recording procedure previously described could be utilized. Figure III-106, "Record of Unconsumed Food", has been prepared within that framework.

The basic serial numbering system could be structured to provide such designations within each major category as shown in the following theoretical meal:

Orange Drink	609
Fruit Cocktail	105-1
Corn Chowder	105-2
Salmon Salad	105-3
Chicken and Gravy	302
Banana Pudding	502

During each meal period the crewmen would enter the numerical designation and estimated quantity of each item of unconsumed food in the appropriate column on the record sheet. Each day, visual transmission of the record could be made to mission control personnel in order to provide hard copy data for subsequent analysis.

The results of this arbitrary meal have been entered on the record sheet shown in Figure III-106 to illustrate this concept.

The complete nutritional value of each item of the meal shown below would be recorded in mission control.

CREWMAN: ____________________

Mission Day	1			2			3			4			5			6			7			8			9		
Meal	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Frozen (100-)																											
% Unconsumed									20																		
Identifier									105-3																		
Dehydrated (200-)																											
% Unconsumed																											
Identifier																											
Shelf Stable (300-)																											
% Unconsumed									10																		
Identifier									302																		
Intermediate Moisture (400-)																											
% Unconsumed																											
Identifier																											
Perishable (500-)																											
% Unconsumed									5																		
Identifier									502																		
Beverage (600-)																											
% Unconsumed																											
Identifier																											

Figure III-106. Record of Unconsumed Food - Concept

Food Type	Food	Series	K Calories	% Unconsumed	Negative K Calories
Dehydrated	Orange Drink	609	80	-	
Frozen	Fruit Cocktail	105-1	86	-	
Frozen	Corn Chowder	105-2	268	-	
Frozen	Salmon Salad	105-3	265	20	-53
Shelf Stable	Chicken and Gravy	302	123	10	-12
Perishable	Banana Pudding	502	281	5	-14
	Scheduled Intake		1103		-79
			- 79		
	Actual Intake		1024		

c. Concept: Record Waste In Preparation (7.1.3)

Concept Description: A log should be maintained of the quantities and types of food items which have either spilled, burned, or otherwise did not become part of the meal(s) served to each crewman. The equipment and techniques that might be considered in accomplishing this task can be similar to that described in Concept 7.1.2.

This data, when transmitted to the appropriate section of Mission Control, will be important in determining: (1) Efficiency of galley layout; (2) Location of food storage areas; (3) Traffic patterns; (4) Applicability of various food packaging techniques; (5) Utilization of food handling implements; (6) Zero-g considerations in food transport and preparation equipment; (7) Food preparation safety requirements; (8) Materials, equipment, and techniques required to control and clean food spills; and (9) Disposal methods associated with galley wastes.

Technical Analysis: A documented description of these, and any other problems, should be maintained especially in the zero- or partial-g phase of operation, so that equipment and/or technique analysis and rework may be accomplished prior to subsequent missions. Additionally, it is most likely that crewmen will provide immediate "fixes" or alternatives when such incidents occur that may subsequently prove of value to the responsible ground crew in modifying the next generation system.

d. Concept: Spares Inventory Concept (7.1.4)

Concept Description: Coincident with the food inventory, a spare parts inventory should be maintained to determine the precise quantities of parts onboard the spacecraft which may be utilized to repair equipment essential to maintain the food storage and preparation equipment. The stated equipment and spares required for its maintenance would include:

1) Freezer: Solenoids, water pump, sensors, switches, seals, thermoelectric junctions, valves, radiator segments.

2) Refrigerator: Fans, fractional horsepower motors, seals, switches, positive expulsion accumulator, pressure sensors, warming light bulbs.

3) Ovens: Magnetron, power supply components, resistance heating elements, timers, switches, seals, fractional horsepower motors, shafts, and bearings.

Technical Analysis: In missions where a large percentage of the food would be composed of frozen and/or perishable products, the timely repair and maintenance of refrigeration systems and the heating devices applicable to this type of food supply will be a significant factor in maintaining mission integrity. Alternatively, similar requirements will have to be met for rehydration equipment where a significant portion of the inventory is composed of dehydrated foods.

e. Concept Evaluation Summary

The concepts described above are summarized in Table III-37. Rating numbers are not applicable since hardware has not, by instruction, been selected.

TABLE III-37

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 7.1	TITLE: Record Food	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
7.1.1	Record Gross Amounts	*		X	-		X
7.1.2	Record Unconsumed Food	*		X	-		X
7.1.3	Record Waste In Preparation	*		X	-		X
7.1.4	Spares Inventory Control				-		X
	*Rating considered "not applicable" since all concepts will be studied.						
	Note: Concept 7.1.4 (Spares Inventory Control) had been part of the Interim Study as an alphabetical designation, but has been numerically redesignated for this Final Study Report.						

7.2 Candidate Quality Assurance Requirements

To assure that all food products and the equipments necessary to store, prepare, and consume the food shall be of the highest possible quality, it is recommended that a program organization be established together with the appropriate procedures for handling the tasks of reliability, quality assurance, safety, human factors engineering, and maintainability. Technical analyses are not required as concluding commentaries in this section.

The following paragraphs define some of the more pertinent techniques which may be used to implement this type of program.

a. Concept: Program Planning (7.2.1)

Concept Description: Quality Assurance personnel should establish close liaison with mission program management and key design and manufacturing engineering personnel from the inception of any program. This would assist in developing and/or obtaining information relative to all factors affecting quality. With this data, it is possible to correlate such associated areas as food supplier competance, hardware design and fabrication, tooling, development, and qualification testing. All quality assurance activities would be governed by either existing procedures or supplemented by such special procedures as may prove necessary.

b. Concept: Procurement Control (7.2.2)

Concept Description: Supplier capabilities before and during the tenure of the program should be checked by making initial and periodic surveys of facilities, procedures, products, and personnel. All procurement orders should be reviewed to ensure that the required quality information and applicable source inspection clauses are included.

c. Concept: Inspections and Tests (7.2.3)

Concept Description: These procedures would be exercised as source inspection of raw material food items, hardware materials, and during manufacturing processes where the failure to determine defects or unsatisfactory conditions could not be tolerated either because safety or quality would be compromised.

d. Concept: Packaging and Shipping (7.2.4)

Concept Description: All food items or equipments should be inspected for conformance to design considerations, configuration, identification, freedom from damage, preservation environment, and packaging.

e. Concept: Reliability (7.2.5)

Concept Description: Reliability Engineering should be an integral part of the program from definition of the food types through processing and eventual storage in the spacecraft. All equipment (prototypes, flight articles, flight support, ground support, and spares) should also come within the scope of the reliability plan. Suggested methods for implementing these considerations include: (1) Reliability prediction, (2) failure mode and effects analysis, (3) fault tree analysis, (4) maintainability and human engineering, (5) design review, (6) failure reporting and correction, and (7) standardization of practices.

f. Concept: Maintainability (7.2.6)

Concept Description: The approach to the attainment of a highly maintainable food system should be made in accordance with procedures which require a formal analysis of the system as a whole and all major subassemblies and components. This technique will help to determine the best maintainability design, reduce the possibility of failure through the development of adequate preventative maintenance inspection procedures, and reduce the downtime penalties of unavoidable unscheduled maintenance.

g. Concept: Visual Monitoring of Equipment Status (7.2.7)

Concept Description: The refrigerator, freezer, and various equipments used to heat food should be designed to provide visual monitoring readouts. These equipment concepts include sublimation, radiators, thermoelectric, and air cycle, for refrigerated storage and hot air convection, radiant heat, and microwave for food heating.

Although specific monitoring techniques cannot be defined, in view of the wide range of concepts, the following general recommendations for visual readout can be made as applicable: (1) temperature, (2) pressure, (3) fluid flow, (4) revolutions per minute, (5) valve position, (6) amperage, and (7) voltage.

Technical Analysis: Although flight qualified systems will be designed for essentially automatic operation, system status should be visually checked to maintain reliability of the food system and assist in isolation of maintenance and/or repair requirements.

The visual readouts may be part of each specific item of equipment; may be interconnected to a central status panel, or may be part of an automatic computer status check system depending on vehicle sophistication and/or size.

h. Concept: Audio/Visual Warning System (7.2.8)

Concept Description: The refrigerated food storage and food heating equipment should include warning lights and sound signals common with the visual readout system described in Concept 7.2.7. This technique would immediately indicate system malfunction in sufficient time to prevent major equipment repair.

Technical Analysis: The refrigerator/freezer combination in a number of missions will contain the majority of available food, and the heating equipment will be used to prepare that food. Unless malfunctions are immediately isolated and rectified, failure of the food system could result. Results of such malfunctions could, in the worst case, terminate the mission or require emergency resupply, or in the best case, probably degrade the hedonic acceptability of the food thus downgrading crew performance.

i. Concept: Safety (7.2.9)

Concept Description: In order to maintain the astronauts' food system at optimum conditions, several specific programs should be instituted under the auspices of a quality assurance engineering group.

1) Assay of Food-Borne Microorganisms and their Toxic Metabolites

Considering the variety of foods and the methods by which each is handled during processing, it is apparent that practically all types of microorganisms are potential contaminants. It is assumed that rigid programs of microbial monitoring of food supplies will be established from the point of raw material acquisition through the processed, packaged, end product.

There should be, however, a requirement to provide the crewmembers with a rapid method of microbial contaminant identification of at least two pathogenic organisms; namely, Salmonellae group and Clostridium botulinum A, B, E and F toxins (Type F elaborates the Type C toxin which is non-pathogenic for humans). A suggested technique might be the development of an initial spot test (Pigoury modified reaction with gloxalic acid) to determine contaminant presence. A second step may be desirable to determine group characterizations using a latex and/or bentonite flocculation technique.

Other techniques such as the detection of enzymatic respiration, gas formation, etc. may be considered as alternative methods depending upon such factors as crew time and available spacecraft facilities.

2) Visual Food Spoilage Indicators

One method of determining the thermal history of frozen foods that is presently being tested for commercial applications can also be considered for application to the space station frozen food system. The following is a brief description of this technique.

A small strip of filter paper (.25 x .50), saturated with a pH indicator, is placed in a dome-shaped, clear plastic capsule. Two spheres (.125 diameter) of an acid/salt mixture are microencapsulated in a wax-like material and placed in contact with the filter paper. The assembly is then bonded to the food package. During the freezing cycle of the food, the acid/salt mixture expands and cracks the encapsulation. If, at any time, the frozen food package experiences a temperature rise in excess of 30°F, the acid/salt mixture melts and saturates the filter paper, resulting in a change in its color.

3) Development of Tests, Procedures, and Processes for Material Selection and Food Equipment Design

Special emphasis should be placed on determining the specific interface between microorganism activity and the materials selected for use in the space station food storage areas, galley, preparation and handling equipment, and the dining area.

Populations which should be studied would include the following representative organisms which are particularly effective in the degradation of coatings and substrates:

a) Aerobic Bacteria (non-fermentive gram negative rods)
   - Pseudomonas spp.
   - Vibrio spp.
   - Alcaligenes faecalis
   - Achromobacter spp.
   - Flavobacterium arboresiens
   - Micrococcus spp.
   - Streptomyces spp.

b) Anaerobic Bacteria
   - Delsulfovibrio spp.
   - Methanobacterium spp.
   - Clostridium spp.

c) Fungi (Saprophytic)
   - Aspergillus spp.
   - Pullularia pullulans

- Penicillium luteum
- Phoma pigmentivora
- Spicaria temphyllium
- Hormodendrum resinae
- Trichoderma "T-1"

4) Surface Finishes, Joints, and Seams

All materials in the spacecraft which may come in contact with the food supplies should be provided with an optimum surface finish to preclude the entrapment of food particles in surface irregularities. For example, all metallic parts and work surfaces should be electropolished to eliminate porosity. The formulation of coatings should provide good flow characteristics during initial application of the material so that an impervious surface may be achieved. The design of refrigerator and freezer compartments, ovens, cabinets, work counters, and tables should include requirements for welded and polished butt joints rather than overlapping seams. Rubber gasket materials should be specified that incorporate compounds in the formation which serve as bactericides, fungicides, virucides, and sporicides. All mechanical joints, hinges, locks, latches, etc. should be designed to eliminate interlocking parts, or when they are absolutely required, should be configured so as to be readily disassembled for cleaning.

j. Concept Evaluation Summary

The concepts described above are summarized in Table III-38. Rating numbers are not applicable since hardware has not, by instruction, been selected.

TABLE III-38

CONCEPT EVALUATION SUMMARY

FUNCTIONAL SUBSYSTEM SUB-FUNCTION NO.: 7.2	TITLE: Quality Assurance	INITIAL STUDY SUMMARY			INTERIM STUDY SUMMARY		
CONCEPT NUMBER	CONCEPT TITLE	RATING	DISCARD	STUDY	RATING	DISCARD	STUDY
7.2.1	Program Planning						X
7.2.2	Procurement Control						X
7.2.3	Inspection and Tests						X
7.2.4	Packaging and Shipping						X
7.2.5	Reliability						X
7.2.6	Maintainability						X
7.2.7	Visual Monitoring of Equipment Status	*		X	-		X
7.2.8	Audio/Visual Warning System	*		X	-		X
7.2.9	Safety				-		X
	*Rating considered "not applicable" since all concepts will be studied.						
	(Note: Concepts 7.2.1 through 7.2.8 inclusive had been part of the Interim Study as an alphabetical designation, but have been numerically redesignated for this Final Study Report. Concept 7.2.9 (Safety) was added during the Final Study Phase.)						

7.3 Software Requirements

a. Food System Log Book

It is recommended that a written log of any pertinent events that occur with regard to the food system, in its entirety, be maintained on a daily basis. Three separate entry criteria should be considered:

1) Food Acceptance and Equipment Utilization

These entries should consist of detailed critiques by the crewmen of each food item prepared and served. The commentaries could be documented starting with the relative ease of withdrawing food supplies from storage areas and transporting them to preparation facilities in the galley. Any procedural changes which would improve the system could be noted for future reference. Observations on the methods of food preparation regarding the use of heating equipment, rehydration devices, handling tools, and serving techniques could be treated in a similar manner. Efficiency of transport of prepared meals between the galley and dining area would be examined and recorded.

During the dining period, crewmen would indicate their attitudes on the total acceptability of each meal. These would include appearance, appetizing odor, flavor, consistency, texture, seasoning, conformance to recipies, and temperatures at which the food is served. Since each meal and, therefore, its component items, can be precisely identified, appropriate alternatives, and modifications can be applied to the next generation food supply.

A similar approach would be used in analyzing the dining utensils, food particle management, spill control, transport of utensils to the clean-up area, and the subsequent housekeeping chores.

2) Malfunctions, Failures, and Repairs

A separate section of the log would be devoted to a detailed description of any malfunctions in the food service equipment. These entries could help in preventing failures by establishing performance patterns in the equipment. Additionally, the data would prove useful both in effecting repairs of failed components and in advising the responsible ground base design groups as to the changes or modifications required for subsequent designs.

It is possible, and even probable, that unanticipated problems in equipment function will become evident during the course of any mission. In that event, a detailed description of all equipment operating characteristics would be useful in effecting invented solutions to correct potentially severe problems at the time of occurrence.

3) Partial-G and Zero-G Operations

The same rationale for the maintenance of a daily log would be applicable to the working characteristics of the food system equipments during an initial artificial-g and subsequent zero-g. During these periods, equipment and procedures which were tested on the ground and found to be satisfactory may, in

9

actual use, require modifications in order to provide the crew with the most efficient operating conditions.

b. Space Cook Book

The food supply for future space stations will consist of food types hitherto unknown in small crew, short duration missions. This will be due largely to the less restrictive weight and volume penalties associated with planned missions.

Future missions will also be able to take advantage of the vastly improved foods that are currently available on the commercial market depending on their applicability to vehicle design constraints. These foods could include many of the dehydrated types (air dried, freeze dried, foam mat dried), frozen and dehydrofrozen, shelf stable, perishable, and intermediate moisture products that are judged to be hedonically acceptable.

In order to utilize these foods effectively and provide the necessary interface between the food and the equipment to store, prepare, and serve the food, the suppliers will be required to do as much recipe development and preprocessing as possible. The following observations support this requirement for preprocessing: (1) Less crew time will be required for food preparation, (2) Lower water vapor and thermal impact from cooking on the environmental control system, and (3) Predictably superior meals can be prepared.

Assuming, then, that preprocessing will be accomplished, that various foods and their combinations will be extensively tested, and that specific data on their preparation will be available, a cook book equivalent can be developed for use in a spacecraft galley.

Since specific menus will be scheduled for each meal of the mission, the cook book format will permit the crewmember responsible for the meal to program various operations such as chilling, heating, thawing, etc. within the framework of crew duty cycles and eating requirements.

In practice, the instructions available in the cook book for the preparation of a theoretical meal might have a format as depicted in Figure III-107.

MENU

609	Orange Drink	Dehydrated
105-1	Fruit Cocktail	Frozen
105-2	Corn Chowder	Frozen
105-3	Salmon Salad	Frozen
302	Chicken and Gravy	Shelf Stable
502	Banana Pudding	Perishable

Preparation and Serving Instructions

609 Orange Drink: Package contains sufficient ingredients to make 6 six-ounce servings. Inject 36 ounces, 55°F water through rehydrating valve. Let stand for a minimum of 10 minutes. Cut spout closure and dispense. If not to be used within 2.5 hours, place in refrigerator to maintain acceptable temperature.

(Example of) Alternatives: Gelatin Dessert. Combine one package of 609 Orange Drink with one package 280 Gelatin in accordance with instructions in 280 Gelatin. Refrigerate for 3 hours. Add fruit, as applicable.

105-1 Fruit Cocktail: Remove from freezer and thaw at ambient temperatures for 10 hours maximum. For more rapid thawing, remove individual portions from package and separate. (Alternatives: TBD)

105-2 Corn Chowder: Remove from freezer and transfer to microwave oven. Set timer for 2.06 minutes. Agitate package for even distribution of contents. Cut spout closure and dispense. (Alternatives: TBD)

105-3 Salmon Salad: Remove from freezer and thaw at ambient temperature for a maximum of 13 hours. For more rapid thawing, remove individual portions from package and separate. (Alternatives: TBD)

302 Chicken and Gravy: Remove from cabinet and transfer to microwave oven. Set timer for 1.03 minutes. Apportion and serve. (Alternatives: TBD)

502 Banana Pudding: Remove from refrigerator, divide into individual portions, and serve. (Alternatives: TBD)

This meal is composed of two hot portions and four cold portions. Individual items should be served in the order they appear on the menu. Allow a maximum of 13 hours prior to meal time for thawing 105-1 Fruit Cocktail and 105-3 Salmon Salad.

The total time to prepare remaining items will be approximately 2.06 minutes.

Required handling utensils will consist of (1) Hot Food Handling Tongs, and (2) Food Handling Tongs.

Crew Comments, Suggestions, Alternatives: ______________________________

____

____

Figure III-107. Sample Instructions For Cook Book

As food items are developed and menus prepared for specific missions nutritionists, chefs, and meal planners can cooperate to suggest combinations of food items which depart from the established criteria and schedules, but will not modify daily nutritional intake or water balance. This would permit a certain flexibility in the food habits and tastes of the crew on a periodic basis.

The crew comments, suggestions, and "invented" recipes or combinations will enable the responsible food management personnel to provide increasingly acceptable meals aboard orbiting spacecraft.

SECTION IV

HUMAN FACTORS CONSIDERATIONS

A. GENERAL

Concurrent with the evaluation of food system concepts in terms of weight, volume, power, etc., a human factors evaluation was made of the concepts that were considered for study. This evaluation was in terms of the operating time required for each piece of equipment. Task time is a trade study factor in the assessment of food system components.

1. Rationale For Determination of Task Time in Zero-G

Time-motion data relevant to the operation of food systems equipment is at present unavailable for zero-g conditions. The available data is either in the form of gross task time for suited astronauts or neutral buoyancy submersion test data. The determination of baseline task times in a zero-gravity field must therefore be based upon the known task times derived from normal one-g time-motion studies. Such data is available from the crew station studies performed by FH/RAD in various aircraft and manned space programs. The derivation of task times for zero-g is based upon the following assumption: Under a closely defined set of operating conditions the time for performing a given task at zero-g is a definite multiple of the one-g task time. Hence, a factor can be assigned to each group of manual operations for zero-g tasks.

a. Work Performed From A Secured Position

The task of manipulating controls, opening or closing equipment doors, and monitoring displays is comparatively effortless in zero-gravity if the subject is fully secured in a seated or standing position. Since little or no effort is required to maintain equilibrium this group of tasks is assigned the factor of 1.0; i.e., task time is the same as for normal gravity conditions.

b. Work Performed From A Partially Secured Position

Accurate manipulation of controls with one hand while using the other hand to secure one's self at the work station requires considerable attention to equilibrium. The effort devoted to maintaining balance and obtaining accuracy will increase the time devoted to the task performance. A factor of 1.2 is assigned to work performed under these conditions.

c. Movement and Placement of Objects

The transfer of a mass from one position to another and placing it into a narrow slot or confined space requires little effort in zero-g, but considerable care is required in the stabilization and guidance of the moving mass. Control must be exerted on the mass to prevent overshooting the desired position. A factor of 1.5 is assigned to this group of tasks.

d. Relocating By Bending and Stretching

The task of relocating or displacement of a mass by reaching, bending, or turning while partially secured in place will demand added time for controlling the movements of the mass and maintaining body equilibrium. A factor of 2.0 is assigned to this group of tasks.

e. Hand and Body Movements, Unsecured

Any movement of hand or body that results in a reaction to move the operator from his position will result in considerable effort to maintain position and equilibrium. This effort increases the task time by a large factor. Hence, work attempted while only partially restrained by one hand or one foot will be assigned a factor of 3.0.

f. Locomotion

Distances travelled from point to point on a space station are generally short because of the size of the work areas involved. Hence the speed of movement is anticipated to be quite low, in order to avoid collision or overshooting the mark. Locomotion in zero-g is quite effortless and soaring velocities of 15 feet per second were readily attained in simulated zero-g flight tests. However, a working pace of 3 feet per second was found to be most commonly used in these tests. Hence, a velocity of 3 feet per second is considered a practical value for stabilized zero-g locomotion.

2. <u>Gross Task Definitions</u>

The functions of the food system were examined and a gross task description was defined for each function. These task definitions form the basis for task-time analyses which determine the crew operation time required for each concept of equipment. The gross task definitions for the food system functions are:

a. Provide For Food

The task of providing for food does not involve activity on the part of the crew. Hence, no task definition is required for this function.

b. Provide For Storage

The task of providing for food storage shall include all activities associated with stocking, restocking, stowing, and unstowing food items provided for the mission. This task shall include access to and operation of all equipment used for food storage such as freezers, refrigerators, lockers, store rooms, containers, and bins.

c. Provide For Preparation

The task of food preparation embraces the operations required to convert stored food items into palatable nutritious meals. This task includes the operation of all equipment necessary for proper food preparation, including ovens, heating devices, cooking devices, reconstitution equipment, chillers, thawing devices, beverage makers, blenders, and package handling equipment.

d. Provide For Serving

The task of serving prepared food involves the sanitary, efficient transfer of food from the preparation area to the dining area by manual means and/or assisted by operation of mechanized conveyor devices.

e. Provide For Consumption

The consumption of food in zero-g entails the proper manipulation and control of those devices necessary to assist the crewman in transferring the food from the table to his mouth. Such devices include trays, containers, food holding devices, utensils, cutlery, napery, food restraint and personnel restraint devices.

f. Provide For Clean-Up

The task of cleaning the food preparation and dining areas involves the operation of conventional and specialized cleaning equipment. These items of equipment include wipers, vacuum cleaners, scrubbers, receptacles, conveyor systems, collection units, storage units, waste handling equipment, washing equipment, dryers, and stowage facilities.

g. Provide For Inventory

The task of maintaining inventories of all food items involves the keeping of records necessary for the logistics of the space station. Such records will indicate the gross amounts of foods withdrawn from storage, the amounts wasted in preparation or non-consumption, and the operational status of the equipment.

3. Task-Time Analyses

A task time analysis was performed for each item of equipment selected for further study. Each task was divided into subtasks consisting of several motions or task elements. The time required to perform each subtask in zero-g was determined by the method outlined in the rationale of paragraph A.1.

a. Task Analyses of Storage Equipment

- Concept 2.1.4: Water Sublimation Freezer

Subtask	Time-Sec
Grasp hand-hold and open freezer door	3.6
Secure self and door	9.6
Identify and remove food packages	24.0
Secure packages, release, and close freezer door	12.0
	49.2

(Applicable to Concepts 2.1.6, 2.1.7, 2.1.8, 2.2.6, 2.2.7, 2.2.8)

- Concept 2.3.1: Storage Locker/Store Room

Subtask	Time-Sec
Open locker door	3.6
Secure door and enter locker	12.0
Remove and secure food packages	24.0
Exit and close locker door	16.0
	55.6

- Concept 2.3.2: Flexible Storage

Subtask	Time-Sec
Unfasten flexible enclosure	30.0
Remove food packages and secure	75.0
Secure remaining food items	45.0
Close and fasten flexible enclosure	30.0
	180.0

b. Task Analysis of Preparation Equipment

- Concept 3.2.1: Hot Air Convective Oven

Subtask	Time-Sec
Switch and temperature controls - ON	7.2
Monitor temperature and timer for pre-heat	20.0
Open oven door and insert food containers	50.0
Close oven door and set timer	8.4
Monitor timer (cooking time TBD)	4.5
Switch OFF, open oven, and remove food containers	54.0
	144.1

- Concept 3.2.2: Microwave Oven

Subtask	Time-Sec
Open oven and insert food containers	50.0
Close oven and set timer	8.4
Switch ON, monitor timer (cooking time TBD)	7.5
Switch OFF, open oven, remove food containers	54.0
	119.9

- Concept 3.2.3: Resistance Oven — See 3.2.2

- Concept 3.2.6: Self-Heating Food Package

Subtask	Time-Sec
Insert food package into clips	12.0
Switch ON, set timer, monitor signal	12.0
Switch OFF, remove food package from clips (cooking time TBD)	10.8
	34.8

- Concept 3.2.13: Combined Microwave and Resistance Oven — See 3.2.2

- Concept 3.2.14: Combined Hot Air and Resistance Oven — See 3.2.1

- Concept 3.2.15: Electrically Heated Food Tray

Subtask	Time-Sec
Insert food packages into tray	45.0
Set tray on power interface	6.0
Switch ON, set timer, monitor (heating time TBD)	7.5
Switch OFF, remove tray	7.5
	66.0

- Concept 3.3.1: Hot Plate

Subtask	Time-Sec
Place food items on plate (6)	45.0
Switch ON (warming time N/A)	3.0
Remove food items	45.0
	93.0

- Concept 3.3.2: Reconstitution Machine

Subtask	Time-Sec
Open inlet port	6.0
Insert packet of powder	6.0
Actuate plunger to open and empty packet	8.0
Remove packaging, close inlet port	12.0
Attach water hose to valve of device	9.0
Inject metered amount of water	30.0
Energize stirring device	45.0
Dispense as required	-
	116.0

- Concept 3.3.3: Chilled Cabinet

Subtask	Time-Sec
Open cabinet	4.0
Select food item (1)	8.0
Close cabinet	4.0
	16.0

- Concept 3.3.5: Hot Beverage Maker

Subtask	Time-Sec
Prepare beverage (see 3.3.2)	116.0
Switch ON, temperature control-set	8.0
Heating time TBD	
	124.0

- Concept 3.3.6: Food Blender

Subtask	Time-Sec
Open blender	6.0
Insert food package into opener	10.0
Open and discharge contents, remove packaging	10.0
Repeat as required (3)	60.0
Close blender	6.0
Switch ON, set timer, time TBD	10.0
Monitor timer signal, switch OFF	6.0
Operate dispenser device as required	TBD
	108.0

- Concepts 3.4.1 through 3.4.5 represent various types of Preparation Counters. Since these are work areas and do not involve operation of devices, no human factors evaluations were made. The use of devices auxiliary to the work area will be evaluated on an individual basis for each device.

- Concept 3.5.1: Snack Bar

Subtask	Time-Sec
Select food item	8.0
Actuate dispenser	5.0
Pick up delivered item (heating time TBD)	5.0
	18.0

- Concept 3.6.1: Food Dispenser Cabinet

Subtask	Time-Sec
Open cabinet	4.0
Release tray from restraints	5.0
Remove tray	3.0
Close cabinet	4.0
Secure items on returned tray	6.0
Open cabinet and insert tray	6.0
Secure tray restraints	5.0
Close cabinet	4.0
	37.0

- Concept 3.7.1: Food Storage Cabinets

Subtask	Time-Sec
Select food item	8.0
Actuate dispenser lever	5.0
Secure item to tray	5.0
Repeat for each item selected	-
	18.0

- Concept 3.7.2: Self-Storing Food Container

Subtask	Time-Sec
Select food item	8.0
Remove from stack	5.0
Secure for transfer to galley	5.0
Repeat as required	-
	18.0

- Concept 3.7.3: Automatic Food Storage Cabinets

Subtask	Time-Sec
Align preparation device with storage cabinet	15.0
Operate lever to open and dispense food package	6.0
Move preparation device to next position	8.0
Repeat lever operation for new food item	6.0
Repeat as desired for other food items	-
Remove preparation device from cabinet	15.0
Set heater controls (heating time TBD)	4.0
	54.0

- Concept 3.8.1: Kneader - Mechanical

Subtask	Time-Sec
Open kneader	4.0
Place food pack on stationary rollers	3.0
Close and lock kneader	5.0
Grasp lever or actuate switch	3.0
Knead food (time TBD)	-
Release lever or deactivate switch	3.0
Unlock and open kneader	5.0
Remove food pack	3.0
	26.0

- Concept 3.8.2: Kneader-Hand Operation

  Hand operation. Kneading time dependent upon type of food to be mixed. No interface with mechanical device.

- Concept 3.8.3: Hot Food Handling Tongs

  Task times not applicable.

- Concept 3.8.4: Clam Shell Handling Device

  Task times not applicable.

- Concept 3.8.7: Scoop - Ice Cream Type

Subtask	Time-Sec
Uncover bulk food container slowly to avoid trailing food particles	5.0
Dip scoop slowly into food container	4.0
Wipe opening of scoop across edge of container to avoid trailing food particles	3.0
Transfer scoop to tray, keeping the open end pointed in direction of travel	3.0
Press wiper lever to release food into tray	4.0
Remove scoop slowly	3.0
Repeat as required	-
	22.0

- Concept 3.8.9: Utility Shears

  Task times vary with type of usage. Not applicable to a comparative study.

- Concept 3.8.10: Hand-Operated Mixer/Blender

Subtask	Time-Sec
Attach water injector to container valve	6.0
Inject metered amount of water	15.0
Remove water injector	3.0
Install container into mixer cylinder	10.0
Operate mixer lever (time TBD)	-
Remove container from mixer	6.0
Uncap mouthpiece for use	2.0
	42.0

- Concept 3.8.11: Rubber Spatula

  Task time not applicable.

- Concept 3.8.12: Food Chopper

Subtask	Time-Sec
Open chopper	3.0
Insert bulk food	3.0
Close and lock chopper	5.0
Actuate handle (time TBD)	-
Unlock and open chopper	5.0
Remove food portions with tongs or other suitable zero-g utensil	(TBD)
Transfer food portions for preparation	(TBD)
	16.0

- Concept 3.9.1: Controlled Spillage Device

Subtask	Time-Sec
Switch ON at start of food preparation	2.0
Running time	(TBD)
Switch OFF at completion of food preparation	2.0
Remove debris collected in plenum	30.0
Stow device for next usage	10.0
Dispose of debris in trash container	6.0
	50.0

- Concept 3.10.3: Waist and Foot Restraint

Subtask	Time-Sec
Don waist belt	30.0
Unlock swivel arms	4.0
Insert arms into slides at rail	10.0
Adjust lengths of arms for work station	12.0
Lock arms at desired lengths	2.0
Insert feet under cabinets for restraint	4.0
Unlock one arm at rail	2.0
Extend other arm to allow movement	4.0
Lock free arm into new position	5.0
Reposition or extend arms as required	12.0

The above tasks are individual motions and are not necessarily part of a sequence.

- Concept 3.11.1: Conveyor Belt

Subtask	Time-Sec
Load package onto belt and secure	15.0
Switch - ON	2.0
Move belt	3.0
Switch - OFF	2.0
Load package onto belt	15.0
Repeat as required	-
Remove packages as they are automatically discharged from belt at destination	-
	37.0

- Concept 3.11.2: Magnetic Conveyor System

Subtask	Time-Sec
Check orientation of package	3.0
Lift package to engage magnets to moving conveyor	5.0
Repeat as required	-
	8.0

- Concept 3.11.3: Mechanical Rail Transport System

Subtask	Time-Sec
Clip package onto rail	6.0
Add packages as required in sequence	-
Transfer line of packages along rail to destination (approximately 3 feet per second)	-
Offload package at destination	5.0
	11.0

- Concept 3.11.4: Dolly-Type Guided Container

Subtask	Time-Sec
Attach dolly to rails	15.0
Load packages into dolly	45.0
Transfer dolly along rails to destination (approximately 3 feet per second)	-
Unload dolly at destination	45.0
	105.0

- Concept 3.11.5: Net-Type Bag

Subtask	Time-Sec
Open net bag	6.0
Insert packages	15.0
Close net bag	5.0
Prepare for transport	3.0
	29.0

- Concept 3.11.7: Food Handling Tongs

Subtask	Time-Sec
Unlock pair of tongs	3.0
Place tongs over package	4.0
Lock tongs onto package	3.0
Repeat for other packages	30.0
Grasp handle near center of mass	3.0
Prepare to transfer	3.0
	46.0

c. Task Analyses of Serving Equipment

- Concepts 4.1.1, 4.1.2, and 4.1.6 do not require special equipment; hence, no task analyses were performed at this time.

- Concept 4.1.3: Tray/Rail Conveyor

Subtask	Time-Sec
Select trays from warmer	45.0
Insert slot onto rail	10.0
Insert trays on rail in order of seating	50.0
Push trays to dining area	3.0
Remove trays from rail and secure	72.0
	180.0

- Concept 4.1.7: Tray Rack/Rail Conveyor

Subtask	Time-Sec
Remove trays from warmer	45.0
Stack trays in rack in order of seating, from bottom to top	45.0
Switch ON	5.0
Control progress of rack to dining area	13.0
Start and stop as required to serve crewmen	60.0
	168.0

- Concept 4.2.1: Storage Rack

Subtask	Time-Sec
Remove trays from warmer	45.0
Stack trays in rack	60.0
Move rack to dining area	5.0
Serve trays to crew	45.0
Stack dirty trays in rack	60.0
Remove rack to galley for cleaning	5.0
	220.0

d. Task-Time Analyses of Consumption Equipment

The motions concerned with the consumption of food vary with the individual and, therefore, are not subject to precise analysis. The task time analyses in this section were performed only for those motions directly relating to the use of special equipment.

- Concept 5.4.7: Tray With Cover

Subtask	Time-Sec
Secure tray	6.0
Open compartment, hold lid	4.8
Extract food portion	7.2
Close compartment	3.6
Repeat for other compartments	78.0
	99.6

- Concept 5.5.2: Closed Liquid Containers

Subtask	Time-Sec
Secure container	4.8
Insert drinking tube or open the delivery valve	2.4
Withdraw contents by mouth	30.0
	37.2

- Concept 5.5.3: In-Package Liquid Restraints

Subtask	Time-Sec
Secure container	4.8
Open delivery valve	1.2
Withdraw contents by mouth	30.0
	36.0

- Concept 5.6.2: Conventional Utensils

Subtask	Time-Sec
Use Spoon	(12.4)
Insert spoon slowly, avoid splashing	5.0
Extract food slowly, avoid trailing droplets	5.0
Lift to mouth	2.4
Use Knife and Fork	(17.4)
Insert fork carefully, avoid skidding	3.0
Insert knife between tines, cut slowly	6.0
Hold food and severed portion with flat of knife	2.4
Extract fork and insert into severed portion	3.6
Lift to mouth	2.4

- Concept 5.6.3: Unconventional Utensils

Subtask	Time-Sec
Use "SPORK"	(21.4)
Use as spoon (see 5.6.2)	12.4
Use as fork (see 5.6.2)	9.0
Use Knife/Fork/Tong Combination	(16.8)
Place utensil on food, span morsel to be cut	3.6
Hold food, slice with cutting edge	6.0
Retain cut morsel either in tongs, or release and and impale with fork end. Transfer to mouth.	7.2
Use tongs (see "SPORK")	(9.0)
Use vacuum utensil (see Fork, 5.6.2)	(9.0)

- Concepts 5.7.1 and 5.7.2: Dry and Wet Wipes or Napkins. Task times are equal for clean-up function and varies with the individual.

- Concept 5.9.3: Chair With Lap Restraint

Subtask	Time-Sec
Grasp chair, open restraint elements	10.5
Sit in chair, grasp table with one hand	6.0
Fold lap restraint over body, release grip	7.2
	23.7

e. Task Analyses of Clean-Up Equipment

- Concept 6.1.2: Hand-Held Vacuum Unit

Subtask	Time-Sec
Connect unit to power source	5.0
Grasp hand-hold, switch ON	3.0
Guide cleaner over unit area (10 sq ft)	150.0
Move to new secured position	5.0
Clean unit area (10 sq ft)	150.0
	313.0

- Concept 6.1.3: Guided Transport Vacuum Cleaner

Subtask	Time-Sec
Connect transport to guides	30.0
Connect unit to power source, switch ON	8.0
Grasp hand-hold at work area	3.0
Guide vacuum cleaner over surface (10 sq ft)	120.0
Move transport to new location	10.0
Repeat cleaning action	120.0
	291.0

- Concept 6.1.7: Hand Cleaning With Disposable Wipes

Subtask	Time-Sec
Obtain wipe	4.5
Grasp hand-hold	3.0
Wipe surface (unit - 10 sq ft)	150.0
Move to new secured position	4.0
Wipe surface (unit - 10 sq ft)	150.0
Discard used wipe	20.0
	331.5

- Concept 6.1.8: Hand Cleaning With Reusable Wipes See 6.1.7

- Concept 6.1.9: Hand-Held Scrubber

Subtask	Time-Sec
Obtain wipe and scrubber	18.0
Install wipe on scrubber	9.6
Connect to power source	7.5
Grasp hand-hold, switch ON	3.6
Guide scrubber over work area (unit - 10 sq ft)	120.0
Move to new position	4.0
Repeat scrubbing	120.0
Switch OFF, remove and replace wipe	36.0
	318.7

- Concept 6.1.10: Guided Transport "Astrovac Cleaning Unit

Subtask	Time-Sec
Attach unit to guides	12.0
Connect to power/vacuum source	22.5
Attach sponge on scrubber	9.6
Apply fluid to sponge, scrub surface (10 sq ft)	75.0
Apply vacuum to sponge, dry surface (10 sq ft)	75.0
Repeat as required	150.0
Detach sponge, disconnect unit, stow	80.0
	424.1

- Concept 6.2.9: Guided Return Rail System (see 4.1.3)

Subtask	Time-Sec
Remove trays and utensils from table	72.0
Attach tray to rail	10.0
Repeat for other trays	50.0
Push trays on rail to galley	3.0
Remove trays from rail and secure	72.0
	207.0

- Concept 6.2.10: Guided Return Carrier Unit (see 4.1.7)

Subtask	Time-Sec
Remove trays and utensils from table	72.0
Stack trays in carrier	45.0
Transport to galley	5.0
Unload and secure trays and utensils	72.0
	194.0

- Concept 6.3.1: Temporary Reusable Soiled Wipes Storage

Subtask	Time-Sec
Grasp soiled wipe	2.0
Insert into opening of receptacle	2.0
Release wipe, remove hand	3.0
	7.0

- Concept 6.3.2: Temporary Debris Collection/Storage Unit (see 6.3.1)

- Concept 6.3.6: Hand Carrying of Debris

Subtask	Time-Sec
Open receptacle, seal and remove liner	24.0
Secure for hand carrying	6.0
Transport to designated area at 3 feet per second	-
Stow and secure for later disposal	30.0
	60.0

- Concept 6.3.7: Manual Movement of Debris Transporter

Subtask	Time-Sec
Attach conveyance to guidance system	15.0
Open receptacle, seal and remove liner	24.0
Stow in conveyance	12.0
Repeat until all liners are removed or until conveyance is filled	108.0
Grasp hand rails or hand-holds	3.6
Propel conveyance to designated area at 3 feet per second	-
Off-load and secure	120.0
	282.6

- Concept 6.3.11: Galley Sink for Hands and Utensils

Subtask	Time-Sec
Open upper enclosure	6.0
Obtain trays and utensils from rack	22.8
Insert into sink, close upper enclosure	42.0
Insert hands through ports	6.0
Activate water flow and cleansing fluid	2.0
Manually wash utensils	144.0
Shut off water, air dry utensils	110.4
Remove hands from ports, dry hands	16.0
Open enclosure and remove utensils	28.8
Stow and secure utensils for wiping	45.0
Close sink enclosure	6.0
	429.0

- Concept 6.3.13: Automatic Dishwasher/Dryer

Subtask	Time-Sec
Open washer	7.2
Remove soiled utensils from stowage	45.0
Place in proper position in washer	45.0
Close washer, power ON, cycle time TBD	9.6
Monitor signal for completed wash/dry cycle	6.0
Open washer and remove dry utensils	54.0
Stow and secure	45.0
	211.8

- Concept 6.3.16: Equipment Stowage

Subtask	Time-Sec
Open compartment	7.2
Observe color codes, nameplates, and numbered areas	10.0
Stow equipment according to code and size	30.0
Secure compartment	7.2
	54.4

4. Typical Food System Analysis

A typical task involving all functions related to the food system is synthesized from the task-time analyses performed above. One concept was chosen from those available for each function. The task-time analysis is presented as both a resume to show the continuity that exists between functions, and a determinant of crew time spent in food system operations.

FOOD SYSTEM TASK-TIME ANALYSIS

Task	Subtasks	Task-Time (Seconds)	Elapsed Time (Seconds)
Provide food	Refer to dated menu selection.	30.0	30.0
	Check food items to be obtained.	60.0	90.0
Obtain stored food items	Open freezer and obtain food packages (see Concept 2.3.1).	55.6	145.6

FOOD SYSTEM TASK-TIME ANALYSIS (cont'd)

Task	Subtasks	Task-Time (Seconds)	Elapsed Time (Seconds)
Transport food to preparation area	Secure food packages in conveyance and transport to preparation area (10 feet).	8.3	153.9
Prepare food	Open microwave oven and insert food containers. Set controls and remove food when timer signals (see Concept 3.2.2).	119.9 Cooking Time TBD	273.8
Serve food	Insert food trays into conveyor. Direct motion of conveyor to dining stations. Crewmen remove trays at each dining station and secure trays to table (see Concept 4.1.7).	168.0	441.8
Consume food	Use conventional eating utensils (see Concept 5.6.2). Eating time approximately 45 minutes (2700 seconds).	2700.0	3141.8
Remove trays and utensils from dining area	Remove trays and utensils from table and insert into carrier. Return carrier to galley. Unload and secure trays and utensils for cleaning (see Concept 6.2.10). Note and record unconsumed food items.	209.0	3350.8
Clean dining area	Obtain wipes. Clean dining table and relevant areas while secured in position. Discard used wipes (see Concept 6.1.7)	331.5	3682.3
Clean trays and utensils	Insert trays and utensils into automatic dishwasher. After cycle is complete, stow and secure the trays and utensils (see Concept 6.3.13). Cycle time TBD.	211.8	3894.1
Clean galley	Obtain wipes. Clean preparation area surfaces. Discard used wipes in receptacles (see Concept 6.1.7).	331.5	4225.6
Stow equipment	Stow equipment in designated stowage rack or compartment (see Concept 6.3.16).	54.4	4280.0

SECTION V

SHUTTLE SUPPLY EQUIPMENT INTERFACE

A. GENERAL

The food system imposes constraints on the resupply vehicle requirements. In addition to the obvious weight and volume penalties for transporting both up and down food and waste products, specific equipments are necessary onboard the shuttle to support the particular resupply mission. Consideration should also be given to possible interfaces between the food system requirements for the resupply shuttle itself, and its support mission requirements. The final selection process for a space station food system, therefore, must assess and evaluate the resupply interface impact to fully appreciate the implications of a selected system.

B. FOOD SYSTEM IMPACTS

The food system impacts upon the shuttle in three significant areas:

1. Physical

Total weight and volume of up cargo and down cargo depend upon:

a. Diet Mix. The particular diet mix influences the total weights of resupplied food as a function of water content.

b. Station Equipment. The station's refrigeration and frozen food storage equipment influence weight and volume by virtue of their need (or lack of need) of cryogenic resupply. The various types of candidate equipment concepts are depicted in Table V-1. Resupply impact on the shuttle is shown for each equipment use on the station as well as the effect of using similar equipment on the shuttle.

c. Clean-Up. The clean-up method chosen determines the amount of resupply of expendables. For example, the use of disposable towels and wipes has a significantly different impact upon the shuttle than does the resupply of expendables for a washing machine. The 10 year totals for resupply of the various alternative systems as a function of mission configuration (number of men/resupply period) are presented in Table V-2. The values for each shuttle launch can be derived by multiplying the 10 year values by the factor .00388 for 14-day missions and .025 for 90-day missions.

TABLE V-1. IMPACT OF VARIOUS FOOD STORAGE EQUIPMENT CHOICES UPON THE SHUTTLE

Concept Number	Equipment	Shuttle Impact If Equipment Is Used On Station	Shuttle Impact If Equipment Is Used On Shuttle
2.1.1 and 2.2.1	Solid CO_2•	Resupply of consumed CO_2 via shuttle. Venting of CO_2.	Resupply of consumed CO_2 for shuttle. Venting of CO_2.
2.1.2 and 2.2.2	Heat Sink•	None*	Heat transfer is highly unpredictable due to the varied shuttle environment.
2.1.3 and 2.2.3	Cryogenic Expansion•	Resupply of cryogenics to station via shuttle. Venting of cryogenics.	Resupply of cryogenics for shuttle. Venting of cryogenics.
2.1.4 and 2.2.4	Water Sublimation•	Resupply of water to station equipment.	Resupply of water for shuttle environment.
2.1.5 and 2.2.5	Vapor Compression•	Moderate failed parts resupply via shuttle.	Highly varying "g" fields disturbs the necessary phase separation.
2.1.6 and 2.2.6	Space Radiator•	High resupply rate of failed components via shuttle.	Not applicable to shuttle mission due to need for alignment of radiators.
2.1.7 and 2.2.7	Thermoelectric•	High reliability yielding low parts resupply requirement.	High power required; low efficiency.
2.1.8 and 2.2.8	Turbo-Compressor•	Moderate failed parts resupply.	Mechanically active system impractical for short missions due to constant high weight.
2.3.1	Storage Locker	None*	Extensive modifications for dynamic forces of flight.
2.3.2	Flexible Storage	None*	Not applicable due to dynamic forces of flight.
2.3.3	Extravehicular Storage	None*	Not applicable to shuttle.

• As a refrigerator or freezer

* As basically passive systems, the resupply of failed components will be minimal

TABLE V-2. WEIGHT IMPACT OF VARIOUS STATION SYSTEMS

Concept Number	Mission•	6/14		6/90		12/14		12/90		25/14		25/90	
	Disposable Item	Weight* (lbs)	Volume* (ft^3)	Weight* (lbs)	Volume* (ft^3)	Weight* (lbs)	Volume* (ft^3)	Weight* (lbs)	Volume* (ft^3)	Weight* (lbs)	Volume* (ft^3)	Weight* (lbs)	Volume* (ft^3)
6.1.2	Hand-Held Vacuum Cleaner	273.0	8.52	273.0	8.42	273.0	8.52	273.0	8.42	546.0	17.0	540.0	16.85
6.1.3	Guided Transport Vacuum Cleaner	546.0	43.3	540.0	42.8	546.0	43.3	540.0	42.8	546.0	43.3	540.0	42.8
6.1.7	Hand Cleaning With Disposable Impregnated Wipes	946.4	35.5	936.0	35.16	1419.6	533.0	1404.0	52.75	1892.8	71.11	1872.0	70.33
6.1.8	Hand Cleaning With Reusable Impregnated Wipes	10.5+	.2341+	10.5+	.2341+	15.75+	.3511+	15.75+	.3511+	21.0+	.4682+	21.0+	.4682+
6.1.10	Guided Transport "Astrovac" Cleaning Unit	26.0+	.4017+	24.0+	.3708+	36.4+	.562+	36.0+	.556+	72.8+	1.125+	72.0+	1.11+
6.2.1	Dispenser for Disposable Personal Wipes	436.8	42.12	470.4	45.36	873.6	84.24	974.4	93.96	1965.6	189.54	2016.0	194.4
6.2.2	Dispenser for Reusable Personal Wipes	73.13	1.628	72.00	1.605	14625.0	3.258	144.00	3.21	304.69	6.79	300.0	6.688
6.2.3	Dispenser for Impregnated Personal Cleansing Wipes	851.76	31.98	842.4	31.64	1703.52	63.96	1684.8	63.28	3549.0	133.38	3510.0	131.88
6.2.4	Receptacle for Temporary Retention of Soiled Wipes	32.76	5.11	32.40	5.054	65.52	10.221	64.80	10.109	142.0	22.146	140.4	21.90
6.3.1	Temporary Reusable Soiled Wipes Storage Unit	8.13	.585	8.00	.578	8.13	.585	8.00	.578	16.25	1.173	16.0	1.157
6.3.2	Temporary Debris Collection Storage Unit	218.4	31.56	216.0	31.21	218.4	31.56	216.0	31.21	436.8	63.12	432.0	62.4
6.3.3 Δ	Combination Debris Collector/ Shredder	364.0	42.13	360.0	41.67	364.0	42.13	360.0	42.13	1092.0	126.39	1080.0	125.0
6.3.4 Δ	Combination Debris Collector/ Compactor	182.0	16.85	180.0	16.67	182.0	16.85	180.0	16.85	546.0	50.56	540.0	50.0
6.3.11	Combination Sink for Hand and Utensil Washing	1492.0	19.22	1476.0	19.0	1966.0	25.63	1944.0	25.34	2475.0	32.0	2448.0	31.68
6.3.13	Combination Automated Dishwasher and Dryer	5077.0	81.35	50213.0	80.46	8423.69	133.84	8331.12	132.37	15563.0	249.4	15032.0	246.67
6.3.14	Dispenser for Disposable Galley Utility Wipes	910.0	130.9	952.0	136.94	1638.0	235.62	1568.0	225.55	2730.0	392.7	2744.0	394.7
6.3.15	Dispenser for Reusable Galley Utility Wipes	88.36	1.97	87.0	1.94	146.25	3.258	144.0	3.21	255.94	5.7	252.0	5.618

• Missions are indicated by (number)/(number) which signifies the number of men and the resupply period
* Weight and volume are given on a 10-year basis
\+ These values are expendables weight and volume (on a 10-year basis) excluding water weight, as derived on individual data sheets
Δ Data presented for reference only; concepts discarded in Final Phase of Study

2. Mechanical

Food preservation requirements onboard the shuttle must be considered in the design of the shuttle itself due to the operation, by-products or operating environment and requirements of the food support equipment. These impacts are also shown in Table V-1.

3. Transfer

Compatibility between the shuttle module's containerization methods and the station's storage configuration must be maintained. The restrictions imposed by the intervening off-loading, transfer, and on-loading constraints such as hatch sizes, man load, and transfer equipment must be considered.

SECTION VI

SPECIAL FOOD SYSTEM STUDY CONSIDERATIONS

A. ORBITING INTERNATIONAL LABORATORY

1. Potential Composition

A reasonably safe assumption is that the currently planned U.S. Space Station program will include at least one configuration which will be destined for service as an international scientific satellite. Research efforts aboard such a vehicle would include the acquisition of data on astronomy, earth resources, science and technology; in short, programs beneficial to both the sponsoring nations and the world in general.

Scientists who would serve in the experimenter/astronaut capacity would probably be recruited, at least initially, from those countries which presently have a rather highly developed scientific posture.

The United States, as the leader in the world's space effort, will, undoubtedly, become the driving force that will plan, organize, and implement an international satellite program. The talent and capability to do this has been amply demonstrated in past and present programs and needs no further embellishment.

A high level of involvement can certainly be anticipated from the U.S.S.R. and several of her central European satellites (East Germany, Hungary, Czechoslovakia) which have demonstrated significant technical competence in many scientific fields. Particular emphasis has been placed on earth resources which is not surprising in view of the enormous land mass, varying climatology, and essentially agrarian economy under consideration.

Great Britain and Canada, acting both jointly or independently, have made significant strides in space technology, particularly in communications and meteorology satellites, and there is presently a competent cadre of scientists, engineers, and technicians who could associate in a cooperative space program.

The Scandanavian countries (Denmark, Finland, Norway, Sweden), although not involved in any major space efforts, have demonstrated a remarkably high degree of capability in basic science research, as well as the design and fabrication of elegant precision instrumentation.

Italy, Spain, and particularly France, presently enjoy a relatively high rank in the scientific and technical community and could make significant contribution to a multi-national satellite program.

In the Central European Group (Austria, Czechoslovakia, East and West Germany, Hungary, and Switzerland) much basic research is promoted under government auspices and there are undoubtedly many competent scientists who could serve as astronaut experimenters.

Other nations (described geographically) which might be expected to participate in this type of program would probably include the Balkan nations (Albania, Bulgaria, Greece, Rumania, Yugoslavia), certain of the mid-East countries (United Arab Republic, Jordan, Iran, Egypt, Syria, Turkey, Lebanon, Israel), at least two countries of the Far East (Japan and China), as well as India, Australia, New Zealand, and selected Latin American countries.

The countries listed above are considered to possess sufficiently developed and organized scientific credentials to provide the initial thrust necessary to implement the early stages of a scientific international space program.

It is unlikely, at least in the foreseeable future, that certain of the underdeveloped or emerging nations will be able to acquire the scientific or technical capacity to lend significant support to these programs.

Countries such as Barbados, Chad, Gabon, Lesotho, Mauritius and Rwanda are presently more deeply concerned with providing some of the basic needs required for their citizenry. Yet, it will undoubtedly be these countries which will reap the most benefit from earth resources investigations. These nations, as their technology advances, could subsequently be included in the roster of participants.

2. Significance of Food

In order to provide an environment conducive to obtaining the maximum benefit from these scientific programs, a great many factors in the habitability design will require specific consideration. Significant among these factors will be the provisions for the food supply and dining requirements as modified by the participation of representatives of perhaps twelve dissimilar ethnic backgrounds.

To properly discuss the elements of a food system applicable to an international space vehicle, certain fundamental philosophic concepts must first be considered. We are dealing with an extremely complex drive which is basic to the very nature of man. The types of things people are willing to eat is determined by an intricate system of attitudes, assumptions, environment, education, and cultural patterns. These include religious restrictions, taboos, and ideas pertaining to the merits or demerits of certain food types with almost no regard for classical nutritional requirements.

Despite the importance of the acquisition of food, nowhere in the world do people eat every edible plant or animal available to them. Each society defines for itself what is "food", and, within each general definition, food has a wide range of meanings. Certain foods, for example, are for selling and others for eating; some for the rich and others for the poor; some are for holidays; some for women or children or the sick or the aged; others are not permitted for people in certain social strata. In most societies, food plays a part in nearly every important social or religious circumstance from the postnatal celebration to the funeral feast. Every society has thus surrounded food with proscriptions, restrictions, likes and dislikes, significances, beliefs, and emotional associations which play a large part in its outlook and practices relative to other aspects of life. These factors thereby limit and rigidly define its choice of food. As each individual grows up in a particular culture and becomes invested in its social strata, he learns to accept the rules and ideologies pertaining to eating habits and the food supply. Changes, if they are ever achieved, are done so with almost painful slowness.

3. Validity of Providing Non-Traditional Foods to an International Crew

The almost extraordinary expansion of our western culture, especially toward urbanization, tends to make us think of food values in terms of the mass of society. This often leads to applying explanations, valid only in our industrial society, to rural traditional societies which are quite different and which operate with different values. If we follow this over-simplification and extend it to designing a food system for international tastes, we may return to the old prejudices which consider modern, urbanized, western man as representative of the whole of human nature.

Since people tend to eat what they like, which is usually what they are accustomed to eating since infancy, serious changes in the types of foods and the manner in which they are presented can often be self-defeating. This fact was graphically demonstrated in the Apollo flight series. The food system specifications, materials, and equipments exceeded those of the spacecraft environment and the requirements of ground-based human test subjects. Nutritionists calculated the projected metabolic requirements for each astronaut very precisely and provided an excess of nutrients in the diet as a safety factor. The finest available foods were selected, tested, and processed by capped and gowned personnel in almost surgically clean surroundings. The food was wrapped in especially prepared packages which were exhaustively researched and tested. The food was consumed by volunteer test subjects for almost two months prior to the flights with no discernible psychological or physiological deviations. In short, the food itself, and the systems for its support and maintenance, were investigated, analyzed, and researched in the greatest detail, with nothing left to chance.

And yet, the astronauts did not eat. Approximately fifty percent of the food supply was returned at the termination of the mission and the crewmen lost weight. To understand possible reasons for this, the mechanism of food intake can be divided into two categories:

a. Physiological Influences

These consist of metabolic factors possibly mediated through a glucostatic component acting on the ventromedial hypothalmic area, with a thermostatic component acting perhaps on another area. Additionally, gastric contractions, distensions, metering of food by mouth and pharynx, water balance and environmental factors influence food intake. Although not to be discounted, these factors are of limited value in determining what and when people will eat.

b. Psychological Considerations

All the comments made in the previous paragraphs can be included as part of this parameter; i.e., habits, customs, traditions, available food, education, etc. In addition, the environment within the spacecraft, remoteness from familiar earth surroundings, weightlessness, and the partial deprivation of sensory stimuli will be adverse superimpositions on the crewman's desire to consume unfamiliar foods.

Other factors which had a negative influence on the desire to eat was the non-traditional shape and texture of the food and the relative complexity of its preparation. Compressed bacon squares, dehydrated beef bars, dehydrated, flavored cereal cubes, chicken cubes, and pork sausage bites cannot be considered as classical meal components under any terms.

Preparation of dehydrated items required the injection of a metered quantity of hot or cold water through a valve in the plastic package, kneading the contents to provide a uniform mixture and consistency, cutting off the valve, and compressing the contents to extrude a portion of food into the mouth.

On missions of relatively short duration (two weeks) it is also perfectly conceivable that astronauts would find the standards for adequate nutrition as set up by the National Research Council to be of no particular importance and select only the more palatable, familiar foods. Each crewman knows that at the end of the mission, his normal inclinations toward eating will certainly be satisfied with the food of his choice.

4. <u>Food Selection Considerations by Geographical Areas</u>

In reviewing the food habits and customs of nations whose scientific and technical groups would contribute to an international space station program, it becomes obvious that the types of food which would be planned for inclusion in the space diet can be selected on the basis of commonality with geographical locations. The following section will attempt to describe certain of these characteristics and considerations.

a. United States

1) East Coast and New England

The American diet has always reflected the ethnic pluralism of its citizens. Although the cafeteria was not a U.S. invention, it servès the population well by allowing people to reduce a meal to its component parts which can then be reassembled according to their individual tastes and particular traditions.

Most American recipies came from Europe along with the great tides of immigration that began about 1820 and increased in volume during the next century.

Specific dishes have become associated with certain areas in the U.S. because of locally available ingredients and because of the people who settled there.

From the early Dutch settlers in New York, we have "Kool" (cabbage), "Sla" (salad), or coleslaw, waffles, "Koekjes" (cookies), and Olykoeks (doughnuts) which were traditionally tossed to children to catch at the Mardi Gras (Fat Tuesday) Carnival (carnelevare - Italian for "taking away meat") which is the day before Lent begins. Americans have thus, for over three centuries, become accustomed to doughnuts as almost a daily ritual.

Jewish immigrants made significant contributions to the American cuisine, especially along the Eastern seaboard. The food types that were contributed varied as did the immigrants' country of origin and it is not unlikely that, as in present day Israel, as many as 73 countries or origin are represented in the U.S. The food, however, does reflect some basic characteristics and ceremonial practices derived from the Kashruth (kosher is the adjective) which is based on Mosaic law, referenced in the Bible, and interpreted in the Talmud.

Since the Orthodox Jews were required to adhere to kosher food preparation, Jewish peddlers very often lived as vegetarians while traveling and only ate meat on arrival at home or at the homes of friends and associates. Many retained this practice which resulted in the establishment of scores of restaurants featuring vegetarian or dairy dishes exclusively.

A strong characteristic of Jewish food is the richness of the diet which includes many cakes and pastries, foods rich in fat and preserves and conserves. Smoked fish such as lox (Russian for salmon), pike, sturgeon, carp, and white fish are frequently encountered.

Most vegetables are cooked with meat but are more often encountered in soups. Noodles and other egg-flour mixtures are used extensively. Gefilte fish, a dumpling made of pike or white fish ground with onions and spices, poached for several hours, and served in its own jelly, is a continuing favorite. Chicken is considered almost an essential item in a Sabbath evening meal.

Many traditional dishes have had their origin with the Pilgrim Settlers. Johnnycake acquired from the Indians, codfish cakes, seafood chowders, lobster, baked beans, and an enormous variety of fish are staples of the New England diet. Less green, leafy, vegetables are utilized here than in other areas; however, yellow vegetables (squash, turnips, and carrots) are popular.

Italian immigrants, chiefly from the south of Italy, were people of poor means so the food ran, and still does, to pasta and tomato sauce, garlic, olive oil, minestrone, pizza, spumoni, and other traditionally Neopolitan foods rather than the more "gourmet" dishes of Northern Italy.

In time the prosciutto, lasagne, cannelloni, manicotti, and tortellini from Bologna along with regional menus from Calabria and Genoa become popular American dishes.

2) Southern United States

There is a preference for vegetables that have been cooked a long time, usually with pork fat, and the wide variety of greens compensates for the low consumption in milk and cheese. Regional favorites include chitterlings, collard and turnip greens, hominy grits, candied yams, and sweet potato pie.

Fried mush, chicken fried in hog lard, squirrel and opposum, as well as barbequed spare ribs, are frequently mainstays of the Southern meals. Black walnut or pecan pies are often encountered due in large part to an abundance of these nut trees.

In the Louisiana area, French recipies were integrated with those of Spain, England, and native Indian populations to become the distinctive Creole dishes. The Acadians, exiled from Nova Scotia, combined Cajun with Creole cooling and introduced jambalaya.

3) Southwest

The Mexican influence is evident in the use of pinto beans and tortillas, tacos, and enchiladas (ground corn made into a flat, thin cake and filled with a variety of ingredients) all originally well spiced with peppers, but now somewhat blander due to the tastes of the large German population.

Tamales, made from a more elaborate dough than tortillas, with pork or poultry filling are steamed and can be eaten as an entire meal. Unfilled, they serve as bread; sweetened, as a dessert; in small portions, as appetizers.

The modern version of chili, well known nationally, was originated by a German in New Braunfels, Texas in 1902 who found a way to extract the pulp from chili pods (there are an estimated 61 varieties of these peppers) and combine it with the right spices to create chili powder.

The popularity of chile con carne (with meat) is attested to by the fact that Jesse James refused to rob a bank in McKinney, Texas because that is where his favorite chili parlor was located, and Will Rogers judged a town by the quality of its chili.

4) Far West

In 1834, when Richard Henry Dana, author of "Two Years Before The Mast", sailed to the California coast, the area was virtually uninhabited except for Indians who brought dried steer hides to the Pacific shores for sale to shipowners.

The first exodus of settlers to the West occurred as a result of the discovery of gold at Sutters Mill in 1848. The second was a result of the enactment of the Homestead Act in 1862, and the third (and largest) was motivated by the defense industry needs in World War II.

The resulting population was a random mixture of virtually every ethnic grouping from any and every part of the country. Identifiable influences on regional food preferences did come, however, from the early Spanish missionaries and the Mexican and Oriental labor force. Although this essentially homogeneous population cannot be readily identified with any specific likes or dislikes regarding food habits, the use of a wide variety of locally grown garden produce and citrus fruits, and the short time cooking of vegetables typical of Oriental cooking, are notable.

b. Great Britain and Canada

A curious contradiction to English foods is that the cooking is reported to be bland and lacking in seasoning, which is quite true as it leaves the kitchen. However, at the table, the food is richly seasoned by the copious use of many condiments such as chutney, mustard, worcestershire, etc.

The large quantities of roast and grilled beef that have been traditionally consumed by the British resulted, in earlier days, from the lack of cattle feed during the winter months. This necessitated slaughter of all but breeding stock each fall and another British tradition was born.

Dairy products, particularly cheese, are a large factor in British diets as are the abundant fish dishes which have become a mainstay of their large breakfasts. Kippered and smoked herring, prawns, oysters, Dover sole are frequently encountered in these often formidable meals. This tradition, which is now fading, dates back to the late 1880's when it was considered unfashionable to eat lunch. Besides the aforementioned fish, other items in this meal included eggs, cold roast beef, kidneys and bacon, sausage, porridge, scones, marmalade, and the inevitable tea.

The British contributed such well known dishes as beef and vegetable pies, fish salads, plum pudding, tarts, mutton chops, roasts, fish and chips, trifles, and kidney stews.

Desserts are not too common; however, the English consume candy at a rate no other nation can rival. Many Englishmen replace sweet desserts with

"Savouries" which consist of some interesting combinations: scrambled eggs with anchovies and capers; creamed smoked haddock topped with walnuts; liver and bacon; prune wrapped in bacon; all served on a square of toast.

Canadian foods are a combination of the homeland traditions which successions of immigrants brought with them from Europe and the native Indian contributions. The French settled in the province of Quebec, and Quebec City is still 90% French. The British influence is strong in the remainder of the country. Because of the size of the country and its relatively small population, many immigrant groups remain isolated and retain their native food habits. Fourth and fifth generation Canadian Scotsmen still have porridge and tea for breakfast and Italian families average a half cup of olive oil per person each day in a country where olive oil is considered as a luxury. Ukranians are settled in large numbers and continue the traditions of their homeland.

Despite this polarization, there are certain foods native to Canada, particularly maple syrup which is served with almost everything and is included in pastries as a replacement for sugar. In the western part of the country, caribou and elk steaks are available while the eastern part produces large beef cattle herds which help promote the English tradition. There is a plentiful supply of fish, bass, trout, salmon, pike, pickerel, and muskellunge.

The Canadians have developed interesting casserole dishes with these fish and the Pacific coast shellfish supply and these casseroles often form the main meal.

c. Scandanavian Countries

The menus in these countries are liberal in the use of fish (fresh, smoked, dried, salted, and canned). The list is long: herring, sprot, salmon, pike, bream, white fish, flounder, cod, shrimp, lobster, etc. These are formed into fish soups, puddings, souffles, salads, and often eaten raw as appetizers.

Green salads, except during the summer months when lettuce, cucumbers, tomatoes, and radishes are plentiful, are not widely used. From fall through spring beets, potatoes, fish, and relish foods form the ingredients for salad supper dishes.

Dairy products and cheese are frequent in the cuisine of these countries and meat is not neglected in spite of the abundant fish supply. Potted calves hearts stuffed with parsley, beef cakes with onions, and baked tongue with mushrooms are served frequently.

Pork is usually served on holidays as are smoked mutton and cabbage; dried mutton and reindeer meat are frequently encountered in rural areas.

Fruit is not plentiful, but berries are used to good advantage. Thickened compotes and sauces from lingonberries, cold soups and sauces from cloudberries (yellow raspberry) and brambleberries, with varieties of jellies and puddings are predominant.

Cakes, as known in the U.S., are seldom served, but coffee cakes and doughnuts are plentiful and cookies are made almost by the ton.

Meal schedules often follow the pattern of a heavy breakfast, a mid-morning snack, lunch, afternoon coffee, and late supper.

d. Italy, Spain, France

A commonality exists between these three countries in the preparation of food in that there is more than one cuisine. There is the cooking of famous chefs (fr. haute cuisine); the thrifty home cooking (fr. cuisine de la famille); the peasant cookery (fr. cuisine du parysan); and the regional cooking superimposed on all three.

The Italians really invented the kind of food now considered to be "gourmet". They have had a long history of development in the culinary arts, dating back to the ancient Romans. Since the three countries under discussion are in such close proximity, there has been a natural transfusion of recipes, spices, sauces, and techniques, although this process took several hundred years to accomplish.

The importance of pasta in the Italian cuisine is characterized by the expression antipasto (appetizer before the pasta) and is a major ingredient in classical Italian meals. From that point on, almost every imaginable vegetable served hot or cold with oil and vinegar is encountered; eggplant, broccoli, escarole, artichokes, asparagus, cauliflower, etc. Chestnuts may be served as vegetable (pureed), or as a dessert in a sweet glaze. Corn meal may be a vegetable dumpling

(Gnocchi) or a main dish (Polenta) with tomato sauce and cheese; a combination applied to many other well known Italian specialties.

Spices play a major role in the cooking of these countries -- basil, thyme, oregano, saffron, garlic, anise, bay leaves, marjoram, to name a few, and the French chefs have an international reputation in their application.

Salad vegetables are plentiful and most meals begin with large servings of greens served with simple dressings. More often than not, many main meals consist of what may be loosely classified as stews, prepared as a three-in-one meal as, for example, the Spanish Cocido Madrileno. This is a combination of chick-peas, potatoes, bacon, sausage, and root vegetables cooked slowly for at least six hours. The liquid is drained off to be used as a soup, then the vegetables are served as a separate course. Next follows the meat.

The meals are usually preceded by a cheese course which in Italy can be comprised of Gorgonzola, Parmesan, Provelone, Bel Paese, Fontina, Cacio a Cavals. In Spain, the major cheese is Queso Manchego and in France, Roquefort, Camembert, Brie, Port Salut, Bonbel, and at least sixteen others.

Many dishes of a regional nature and with a peasant lineage have since become internationally known gourmet preparation commanding formidable prices in better restaurants. An example is the French Bouillabaisse a la Marseille which can be readily obtained in France and its counterparts in Spain and Italy.

The precise amount of essential spices to be added (saffron and fennel) has been hotly debated by some of the world's greatest chefs who have, on occasion, come to blows over the subject. Also, these so-called "peasant" dishes can be economically deceptive. The ingredients for this dish were priced to feed six persons. The bill for raw materials in the New York area was $23.00.

Meal schedules in these three countries all follow a similar format. Breakfast is usually light with rolls and coffee. Lunch becomes a celebration of about two hours with no holds barred; supper at eight can be a repeat performance.

Meals traditionally end with fresh fruits for dessert as confectionary products are not emphasized. When pastries are made, they are elegant and decorative in the extreme -- Casata Siciliana, Bisque Tortoni, Crepes Suzette, Baba au Rhum. Espresso, the strong black demitasse, tops off the meal.

e. Central Europe (Austria, Czechoslovakia, East and West Germany, Hungary, Switzerland)

This is an area which has become known for the development of rich foods, well seasoned, and usually served with gravies. For instance, the Hungarian Gulyas (goulash), Sour Cream Paprikas with fish, lamb, veal and fowl combinations are almost all served with dumplings. The Swiss, Austrians, and Germans do similar things with veal (Wiener Schnitzel). Mutton and pork are not too popular and, when occasionally prepared, are served with sour cream and sauerkraut.

The Czechs specialize in roast goose which is served with dumplings and is considered to be a national dish much as is the American turkey.

Breads are highly accepted and are generally made of rye or whole grain flours. The techniques that evolved from baking bread have been applied to pastries and this part of the world excels in Tortes, fifteen layered cakes, and cheese and fruit strudels.

The eating pattern consists of an early but light breakfast followed by a second heavier meal. The mid-day meal varies; usually, it is the big meal of the day. In Germany it may be a casserole dish; in Austria an elaborate dinner; in Czechoslovakia and Switzerland a lunch as we know. When heavy dinners are transferred to the evening hours, it is a transfer for social reasons only.

f. Russia

The relatively young republic of socialist workers of today's Soviet Russia is very different from the Russia of pre-Revolutionary days whose upperclass was famous for the lavishness of their tables. There has been, at least on the surface, a return to the peasant dishes which, when served in better restaurants of the United States, became expensive "gourmet" meals.

The enormous land mass of Russia, together with the (until recently) primitive travel arrangements, has not permitted much transfusion of native dishes between some of the most diverse ethnic cultures in that country.

In the area around the Black Sea, rice is prepared with lamb in the Turkish manner. There, the predominant menus in the areas that border what is now Red China are heavily saturated with oriental dishes. The Ukraine cuisine resembles neither of these, but has developed its own recipes and customs.

There are, however, many commonalties in Russian cookery. Bread is a staple of the most significant proportions (about a pound per day per capita) and, because of this consumption, has probably evolved into the finest of baked products anywhere in the world. In the Moscow central bakeries, for example, some 130 different kinds of bread are made and sold on a daily basis. However, Blini (pancakes made of yeast leavened bread), Pierogs (pastries stuffed with cabbage, eggs, meat, fish, or rice), and Borsch (beet, spinach, or cabbage soup) are almost national favorites.

The old custom of providing hot food at railroad stations still is in effect. Long distances and the lack of funds for dining car meals necessitated the establishment of these food purveyors.

Much fish is used in Russia. Small smoked sardines, skinned and fileted sprats, salt herring, and one of the chief exports that bolster the Russian exchequer, sturgeon roe (Caviar).

Tea is the universal beverage: on long or short journeys; at breakfast with black bread and, possibly, an egg or sausage; at noon in cooperative dining halls with hot dinners; and at eight o'clock at night with cold supper at home.

g. The Balkans

These countries are closely identified with each other in their food preferences and eating habits. As a matter of fact, the menus and dishes served in each of these countries are also favorites of the Turks, Slovenes, Hungarians, Montenegrins, Dalmations, Bosnians, and Germans.

Cold cooked vegetables such as squash, eggplant, and pumpkin are favorites. Much fowl, occasionally fish, but little meat is eaten. Dairy products are the backbone of the diet.

Strong unadulterated coffee in the Turkish style is preferred, but all except the people of Greece insist on highly seasoned food.

h. Middle East

This is the area from which a great many of the foods we know today were derived. The first lemons and oranges; the rice and tea of China; chick peas still mashed with sesame seed oil into "hummous", a staple of the general area; apples, apricots, dates and figs; melons, pears and plums.

A still highly prized dish is lentil stew, the pottage for which Esau in the Old Testament is thought to have sold his birthright for.

In 1833, Alphonse de Candolle in France pieced together the writings of ancient historians and archeological evidences to publish "L' origine des plantes cultivies". Some twenty-seven crops, said de Candole, were cultivated in what is now called the Old World, more than 4000 years ago, each of which is thoroughly familiar to the average American.

Many of the people are allied with the Moslem faith which forbids the eating of pork, but mutton and lamb with goat and kid as a variation form a very important part of the diet.

Flat loaves of thin hard bread; dolmas (stuffed vine leaves) kebabs; small cubes of lamb roasted on skewers; the specially prepared curdled or soured milk which serves as a beverage or a soup; figs and dates preserved in sugar with other fruits; honey and sweetmeats are common to all of the countries bordering the Mediterranean Sea.

The differences between these countries and their food habits lies essentially in the number of meals, the timing of them, and the manner of serving. The modern wealthy people all over eat in our manner, but most of them still sit on the ground with the food spread before them. If one eats in Arabian fashion, one will pick the meat out of a bowl with the thumb and first two fingers and manipulate it with a piece of bread held in the hand. In Turkey, rose petal conserve might be offered with a spoon and a glass of water and the conserve would be eaten followed by a swallow of water, after which one would find the taste of roses lingering in the mouth.

In Syria, tough rolls and coffee might be served for breakfast, but dinner could be a superb creation washed down with an excellent wine.

The recipes generally produce a very fat food so the people do not use butter since the fat in the prepared foods is ample.

i. Far East

(1) China

To an unaware, non-oriental individual the scope, variety, and unusual aspects of Chinese cuisine and its ingredients may appear to be totally unrelated to what is considered as fine cuisine. However, the Chinese have developed their menus over a period dating back at least 5000 years. In fact, current Chinese principles of cooking vegetables (their staple) are taken from a 600 B.C. philosopher, Lao Tze, who, in experimenting with plants, classified 365 edible varieties and discovered that their nutritional value could be destroyed by improper (fast or lengthy) cooking. So his followers, the Taoists, based their diet on raw or partially cooked vegetables, a tradition which persists today.

Approximately half a dozen different Chinese cuisines have developed over the centuries. Shanghai, Peking, Manchuria, Szechwan, Fukien, and Canton were the centers of various cookeries, although most Americans are familiar only with the Cantonese.

The Chinese strive for subtlety in food flavoring and meals are often composed of various separate dishes, each designed to present one of the "eight immortal flavors" which forms the basis of Chinese cuisine.

This approach is complemented by the use of a variety of many basic ingredients used in very small quantities. In China, as well as the United States, Chinese markets sell their products by the ounce to permit this philosophy to be fully, but economically, exercised.

In China seaweed, stalks of water lilies, melon seeds, etc. are considered great treats, as are shark fins used to thicken soup and provide unusual flavors. China's so-called 100-year-old eggs are really 100 days old. They taste something like good cheese and they are as close to cheese as the non-dairy

Chinese ever got. They do, however, have an endless list of soybean products (their dairy equivalent).

(2) Japan

The ceremonials of the Japanese as related to the preparation and service of food are precise and rigid. The choice of food for a meal is no more important than the manner in which it is to be cut, colored, and arranged.

Customary dining revolves about the preparation of each dish at the table; hence, the food is cut into small pieces to permit rapid cooking. In addition, the Japanese consider the serving and eating of large pieces of food to be the grossest of bad taste.

Rice, the staple of Japan, as in China, is available in many varieties and the preparation is an art in itself. There is no resemblance, either in flavor or appearance, between the rice prepared by a Japanese cook and the rice appearing on the average American table.

Beef is a relatively recent item appearing on the Japanese menu. Until the American diplomat, Townsend Harris, went to Japan and pushed the issue, no beef was eaten. Japanese cattle were used as beasts of burden and they were regarded as virtual members of the family. To muffle Harris' complaint about the lack of "real meat", the Japanese slaughtered the first cow in 1856.

Unlike other Oriental countries, the Japanese eat regular meals more than twice a day. Dinner in a Japanese middle class home consists of a clear soup followed by possibly raw, roasted, or broiled fish. The usual rice dish accompanies this. Salads may consist of cucumbers, tomatoes, soya curd, sesame seeds, vinegar, sweet sake, and sugar. Dessert might be an iced bean curd.

5. Conclusions

a. Food Selection

The data presented in the above sections must be considered in a very general fashion only. What has been presented is the classical approach to food habits, customs, menus, eating schedules, and food types as a means of establishing some baseline for further work.

In considering what the impact of these ethnic food requirements might be on the recruitment of astronaut/scientists and on the engineering aspects of an International Space Station Food System, the following modifiers to the subject matter should be considered:

(1) The place of origin of an individual, whether urban, suburban, or rural, will make significant differences in the food requirements and eating habits.

(2) The higher the educational plateaus that have been achieved, the more tolerance there is for change and variety.

(3) In those scientific and/or academic communities from which crewmembers would be recruited, attendance at conferences and symposia are common. Since these are often held in widely scattered geographical areas, they present the opportunity for breaking with traditional food habits.

(4) The sophisticated communications media, the growth of international advertising, and the establishment of modern travel aid in the exposure to, and the amplification of, diverse cuisines.

(5) The sum total of the characteristics of the individuals who would be selected as crewmembers on an orbiting vehicle are inherently such that, among other things, rigidity in traditional food habits would not be exercised. These are generally adventuresome types whose goals and motives are less mundane than average; whose education, experience, and exposure to various social situations is more extensive; and who, when faced with the opportunity of joining an international cadre of their peers, would largely forego the traditionalist's approach to food.

It seems likely, therefore, that in composing the food requirements for an aggregate of ethnic cultures, satisfactory compromises can be achieved to assure a mutual agreement between crewmembers on the food supply.

b. Impact on Food Management Systems

In discussing a theoretical cuisine for an Orbiting International Laboratory with various food suppliers and processors, it became evident that, even at present, almost any reasonable recipe and combination of basic food ingredients can be processed and packaged in accordance with the engineering requirements established elsewhere in this report.

It is possible, however, that a larger variety of prepared foods will be required for the international crew than would be planned for an exclusively American complement. The rationale to substantiate this statement is based upon experience from previous missions and personal observation. If an American crew were polled on their food requirements, it is likely that of the broad spectrum of foods that could be made available, a relatively narrow band width of food types could be agreeably negotiated. These choices would probably appear as uncomplicated meals. The broad experience of the United States airline purveyors bears this out. Their continuing survey of food preferences has evolved menus that adhere largely to steaks, fowl, and simple seafood recipes -- all served as relatively large sized pieces of the basic ingredients. Another example is the experience of the chef of the liner S.S. France. On a United States to France crossing with a predominance of American passengers, seven grill stations are totally occupied in preparing broiled steaks. On a France to United States crossing with an essentially European passenger complement, only three of the grill stations are operated; the third used primarily as a standby operation.

If, however, the same optional selectivity were offered to an international crew, the outer limits of the food types that might be desired and could be made available would necessarily be very extensive. Correspondingly, the agreeably negotiated food items would also result in a narrow bandwidth, but one of larger magnitude than that selected by the exclusively American crew.

The new guideline for the spacecraft food system impact then becomes one of developing, preparing, and storing a larger variety of food types. Although the equipment design may not change appreciably, the volume certainly will.

Similarly, the hardware required to heat, chill, rehydrate, or serve an international cuisine will be appreciably impacted for the same reasons; the larger variety will require more complicated procedures in maintaining temperatures, varying oven settings, etc. to achieve an acceptable end product.

The crew time required in the preparation of meals will be extended due to the procedural techniques that a potentially extensive menu may engender. In a 12-man international crew dining situation, with possibly four or five different items to be served, the crewman on galley duty will be required to do some very extensive planning and scheduling in order to bring all the items together at the proper time and temperature yet offend no one's sensibilities.

B. SPECIALIZED AREAS

1. Special Dinners

During the course of any mission cycle, whether of 14-day or 90-day duration, consideration should be given to providing special dinner menus for the crewmen as a means of acknowledging certain events. These could include birthdays, holidays, Sundays, postnatal celebrations, anniversaries, etc.

Fairchild Hiller's experience with personnel confined in space chambers for relatively long periods of time has indicated that due to the absence of normal sensory stimuli, diminished activity, and monotony of diet, some rather strange psychological abberations become evident. These characteristics were not the classically psychotic behavior patterns, but rather what may be termed as "peculiar" deportment. In order to modify this condition, many tactics and psychological techniques were instituted. One of the most effective was the promise of providing a special Sunday meal. The resulting discussions as to menu selections, dining hour, and attendant activities resulted in a high degree of anticipation on the part of the crew, with an accompanying reduction in non-productive behavior.

Although the flight crew will be composed of highly trained and motivated individuals, it is very likely that the institution of similar "reward" criteria can have only beneficial results.

The food types and menus may be preselected by the crewman concurrent with the technology of preparing, packaging, and storing these items aboard the spacecraft. The advent of commercially prepared and available convenience foods makes this program rather simple to implement.

Furthermore, it is not likely that any additional items of hardware or equipment would be required to provide and prepare these foods.

2. Special Diets

It is conceivable that in a long-term mission (90 days), one or more of the crewmen may develop a physiological condition which affects his appetite in general, and his acceptance of the prescribed meal plan in particular. In that eventuality, it is considered desirable to institute a special diet section in the food inventory to accommodate this possibility.

Illness may change a crewman's psychological orientation to his (new) everyday occurrences and interpersonal relationships; the need for the familiar and customary then becomes immeasurably increased. Because of what, how, and with whom he eats is an everyday occurrence, illness, which interrupts this pattern, may have serious psychological repercussions. The frustration that will undoubtedly become evident in a crewman as he changes from an independent, healthy, contributing individual to one dependent on his fellow crewmen may be reflected in regressive behavior. A properly designed supportive diet will aid in modifying this condition.

It is recommended that a quantity of food types be placed aboard the space vehicle to accommodate the following three diets:

a. Soft Diet: Consists of precooked, packaged fruits and citrus fruits, soups and broths, dairy products, ground beef, fish, puddings, custards and gelatin, milk beverages, tea and coffee substitutes.

b. Mechanical Soft or Dental Diet: Essentially similar to the soft diet, but with the solid meats modified to fit the definition of mechanically soft.

c. Liquid Diet: Usually served in 2-3 hour increments rather than normal eating schedule due to its low nutritive value. Consists of those food types which lend themselves to being strained or pureed. These foods are suggested for patients with severe infections or gastrointestinal tract disturbances. Since an individual with a medical condition requiring this type of diet does not have the desire to eat very often, it is recommended that a high protein, high calorie beverage be included in the provisions.

3. Emergency Food Considerations

In the event that spacecraft crews are faced with contingency operation of the vehicle due to an emergency situation, it is recommended that a special food supply be provided in the central axis tunnel/core shelter equivalent.

In designing the contingency food supply, the following assumptions should be considered:

a. In stressed situations, the eating habits of the crewmen may be classified under three broad categories which are based on body configuration and can be utilized with some degree of confidence. One is the ectomorph (characterized by elongated extremities), mesomorph (characterized by large bones and muscle mass), and endomorphs (who are rounder and have, at least potentially, a lot of adipose tissue). Since the selection of crewmen will probably be made from the first two categories, a good guide to eating requirements would be that the ectomorph will refuse food during stressful situations, while the mesomorph will require food in order to function.

b. The contingency food supply should support the crewmen for 14 days. The type of food to be provided should consist of dry and rehydratable products packaged in plastic films.

c. The caloric value of the food should be 1500 Kcal man/day.

The weight and volume of this food supply is given below:

1500 Kcal =	.74 lb of food nutrition
Add	.03 lb water (normally present in dehydrated food)
Sub-Total:	.77 lb food/man/day
Add Package Weight	.11 lb (includes flaps and valve)
Total:	.88 lb/man/day

The total volume of the packaged food = .25 ft^3 man/day.

Providing 1500 Kcal/man/day will permit a crewman to function intellectually, perform certain hard physical tasks, and endure some heat stress until rescue is effected.

An alternative diet, and one that is considered a bare minimum, can be supplied by 1000 Kcal/man/day. The weight and volume of this food supply is given below:

1000 Kcal =	.50 lb of food nutrition
Add	.02 lb water (normally present in dehydrated food)
Sub-Total:	.52 lb food/man/day
Add Package Weight	.08 lb (includes flaps and valve)
Total:	.60 lb/man/day

The total volume of the packaged food = .17 ft^3 man/day.

Providing 1000 Kcal/man/day will permit a crewman to function intellectually, perform certain light physical tasks, and endure only limited heat stress until rescue is effected.

The water requirement for each crewman is approximately 5.5 lb/day less the small increments of water contained in the dehydrated food. It is assumed that the station potable water system will supply this quantity.

SECTION VII

FOOD HANDLING IN ZERO-GRAVITY BY ELECTROSTATIC RESTRAINT

A. OBJECTIVE

Concurrent with the food system study, an advanced technique was investigated to develop a system which would simulate a gravitational force on the food and food handling devices while crewmembers work and dine in a sustained zero-g condition. It was felt that such a system would improve the psychological well-being of the crew-members by providing a more natural environment during food preparation tasks, serving, and dining. The electrostatic dining system described in this section of the report could have application to any of the missions considered in this study.

B. APPROACH

The underlying principle to be used in this system is the force due to electrostatic attraction, an extension of the electrostatic work bench reported in NASA Report N69-37369 dated April 1969. The guidelines adopted were:

1) Safety: Reduction or elimination of food contamination, electrical shock, harmful energetic rays (X-rays, ultraviolet, etc.), noxious gases (ozone, nitrous oxide, and nitric oxide) and otherwise rendering the system fire- and explosion-proof.

2) Low electrical power drain.

3) Elimination or reduction of R.F.I. and E.M.I. which might interfere with communication and guidance equipment and scientific experiments.

4) Convenience of food manipulation and naturalness of the process of eating.

5) Applicability to a variety of food preparations.

C. TECHNICAL CONCEPT

When two electrically charged objects are near each other, an attractive force exists between them provided the objects are oppositely charged. Electrical charges can be sustained on the parallel plates of a capacitor by maintaining a voltage difference between them. If an external object possessing a positive charge is then brought within the region between the plates, it is immediately attracted to the oppositely charged plate. Several methods are used to place a charge upon an object, such as friction or electron bombardment. However, an effective technique generally used in commercial electrostatic precipitation systems is a shower of ions. This shower of ions is produced by the result of concentrating a sufficiently high voltage on the surface of a needle-like electrode. Voltage concentrations or electric fields in the order of 10^8 volts per centimeter are necessary although there are techniques and materials which can lower this requirement[1]. The use of a needle point as an electrode effectively intensifies the voltage concentration; that is, extremely high fields are produced at the tip giving rise to electron emissions. These electrons, in turn, tend to ionize surrounding air molecules, leaving them with a net positive charge. These positive ions flow toward the negative electrode, creating the so-called ion shower. This ion shower will impinge and positively charge any objects placed in the path of the ion migration.

The composition of the object introduced into the ion shower can be either a conductive or a non-conductive material. Both materials are capable of taking a surface charge; however, conductive materials tend to distribute their surface charges evenly over the entire surface, whereas the non-conductive objects orient their surface charges in a preferential manner depending on the surface shape and electrical characteristics of the material. For either case, the size or amount of charge that can be acquired by the object is dependent upon the capacity and potential of the object in the electric field.

To maintain a net charge on an object, ions impinging upon the surface must be supplied faster than the charge can dissipate. Figure VII-1 depicts a model of an electrostatic system illustrating two resistances through which an object could dissipate its charge. For example, if the object is touched by a crewmember, the surface charge dissipates at a rate limited by the resistance of the human body (to ground). If the object is suspended in air, the dissipation rate would be very low -- limited by the dielectric strength of the air. When the object is in close proximity to the table (negative electrode), an insulative coating on the table prevents the object from leaking its surface charge faster than it is supplied. This phenomena is illustrated in Figures VII-2 and VII-3.

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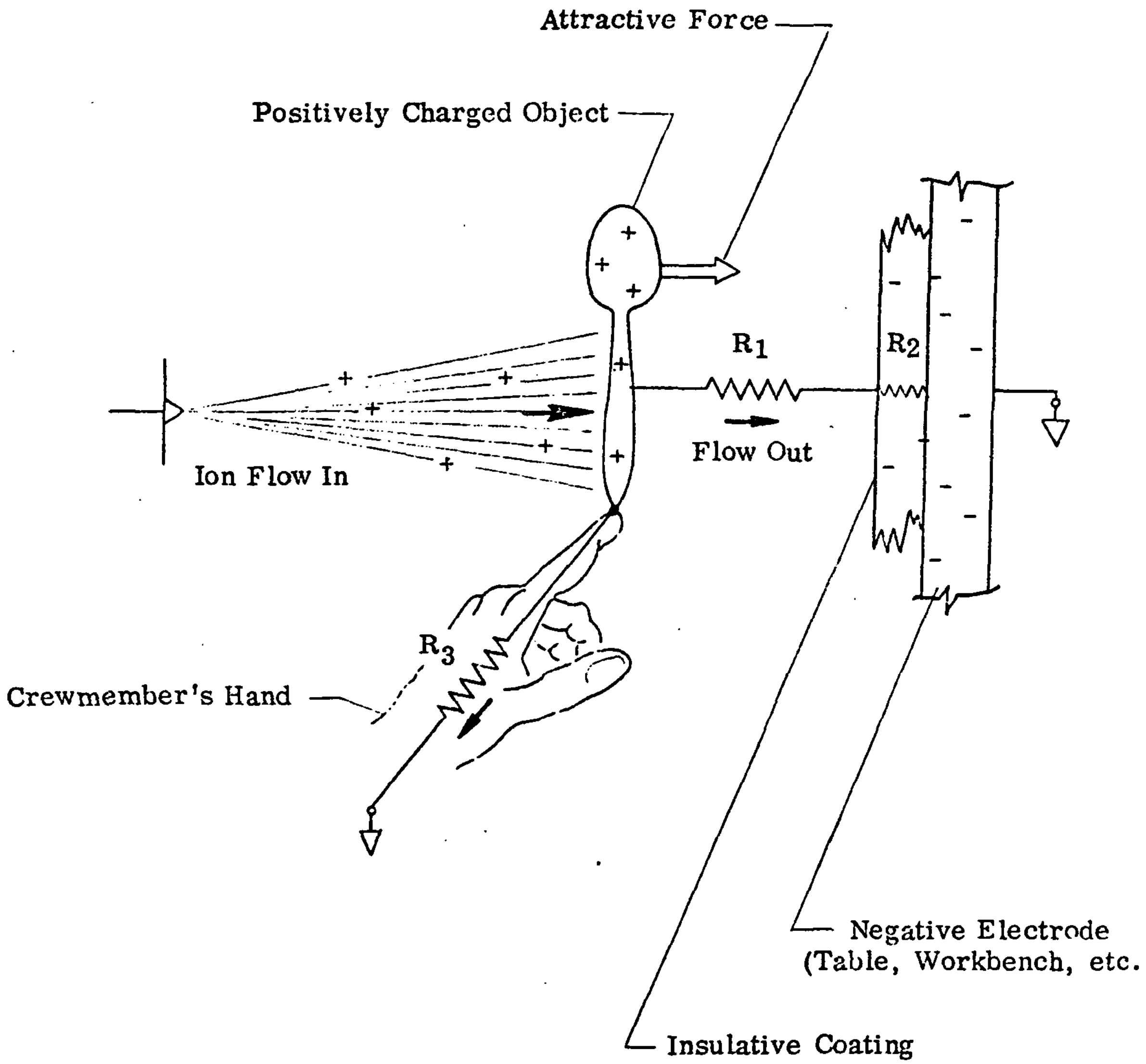
(1) Loeb, Leonard B., Basic Processes of Gaseous Electronics, University of California Press, 1955.



R_1 represents dielectric value of air

R_2 represents dielectric value of table coating

R_3 is the resistance of crewmember's body

Figure VII-1. Electrostatic Model

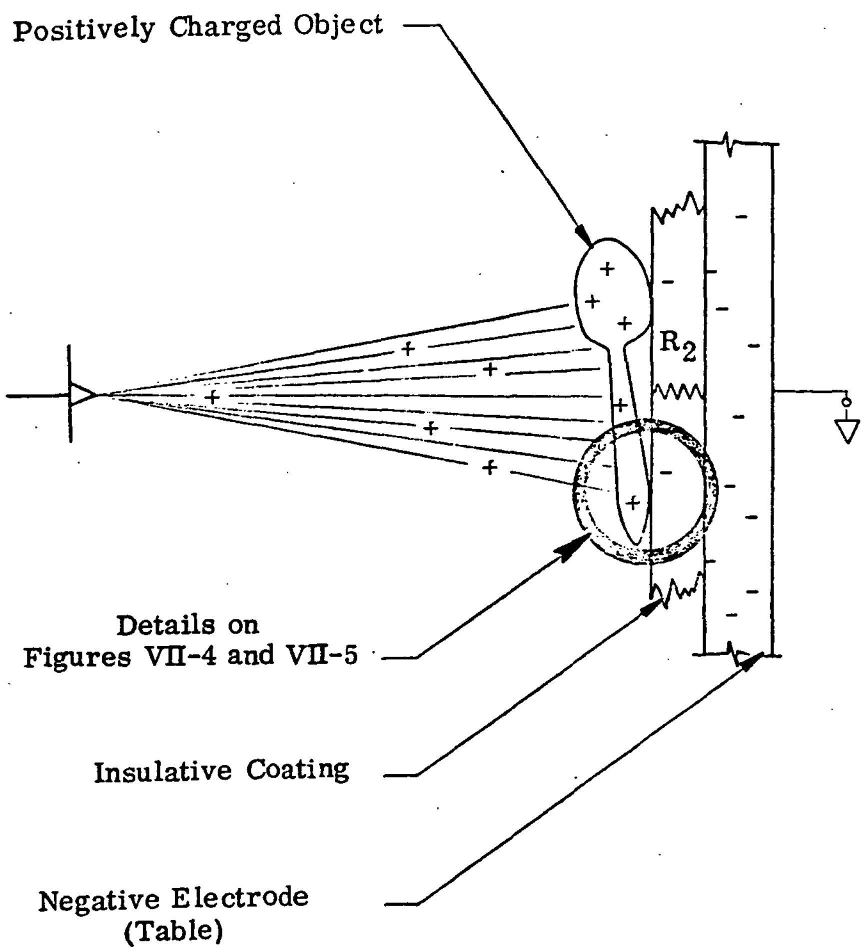


Figure VII-2. Charged Object in Close Proximity to Electrode

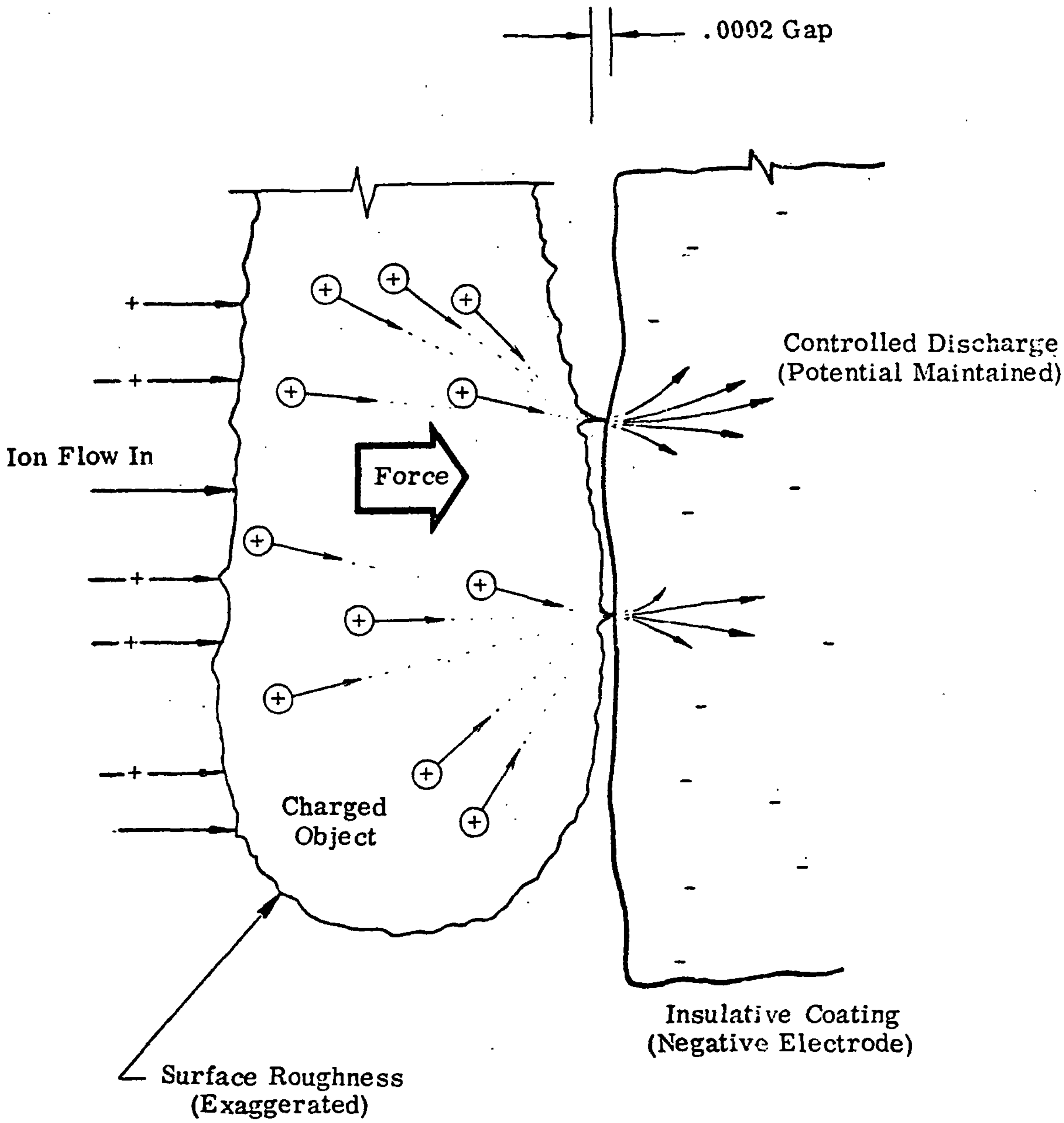


Figure VII-3. Development of Adhesive Forces

Once the condition of charge is ascertained upon the object, the force of attraction the object experiences varies with its distance from the table (negative electrode). Accordingly, the overall magnitude of the force can be heightened by increasing the voltage difference between the object and the negative electrode; however, there is a unique breakdown voltage above which value arcing occurs (R_1 approaches zero, see Figure VII-1) and the net charge on the object effectively drains away -- reducing the attractive force to nil. Paschen curves describe the maximum allowable voltages that can be applied between oppositely charged objects before arcing will occur.

The Paschen curves in Figure VII-4 typically show the breakdown or arcing voltages for several gases versus the spacing between (oppositely charged) objects at a specific ambient pressure. Note that for a given pressure and specific gas, the voltage necessary to cause a discharge arc reaches a minimum at a particular distance between the objects. As the spacing increases (to the right of the minimum) the voltage difference necessary for breakdown climbs as a slow linear function. However, as the spacing decreases (to the left of the minimums) there is a rapid rise in the required voltage difference to cause an electrical breakdown of the air between the objects. Such small distances (in the order of .0002 inches) are achieved by the mismatching of surface roughnesses. Because of this phenomenon it is possible to maintain extremely large voltage differences between the objects without a discharge arc occurring. Since the forces of adhesion increase with increasing electric fields, extremely large forces occur -- holding the objects together. However, these forces are only developed provided the surface of the electrode (table top) is coated with a highly resistive coating. This coating prevents the charged object from touching the electrode which would cause an immediate discharge. Figure VII-3 illustrates how the discharge is moderated and contained.

As a matter of interest, these extraordinarily large adhesive forces would not develop between the surfaces of highly polished objects. As the spacing decreased, the unmoderated discharge would rapidly occur as soon as the electric fields between the objects exceeded the breakdown voltages presented by Paschen's curves. The voltage differences and thus the electrostatic forces of adhesion between the objects would cease to exist, as illustrated on Figure VII-5. This phenomenon was studied by other investigators[2] who reported that a positively charged object in physical contact with a suitably coated negative electrode developed an extremely high force.

(2) Hagen, G.E., "Study of an Electrostatic Zero-Gravity Work Bench Prototype," NASA Report N69-37369 dated April 1969.

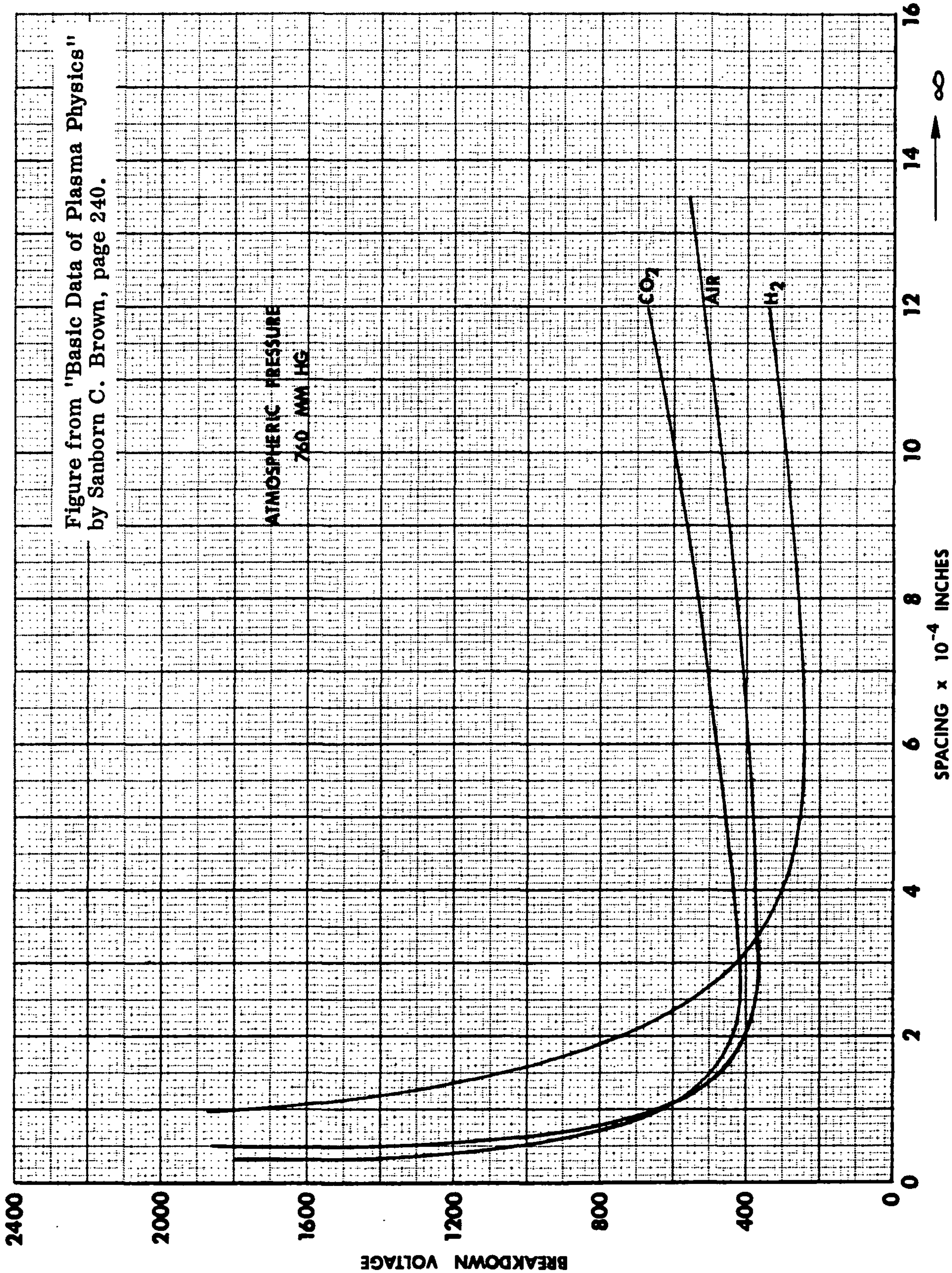
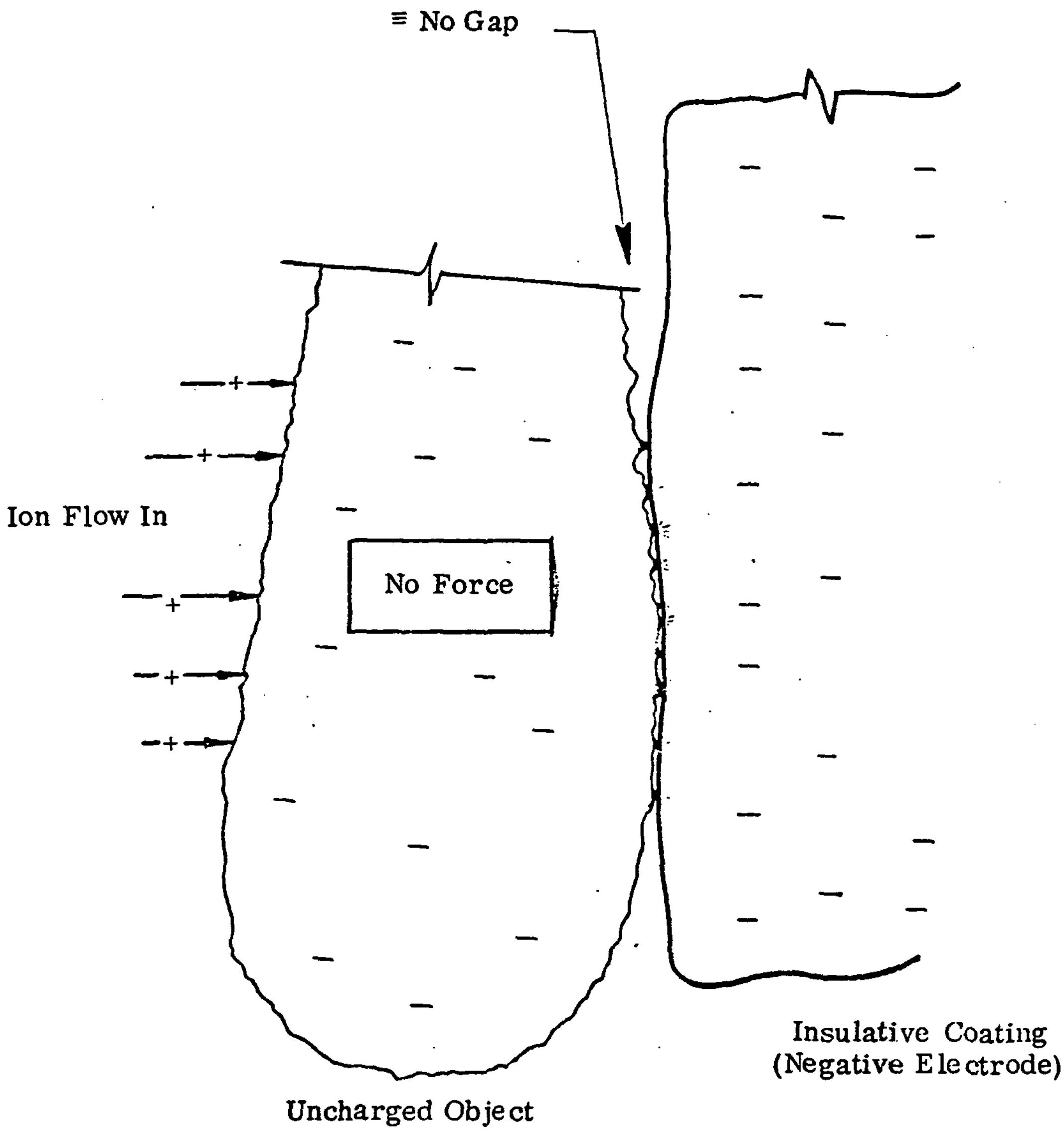


Figure VII-4. Paschen Curves For Several Gases



Potential between object and electrode is neutralized.

Figure VII-5. Complete Discharge of Object

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Thus, a simple restatement of the electrostatic force field concept is:

1) Establishment of an ion shower within a region of interest.
2) Charging an object placed within this region.
3) Utilization of attraction forces which cause the object to migrate toward the electrode (working surface).
4) Establishment of intensified adhesion forces upon contact with surface.

D. APPLICATION OF CONCEPT TO FOOD HANDLING

In order to provide suitable gravity effects for crewmembers dining in zero-g conditions, three mechanisms associated with positive-g food handling and food transferring techniques must be simulated. These mechanisms provide for (a) utensils and dishes adhering to table surfaces, (b) foods adhering to dish surfaces, and (c) foods adhering to utensil surfaces.

First, consider the so-called charged object as it is applied to the utensils and dishes adhering to the table surface. A number of properties which must be considered in the design are:

1) Material: The objects could either be conducting or non-conducting, relating to the distribution of the surface charge and the ease of discharge.

2) Shape and Surface Roughness: Surface shapes which have needle-like points give rise to extremely high electric fields or voltage concentrations, while generously curved surfaces distribute and diminish the electric fields. Also, surface roughness is instrumental in creating high electric fields between the object and the surfaces.

3) Size: The physical size of the object determines whether the preferential distribution of electric charge on the surface of non-conductors is significant. Also, large solid objects introduce undesirable shadow effects by shielding the benefits of the ion stream from objects in their wakes.

4) Location: Variations in the electric field exist throughout the interelectrode region. Locations near the edge of the ion shower experience fringe effects which can cause spatial variations over small distances. Also, the dependence of the attraction forces as a function of location has already been discussed.

5) Mass: This property is important in that for a given acceleration, objects with relatively large masses require proportionately large forces to arrest their motion.

6) Consistency: This property relates to the variety of food which can be handled by the system. Solid foods present no special problems; however, liquids or particulate mixtures containing varied consistencies may lead to problems of stability under perturbation. If an instability occurs, food might fly apart and splatter.

An example of using these design considerations would be the choice of a metallic, open mesh grid with a suitably roughened surface as a plate for solid food. This choice would result in:

1) Uniform charge distribution; lower secondary emission.
2) Surface conditions that would intensify adhesion to the dining table.
3) Ions that streamed through the plate open mesh--reducing the shadow effects.
4) Reduced mass for the plate.

Secondly, consider mechanisms that relate foods adhering to dish surfaces. The first problem encountered is when the food and the container (plate, cup, bowl, etc.,) are both charged positively and the question arises as to how they can remain in close proximity of each other.

A preliminary analysis presents two possible solutions. If the construction of the plate is an open mesh, then the grid size may be the critical factor. That is, if the grid is sufficiently open, most of the force will exist between the table and the food (providing that the plate and the food are close to the table). This type of problem is suitable for analytic solution(3). Another solution is to make the food container an electrical extension of the table top and mechanically held in place when in use. This technique could be applied to cups, bowls, or dishes.

The last mechanism to consider is that of foods adhering to surfaces of utensils. When a utensil is held by a crewmember, the surface charge is effectively drained and the utensil is brought to ground potential. Accordingly, the food, being positively charged, would thus be attracted to the utensil. Since the food is a very effective non-conductor (depending upon the amount of metallic ions in solution), its ability to completely dissipate its surface charge (into the grounded utensil) will be sufficiently delayed. That is, a total discharge is delayed long enough to transfer the food to the mouth and ingest it.

E. FORCES INVOLVED

The generation of different forces are inherent to the manipulative techniques of eating; these forces are generated during the processes of slicing, scooping, spreading,

(3) Morse and Feshbach, Methods of Theoretical Physics, Volume II, McGraw-Hill, New York, 1953, pp. 1231-1240.

mashing, etc. Components of these forces are both perpendicular and tangential to the dining table. Since normal forces in the order of 10^3 to 10^4 dynes probably represent the extent of electrostatic attractions, this means that the retarding force available to arrest the velocities of objects is only 1 to 10 grams (1g environment). Thus, great care must be exercised while eating to prevent tangential forces and outward normal forces from exceeding these limits. A compromise must be reached to suppress or obviate the occurrence of these excessive forces. This compromise is a trade between providing a more natural eating environment and the degree to which foods must be specially prepared. For example: a relatively dense steak or roast could be pre-sliced while coffee or tea could be stirred slowly in order to restrain forceful motions.

F. REDUCTION OF THE OPERATING POTENTIAL

It would be desirable to reduce the operating voltage of the electrostatic dining system to levels considerably lower than 30 kilovolts. The extent to which this could be accomplished can be determined by an analytical-experimental program. For example, the workbench prototype reported by Hagen[4] performed well at 30 kilovolts, but it is technically feasible to reduce this potential difference by 60% or more. That is, by inserting a secondary grid 3 to 4 inches forward of the needle-like point, intensely high field strengths would be preserved but requiring about one-quarter the original voltage potential. Figure VII-6 illustrates this technique. Field strengths in the inter-electrode area would degrade somewhat; however, a technique (with bias voltages) reported by Hagen can restore and amplify the original field-strength effects. He observed that with no bias voltage, adhesive forces between a given object and the table top rose to only 2 grams; but, the introduction of a bias (located beneath the table surface) of 600 volts dramatically magnified the comparable force to 11 grams. Based on these experiments it would appear feasible to design an electrostatic dining system which operates significantly below 30 kilovolts yet maintains field strengths at elevated levels.

G. ATMOSPHERIC CONDITIONS

Since the system depends upon the ability to hold charges, the atmospheric humidity will play a significant role in the performance of the system. The lower the humidity, the more close to ideal performance.

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(4) op.cit.

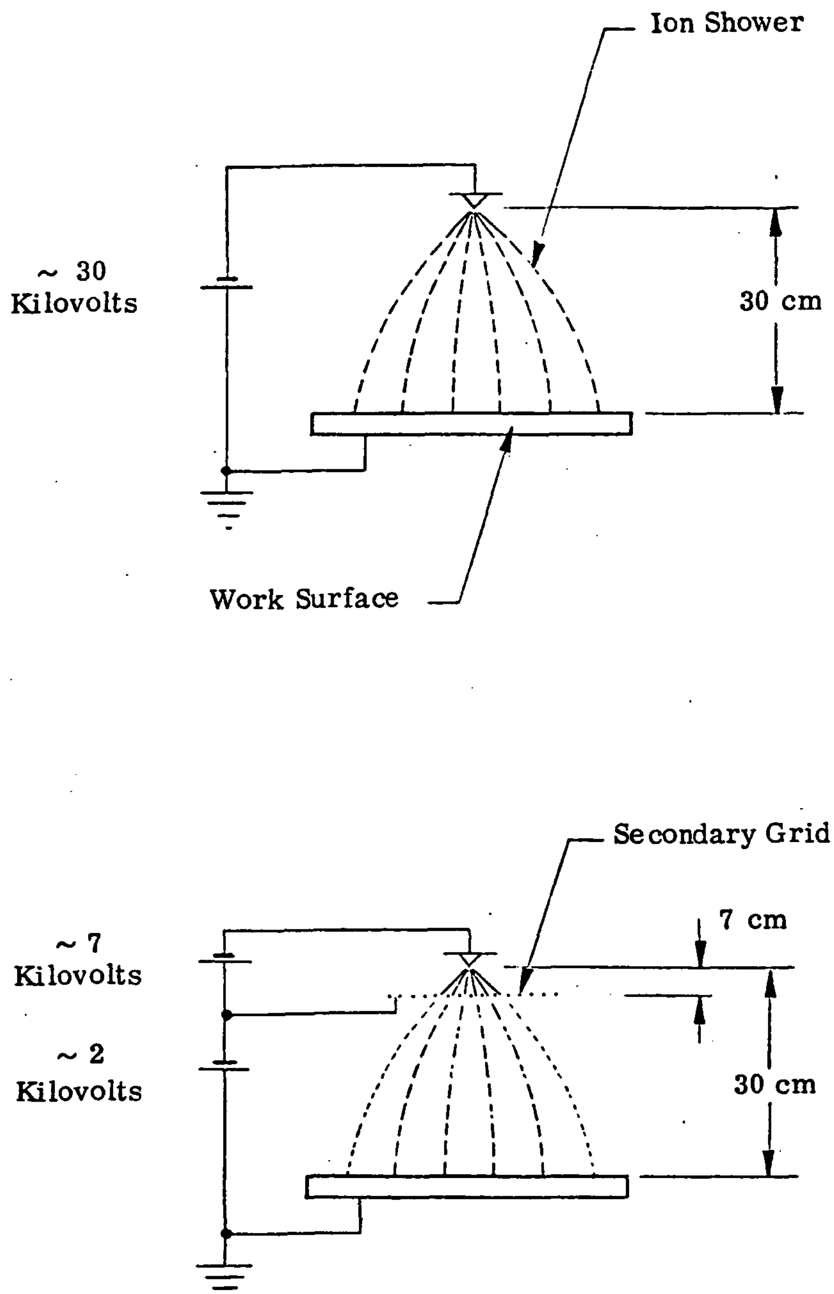

Figure VII-6. Influence of Secondary Grid

H. MATERIALS SELECTION

The selection of materials is instrumental in optimizing the overall performance of the system. For example, the use of fired-on porcelain as the insulative table coating would prove beneficial if it were not subjected to the destructive tensile stresses imposed during lift-off and launch. Alternative materials shown on Table VII-1 have similar electrical properties, but are lighter and capable of withstanding the environmental forces. Another example is the material selection for the steel needle electrode. A number of alternative metals and composite designs for the electrode could result in a highly effective ion shower operating at greatly reduced voltages. Primarily, however, the choice of the materials is still governed by health and physical safety standards.

TABLE VII-1. PROPERTIES OF MATERIALS

Material	Electrical Resistivity (Microhm - Cm)	Ratio of $\left(\frac{\text{Strength}}{\text{Weight}}\right)$ 1000 in.	Tensile Strength 1000 psi	Specific Gravity
Polystyrenes, General Purpose	$10^{25} \rightarrow 10^{16}$	250	8 → 5	1.06
Modified Polystyrenes	$10^{23} \rightarrow 10^{12}$	333	11 → 3	1.1
Polymethylstyrenes	$5{*}10^{23} \rightarrow 2{*}10^{14}$	-	-	-
Teflon, TFE, FEP	10^{25}	51	4	2.3
Polypropylene	$10^{22} \rightarrow 10^{16}$	185	-	-
Plastic Laminate (Low Pressure)	$10^{22} \rightarrow 10^{17}$	-	-	1.7
Nylons 6 and 11	$10^{21} \rightarrow 10^{18}$	323 and 250	12 → 8	1.1
Melamines (Electrical, not shock resistant)	$10^{19} \rightarrow 10^{17}$	-	-	-
Melamines, Glass Filled	$7 * 10^{16}$	217	10 → 3	1.8
Ceramics (Standard Electrical)	$10^{21} \rightarrow 10^{19}$	78/22	7 → 2	2.5
Steatite	10^{20}	150/40	15 → 4	2.7
Epoxies	$10^{20} \rightarrow 10^{18}$	368/296	16 → 5	3/1.1
Phenolics (Molded General Purpose)	$10^{19} \rightarrow 10^{15}$	179	9 → 2	3/1.2

SECTION VIII

RECOMMENDATIONS/CONCLUSIONS

A. GENERAL

The Food System Study evaluated a spectrum of possible systems comprised of a variety of conceptual elements combined to fulfill requirements for a range of mission profiles. While all basic functional elements were considered, of necessity, the depth of analysis was limited in scope, consistent with the study objectives. The technical data generated, therefore, provides the designer with a preliminary assessment of system requirements and equipment design characteristics for the specific constraint parameters considered. In addition, the computerized evaluation modeling technique developed during the study has proven to be a rapid and workable tool for integrating and optimizing these data.

B. RECOMMENDED FUTURE STUDY PROGRAM

It is recommended that the data produced in the present food system study be utilized as a basis for generating specific and detailed food system specifications fully reflecting interfaces for the manned spacecraft vehicles contemplated by the NASA in the next ten years. The objective of the follow-on study would be to identify and define system performance characteristics, functional features, required interfaces, equipment development requirements, support requirements, special study areas, and preliminary cost and schedule data for realistic mission parameters. The basic tasks would be as follows:

1. Identify Applicable Mission(s)

Due to the variety of potential configurations and options being considered for future manned spacecraft and the significance of establishing realistic mission requirements to ensure selection of an appropriate food system, the primary task would be to review and establish specific design vehicle guidelines for the study. Successful completion of this task should not only produce discrete spacecraft mission identification requirements, but should further identify preliminary interface impacts.

2. Systems Definition and Integration

The present food system study results should be reviewed, refined, and updated to reflect applicability to the new mission model(s) with specific emphasis on the interfaces imposed by these alternate space systems. The concepts for equipment elements would then be re-assessed and evaluated and tradeoffs performed to a depth consistent with a preliminary design analysis. Those technology items requiring development in order to ensure the validity of the assessment would be identified and design specifications prepared. The evaluation modeling technique should be refined to perform the detailed systems integration recognizing the impact of crew/mission/interface requirements.

3. Systems Optimization and Specifications

The evaluation model should be used to determine optimum systems for the applicable mission model(s) in terms of system weight, power, volume, reliability, crew acceptability, and cost. System tradeoffs would be performed for equipments and technique oriented concepts such as steward service versus self-service, bulk versus meal portion packaging, and the various dining equipment options. The tradeoffs could be based on cost ($/lb launch weight, $/lb resupply weight, etc.) or related penalty factors (weight = 2 x volume, weight = 1.7 x power, etc.). Finally, specifications would be prepared describing both individual equipment and complete food system(s) requirements for the realistic manned space systems considered. The specifications would also identify supplementary requirements for special diets, multi-national crews, special and emergency situations, contingency foods and experiments, as well as interface requirements for spares, resupply support equipment, and onboard systems.

C. RECOMMENDED LIST OF TECHNOLOGY DEVELOPMENT AREAS

The validity of any systems performance data is a function of the confidence level attained for equipment element characteristics. Major equipment items will have a significant impact on the overall system and may be critical in the final selection process. For those technology items previously identified as requiring basic engineering development, a plan should be generated outlining a recommended program of research, laboratory models, and prototype testing to verify performance characteristics, interfaces, and designs. Typical equipment items or systems that may fall in this category include:

1. Zero-Gravity Dishwasher/Dryer (Laundry Optional)

The tradeoff between reusable versus disposable plates, trays, dishes, utensils, cooking devices, etc. is contingent upon the development of an acceptable dishwasher. Requirements for water consumption, detergent use, temperature and distribution to determine cleansing efficiency washing action, power requirements, pretreatment and stacking arrangements must be determined. A liquid-gas separation device may return fluid to either an onboard reclamation system or one integral with and only for the dishwasher.

An optional design approach would be to develop a combination dishwasher/laundry since many of the washing functions are identical. Removable adapters could be used for either holding laundry or loading dishes so as to maintain separate cleansing areas for each operation. Concurrent with the development of the dishwasher, a study should be performed to develop and test a general purpose liquified concentrate to be used for all cleansing and sanitizing functions. The properties of such a concentrate should include high solubility in water to facilitate mixing in zero-gravity; ease of separation during water reclamation; a lack of odor, taste, or toxicity; and compatibility of vapors with the environmental control system.

A test program should include engineering laboratory feasibility tests, models and mock-ups, zero-gravity flight tests in a KC-135 aircraft to verify design approaches, and fabrication of a working prototype model for delivery to NASA.

2. Self-Heating Food Packages

Disposable or reusable food packages containing either individual or bulk meal items can be designed with integral surface heating elements and electrical connections for plugging to an external power source. This technique provides a simple, reliable, and inexpensive method for heating precooked and packaged foods. After reprocessing, the package can be inserted into a holder from which the crewmember could eat with conventional-type utensils. Pre-cut and portion size foods prepared in gravies or sauces, stews, vegetables, certain dessert items, and breakfast cereals would have high applicability with this technique.

A development program would investigate packaging materials and food compatibility, reliability of circuitry and connections, heating capabilities as a function of food types, preparation times, power requirements, weight and volumes for launch and stowed positions, and handling characteristics.

The majority of engineering and development tests could be laboratory performed at one-gravity. Zero-gravity flights could verify heat transfer characteristics to establish realistic heating times and power impact.

An area for future investigation would be to provide the self-heating food package concept with a temperature sensing capability. Current applications of the self-heating package technique are operated "open-loop"; that is, the electrical current is controlled with a timing mechanism that shuts off regardless of the temperature of the food sealed in the package concept. A crewmember is required to make a time consuming judgment based on tactile discernment as to whether the food is sufficiently warmed or not.

3. Reprocessing Equipment

Of major significance in developing total food system power requirements is the individual power assessment for the food warming or heating equipment technique. The heat transfer characteristics of foods reprocessed in a forced air convection oven, microwave oven or resistance heater oven should be verified in a zero-gravity environment. Ideally, it might be suggested that prototype equipment be placed aboard Skylab as an experiment to establish optimum equipment performance characteristics. Prior to that step, or in lieu of it, partial verification tests could be performed aboard a KC-135 during the approximately 20-30 seconds of zero-gravity produced during the parabolic flight. These tests could utilize temperature probes on the food and surrounding equipment to measure temperature changes and establish a profile related to gravity. Additional factors that should be evaluated include the efficiency and effectiveness of holding, restraint and locating devices internal to the ovens, and associated power requirements.

4. Storage Techniques

Several concepts of providing frozen and refrigerated storage temperatures were considered and evaluated during the course of the study. Three concepts (Sublimation, Radiator, and Thermoelectric) of refrigeration and two concepts for the freezer (Space Radiator and Thermoelectric) indicated highly acceptable performances based on their power, weight, and volume requirements.

However, it is recommended that the Space Radiator Concept, as applied to both refrigerator and freezer units, be given primary consideration; the freezer and refrigerator units based on the space radiator technique exhibited overall performances clearly superior to the remaining cold storage concepts evaluated.

An alternate secondary recommendation would be the Water Sublimation technique as it applies to the refrigerator, only. Based on an overall judgment of comparable power, weight, and volume penalties, the water sublimator refrigeration appears to be almost equal to the Space Radiator technique. It is the large weight penalty associated with the sublimation refrigerator that downgrades the concept to second best.

The weight penalty emanates from the limited rate at which the sublimation process occurs under the given ambient conditions; consequently, an inordinately large surface area is required to extract sufficient heat from the circulating refrigerator coolant. In addition, it should be mentioned that the sublimation technique, as it is applied to the freezer concept, resulted in sublimator sizes and weights that were prohibitive to consider for spacecraft application.

Thus, a future area for investigation would be to determine the optimum parameters and geometry required to minimize the size and weight of the sublimation unit. The investigation would also evaluate the techniques required during the start-up transient process when the unit re-starts from a dry condition following routine maintenance.

5. Zero-Gravity Sink

Maintenance of cleanliness and health standards in the galley and food handling areas are critical factors in the closed environment of a space vehicle. A personnel handwasher and sink should be part of the galley for use by the kitchen staff or individual crewmembers during food handling, food preparation, prior to and after dining, and clean-up tasks. The sink should also be designed to accept small utensils, trays, dishes, or miscellaneous preparation devices that require hand scrubbing to remove congealed or caked-on food wastes. This could be accomplished by fabricating the sink as an enclosed sphere with a hinged parting line at the diameter to provide a full access opening. When closed, iris-type hand openings permit access into the sink for operating internal water controls for flow and temperature during washing. A directed airflow would be used to control water positioning and recovery after use.

A test program should develop requirements for water distribution, flow rates, total water usage, water temperatures, cleansing efficiencies, power inputs, phase separation characteristics, and water recovery efficiency. Both one-gravity laboratory tests and zero-gravity flight tests would be required to fully evaluate, assess, and verify performance data.

6. Food Debris/Wastes Controlled Spillage Device

The food preparation and dining areas are subject to inadvertent spillage of foods and beverages, food particle and liquid droplet separation during preparation and consumption, and food wastes and debris loss in the zero-gravity environment. To minimize cleansing and retrieval tasks, a concept for "controlled spillage" would provide a simple mechanism for maintenance of cleanliness standards in the food management section of the spacecraft as well as reducing crew time tasks.

The preparation counters could be made as part of a plenum chamber where an induced directional airflow could ingest spilled particles through a series of orifices in the top surface. The plenum receptacle would be teflon lined to facilitate cleaning and by virtue of its hydrophobic surfaces, reduce particle adherence to the walls. Bacterial and odor control filters would process the cabin air used in collection prior to its cabin return. A similar device could be built directly into the dining counters or table tops. For the dining area, additional access to the plenum chamber could be provided by the use of teflon iris-type openings, through which solid wastes such as napkins, wipes, linens, or disposable utensils could be inserted. These items would be directed to a clean-out filter trap where wastes would be "bagged" and disposed of by the onboard waste handling devices.

A test program would be required to verify performance characteristics of this device with emphasis on power requirements to produce sufficient airflow to control specific wastes. The inter-relationship of waste types and sizes, airflow requirements, and power could be established on a preliminary basis in one-gravity and negative one-gravity laboratory tests prior to actual zero-gravity tests. Cleansing efficiencies, adherence characteristics, bacterial buildups, and odor control effectiveness could be verified in engineering laboratory tests.

7. Bulk Mixer and Dispenser

Considerable savings in weight and volume can accrue for crew sizes of six (6) or more men if present individual beverage packages can be replaced by a bulk mixer and dispenser. This device would be a multi-purpose unit for beverages, soups, or liquids and could contain a variable-size orifice to dispense different consistency mixes. A measured amount of fluid would be added to a soluble package of dry concentrated mix to create a homogeneous mixture either by hand or mechanical agitation. The device would then dispense by positive displacement a controlled and measured amount of mix on demand.

A test program would be required to develop efficient mixing and dispensing techniques for various consistencies of fluid. One-gravity laboratory tests could primarily be used to verify basic orifice sizes, dispensing rates and efficiency, and residue problems. Zero-gravity tests would establish mixing performance and final dispensing characteristics.

8. Food Restraint Techniques

The objective of creating an earth-like food system for multi-manned space vehicles is contingent upon the premise that preparation and dining techniques will not require unique or special skills, equipment, or personnel. Also, that a variety of food familiar in appearance, taste, and aroma would be made available to the crewmembers. All equipments and systems generated in this study are based upon the assumption that this objective can be achieved. Although some data are available on eating in zero-gravity, considerable additional effort is recommended if more advanced food systems are contemplated than presently existing on Apollo and planned for Skylab.

A basic zero-gravity test program could determine the effects, desirability, efficiency, and preference for various types of adhesive/cohesive foods, edible food coatings, membranes, food flaps, or mechanical cover devices. Food types could be checked for determination of the most applicable restraint or whether any restraint is required. It is recognized that once foods are in opened trays or dishes, standardized utensils can be used, with care, to eat in a normal manner. Whether a similar capability exists in preparing food from bulk storage or individually in ovens is uncertain. The test program could identify and verify the need for and recommend techniques as well as solutions to problems of preparation and dining.

The electrostatic dining system discussed in detail in Section VII of this report offers a more advanced but higher development risk concept to achieve similar objectives of food restraint. A suggested program outline follows in the next paragraph.

D. ELECTROSTATIC DINING SYSTEM

The concept of an electrostatic dining system as described in Section VII could be adapted in future spacecraft to minimize zero-gravity acclimation problems in work areas as well as the food management section. The preliminary analysis conducted during the study program indicates that the concept is feasible. An analytical-experimental program is recommended to develop a working model of the system capable of demonstrating the techniques of zero-gravity food handling. An outline of such a program could be as follows:

1. Analytic Phase

a. Determine the static and dynamic electric field and force distributions using a variety of food consistencies with the food/utensil/container and crewmember interactions. (Computer analysis)

b. Determine shadow effects of an open mesh metallic plate upon the table/food/plate system.

c. Develop the concepts of the food container being an electrical extension of the table top, culminating in detail design data.

d. Examine a variety of electrode designs and potential-difference requirements for augmenting ion production at lower voltages.

e. Optimize the influences of the biasing field in conjunction with a charging field.

f. Perform trajectory analysis on the effects of force perturbations during eating procedures; determine the degree to which foods must be specially prepared and the amount of motion restraint that crewmembers must practice to reduce excessive lateral and outward normal forces. (Computer analysis)

g. Tabulate the electrical and dynamic (mechanical) properties of foods to determine which varieties can be handled by the system.

h. Determine the stability of a charged liquid, particulate conglomeration, or resilient food such as soup, hash, or jello under a perturbing force.

i. Investigate any potential health hazards due to ingesting ions such as N^+ or NO^+.

j. Specify overall system safety, ease of operation, and maintenance without electrical interference.

2. Experimental Phase

a. Develop models of various electrode systems to finalize the design for ion production at lower voltages.

b. Experimentally verify the relative influence of biasing versus charging electric fields.

c. Place foods of various consistencies within the system to determine the adequacy of the analytical program.

d. Determine optimum designs for various types of utensils and holders. A laboratory model of the extension of the table container should be constructed and used.

e. Use various materials for the insulative table coating to find the most suitable for the mission.

3. Prototype

a. Fabricate, test, and deliver a working prototype model of the zero-gravity electrostatic dining system.

E. INTERNATIONAL CREWS

In Section VI of this report, Special Food System Study Considerations, a detailed discussion and food history preference analysis was included describing the potential problems of selecting a food system for multi-national crews. Eating habits, food types, preparation techniques, seasonings, and even personal hygiene differences can significantly impact food selection and equipment items.

A special study is recommended to expand potential data accumulated in the follow-on study program so as to specifically evaluate selected crew mix options in terms of systems changes that may result from the crew selection. The study would follow the guidelines outlined in paragraph B, Recommended Future Study Program, and would be concerned with the identification of various crew nationality mixes, preference and critical differences by nationality, significance of differences with respect to food and equipment, impact of differences on selected systems, and a change matrix depicting requirements to accommodate the various crews.

F. COMPUTERIZED MEAL PLANNING

It became apparent during the course of the present study, in the review of literature and in discussions with food nutritionists, that existing techniques for planning space diets were inadequate for advanced missions beyond Apollo and Skylab. While it is possible to physically plan and itemize a preselected menu, any deviation or variance creates an uncontrolled situation where accurate recording, inventory, and logistics becomes extremely difficult. When the objective of creating a varied, optional, and crew selected diet is superimposed on this condition, it becomes almost a hopeless task for the planner to maintain order in the food system.

A system is required to not only provide initial meal menu plans and record on a continuing basis amounts of consumed, spoiled, wasted, and unconsumed foods, but also to maintain an inventory and logistics control for resupply provisioning, and to simplify the procedures and processes necessary to enable the food planner to make recommendations for food consumption requirements on a daily basis. This monitoring of consumption should therefore assess the food types, caloric intake, nutritional aspects of the consumed food, the degree of acceptance, and crewman workload factors and assimilate these data with respect to food requirements, onboard inventory, and preference ratings in order to produce a series of recommended menu options for the crewman. A cumulative inventory control for each food type would also provide an input to determine resupply and provisioning needs.

G. PACKAGING DEVELOPMENT

During the course of the Food System Study, surveys were conducted of both commercial and space-type packaging data in order to arrive at realistic assessments of packaged food weight and volume penalties to be assigned to the various missions. In addition, compatibility of food and package type had to be determined to maintain integrity of the food in its stored environment and during handling functions. Two problems became apparent as information was compiled. One, a surprisingly limited amount of test work had been done on any optimization or development of minimum weight packaging materials with respect to specific food types and environment; second, only generalized data could be found on bulk packaging options, techniques, or arrangements to arrive at optimum configurations for the missions considered. Although packaging contributes an obviously significant penalty to the system weight and volume, a disproportionate amount of engineering data are available.

Commercial packaging weights vary from .016 lb/lb food for 2 mil polyethylene film to .124 lb/lb food for peel top aluminum cans. The range of space type packaging was found to be from .104 to .217 lb package/lb food, due to the more stringent environment requirements. Since a ground rule of the food system study was to design to a normal one-atmosphere, commercial packaging weight criteria were used and an approximation of 10% of food weight was allocated for packaging. No provisions were made for packaging protection in the event of loss of cabin atmosphere. If space type criteria had been used, then approximately 10% - 20% of food weight would have been allocated for packaging. This variation creates major impacts on storage, resupply, and disposal requirements, and should be resolved as part of a development effort to determine minimum weight packaging materials to meet environment and handling criteria. This effort would also entail determination of the compatibility of specialized materials or laminates with food types to ensure against storage deterioration, spoilage and appearance, taste, or aroma changes.

Upon the establishment of minimum weight packaging materials and a food type compatibility matrix, the study should then explore the development of bulk packaging configurations for the various food types. This may include a determination of whether such food items as roasts, steaks, chops, or hams should be pre-sliced, separated by dividers, packaged in cylindrical, tetrahedral or square containers, and what the optimum size of the final package should be for storage, reuse, and disposal constraints. The output of this effort should be a parametric study defining packaging options, penalties and constraints for specific crew sizes and resupply periods for each food type.