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31 DECEMBER 1970

NASA APPROVED

DATA BOOK
SPACE STATION/BASE FOOD SYSTEM STUDY
BOOK II
SUPPORTING TECHNICAL DATA

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

Contract NAS9-11139
DRL Line Item No.12

Prepared by
Manned Space Systems
FAIRCHILD HILLER
FAIRCHILD REPUBLIC DIVISION
...NEW YORK 11735

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CONTENTS

CONTENTS (concluded)

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 Book II of the Data Book. The Data Book, containing the detailed technical data, supporting analysis, and selection rationale for each of the concepts considered in the Final study, has been prepared in three books:

Book I - Element Concept Data Sheets

This book contains the detail engineering data sheets for all concepts studied in the Final phase of the contract effort as well as those concept sheets only carried through the Interim phase due to non-applicability or deleted missions.

Book II - Supporting Technical Data

This book contains formulae, assumptions, calculations, and supporting analyses for the element concept data sheets.

Book III - Study Selection Rationale Sheets

This book contains the supporting rationale sheets utilized in selection and support of those concepts studied in the Final phase of the contract.

The results of the study have been compiled in the Final Report - Volumes I and II, which contain the documentation and summary of the contract effort.

The program 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

Due to the bulk of data assembled in Book I of the Data Book, all supporting assumptions, formulae, calculations, and analyses have been compiled in this book. This document, therefore, provides information to the user pertinent to the development of the performance characteristics calculated for the data sheets in Book I. Sample calculations are shown, as well as the rationale used in developing these data.

SECTION II

TECHNICAL DATA

The following technical data are presented by functional subsystem area for the critical equipment items pertaining to food storage techniques (freezers and refrigerators), reprocessing techniques (ovens), consumption and dining utensils, and clean-up devices. Data pertaining to food inventory are presented in detail in Final Report, Volume I, Section III, paragraph 1.0. Data pertaining to Functional Subsystem Area 4.0 - Provide For Serving of Food, are primarily technique oriented rather than equipment options and as such are presented in Final Report, Volume I, Section III, paragraph 4.0 and in Data Book, Book I, Section II, Functional Subsystem Area 4.0.

No equipments design were considered for Functional Subsysteam Area 7.0 - Provide For Recording of Food. Narrative information is presented in Final Report, Volume I, Section III, paragraph 7.0.

FUNCTIONAL SUBSYSTEM AREA 1.0

PROVIDE FOR FOOD

Detail data for this functional subsystem area are presented in Final Report, Volume I, Section III, paragraph 1.0

FUNCTIONAL SUBSYSTEM AREA 2.0

PROVIDE FOR STORAGE OF FOOD

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.1.4 Title: Water Sublimation Freezer

Assumptions:

Formulae:

Significant Factors:

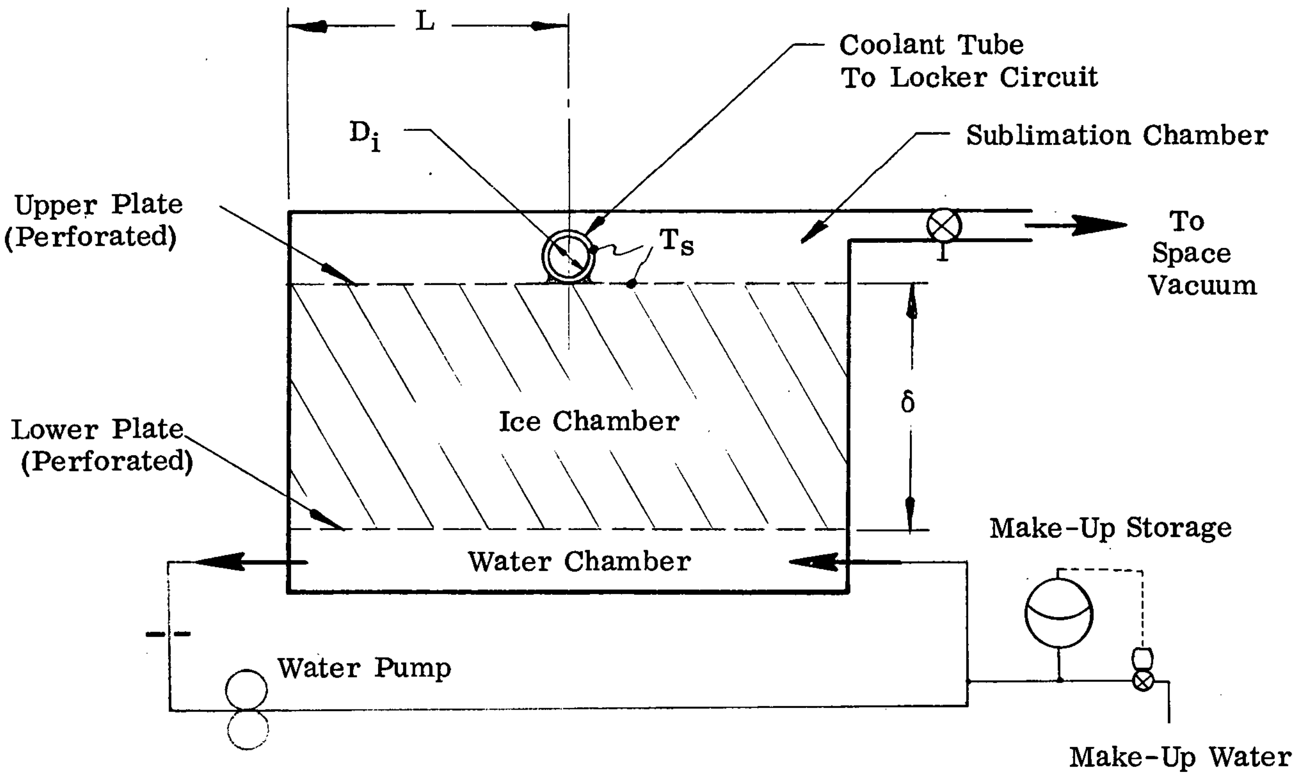
General Information:

References:

"Sublimation of Granular Solids", International Developments In Heat Transfer, 1961 International Heat Transfer Conference, p. 707-711, published by ASME.

The water sublimation equipment receives warmed coolant fluid as it leaves the freezer or refrigerator locker and extracts heat from it. The coolant is then redirected back to the cooling circuit within the locker. 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 following analysis considers only that portion of the cooling process external to the locker; that is, the extraction of heat from the coolant tubes using the water sublimation technique. The analysis of the locker and associated internal cooling configurations are detailed in Concept 2.1.6 (Space Radiator Freezer).

A schematic drawing of the sublimator unit is shown below. The coolant tubes pass through the sublimator and return to the locker cooling circuits at a lowered temperature.



Schematic of Sublimation Process

Solidified water sublimes in the region of the upper perforated plate. The products of sublimation pass through the upper perforations and are vented to the vacuum of space. The heat of sublimation is absorbed along the upper plate and associated tube; this results in a coolant temperature reduction.

The solidified water located in the ice chamber is continuously utilized in the vicinity of the upper plate while new ice layers are being formed just above the lower plate. The eroding surface of the ice is continuously forced against the upper plate due to the static pressure maintained in the water chamber. The pressure is maintained by the circulation pump in the water loop.

The analysis is presented with the following assumptions:

1. Assume perforated plates are $1 \times L\ ft^2$ in area.
2. Assume plates are solid for conductive heat flow.
3. Assume tube walls and upper plate are at a uniform temperature T_s.
4. Assume the system has passed through the starting transient and is at steady state.

The required temperature of the upper plate is determined by calculating the tube wall temperature required to sufficiently cool the transport fluid before it is circulated back to the freezer locker.

The energy balance on coolant and tube is

$$h_c A \ \Delta T_c = \Delta \text{enthalpy} \tag{1}$$

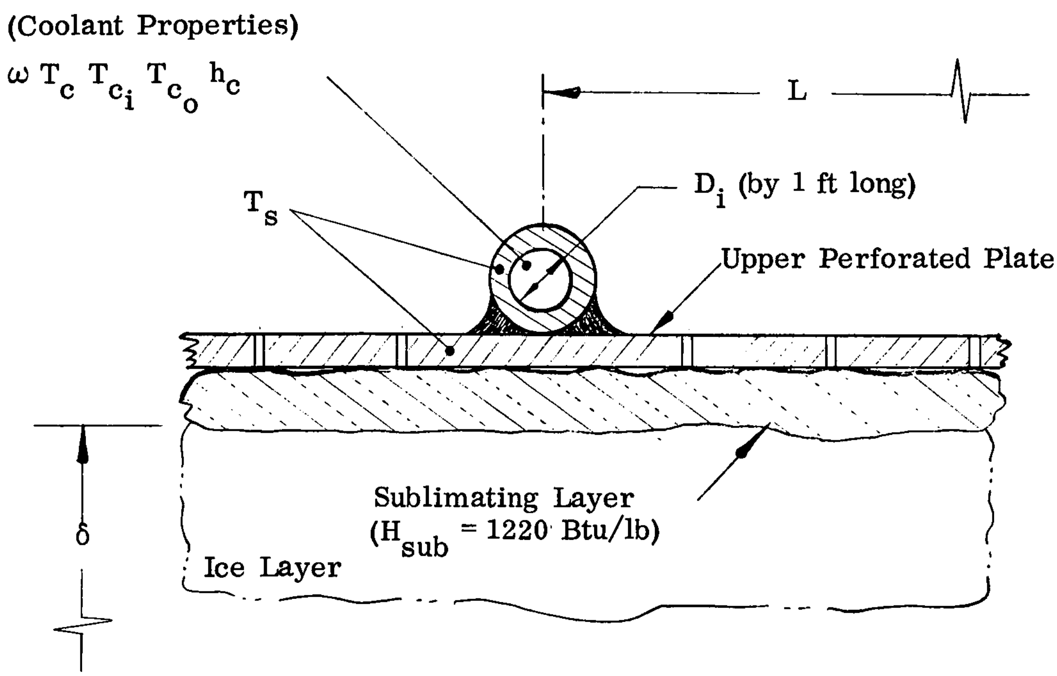
$$h_c \pi D_i (\bar{T}_c - T_s) = \omega Cp_c (T_{c_o} - T_{c_i}) = 2 \omega Cp_c (\bar{T}_c - T_{c_i})$$

and the energy balance on upper perforated plate is

$$Q_{conduction} + Q_{coolant} = Q_{sublimation} \tag{2}$$

$$2 L \frac{k}{\delta} (32 - T_s) + h_c \ \pi D_i (\bar{T}_c - T_s) = H_{sub} \ \dot{m} \ (2L)$$

where $\dot{m}$ is the rate of sublimation per unit area and the remaining parameters are described by the schematic below.



the energy balance on the lower perforated plate is

$$2L\frac{k}{\delta}(T_s - 32) + H_{ice}\,\dot{m} = 0 \tag{3}$$

Substituting (1) and (2) into (3) gives

$$2\,\omega Cp_c\,(\bar{T}_c - T_{c_i}) = (H_{sub} - H_{ice})\,\dot{m}\,(2L) \tag{4}$$

The rate of sublimation per unit area is given in the reference for planar surfaces where the vapor pressure at the surface is greater than the total pressure of the system as

$$\dot{m} = 2.784\,(P_e - P_i)\,\alpha\,\sqrt{M/2\,\pi R T_s}$$

where

$\dot{m}$ = lb/hr ft^2
α = accommodation coefficient (assume .70)
P_e = vapor pressure at T_s in mm Hg Abs
P_i = partial pressure above surface
M = molecular weight, lb/lb mole
R = gas constant, 1545 ft-lb/°R-lb mole
T_s = surface temperature, deg R

FREEZER CALCULATIONS

The following values are constants or have been determined in the analysis for the freezer locker in Concept 2.1.6 (Space Radiator Freezer) and apply here also.

ω = .616 lb/hr per ft^2 of freezer interior sheet

$\bar{T}_c$ = -19.2°F

Cp_c = 0.52 Btu/lb °F

T_{c_i} = -29°F

h_c = 11.95 Btu/hr ft^2 °F

D_i = 0.218 inch

k = .97 Btu/hr ft °F

H_{sub} = 1220 Btu/lb

H_{ice} = 144 Btu/lb

Determine the required temperature for the upper perforated plate from equation (1)

$$T_s = T_c - \frac{2\,\omega\, Cp}{h\,\pi\, D_i}\left(\bar{T}_c - T_{c_i}\right)$$

$$T_s = -19.2 - \frac{2\,(.616)\,.52}{11.95\,(.218)\,\pi}\left(-19.2 + 29\right)$$

$$T_s = -28.4°F$$

Determine the desired rate of sublimation from equation (4)

$$\dot{m}\,(2L) = \frac{2\,(.616)\,(.52)\,(-19.2 + 29)}{1220 - 144}$$

$\dot{m}\,(2L)$ = .00584 lb/hr per ft^2 of freezer internal sheet

Determine the rate of sublimation actually produced per ft^2 of sublimating surface

at T_s = -28°F (432°R)

P_e = .202 mm Hg absolute

P_i = 0

so

$$\dot{m} = 2.784\ (.202)\ .70 \left[\frac{18}{2\ \pi\ (1545)\ 432} \right]^{.5}$$

$$\dot{m} = 0.000815 \text{ lb/hr ft}^2 \text{ of upper plate}$$

Determine the required area for the upper perforated plate

$$(2L * 1) = \frac{\dot{m}\ (\text{required})}{\dot{m}\ (\text{actual})}$$

$$(2L * 1) = \frac{0.00584}{0.000815}$$

$$(2L * 1) = 7.16 \text{ ft}^2$$

where

$2L = 7.16$ ft (width of sublimator)

The consequence of this value for 2L is that for every square foot of internal aluminum sheet in the freezer, an area of 7.16 ft^2 of perforated sublimator plate is required to remove sufficient heat from the coolant tube. In addition, the foregoing mathematical investigation must be rendered invalid since the analysis was predicated on the assumption that the perforated plate and associated coolant tube were at one uniform temperature, T_s. It is obvious that large gradients would exist across a plate 3.58 (1/2 * 7.16) feet in width.

To preserve the technical continuity of the analysis, the calculations for the water sublimation refrigerator concept will be presented here rather than in section 2.2.4.

REFRIGERATOR CALCULATIONS

The following values are constants or have been determined in the analysis for the refrigerator locker in Concept 2.2.6 (Space Radiator Refrigerator).

ω = .230 lb/hr per ft^2 of refrigerator interior sheet

$\bar{T}_c$ = 30.4°F

Cp_c = 0.55 Btu/lb °F

T_{c_i} = 20°F

h = 4.44 Btu/hr ft^2 °F

D_i = 0.218 inch

k = 0.97 Btu/hr ft °F

H_{sub} = 1220 Btu/lb

H_{ice} = 144 Btu/lb

Determine the required temperature for the upper perforated plate from equation (1)

$$T_s = 30.4 - \frac{2\ (.230)\ .52}{4.44\ (.218)\ \pi} \quad (30.4 = 20.0)$$

$$T_s = 21°F$$

Now, determine the desired rate of sublimation from equation (4)

$$\dot{m}\ (2L) = \frac{2\ (.230)\ (.55)\ (30.4 - 21)}{1220 - 144}$$

$$\dot{m}\ (2L) = 0.00221 \text{ lb/hr per ft}^2 \text{ of refrigerator internal sheet}$$

Determine the rate of sublimation actually produced per ft^2 of perforated surface

at T_s = 21°F (481°R)

P_e = 2.75 mm Hg absolute

P_i = 0

so

$$\dot{m} = 2.784\ (2.75)\ .70 \left[\frac{18}{2\ \pi\ (1545)\ 481}\right]^{.5}$$

$$\dot{m} = 0.01052 \text{ lb/hr ft}^2 \text{ of upper plate}$$

Now, determine the required area for the upper perforated plate

$$(2L * 1) = \frac{\dot{m}\ (\text{required})}{\dot{m}\ (\text{actual})}$$

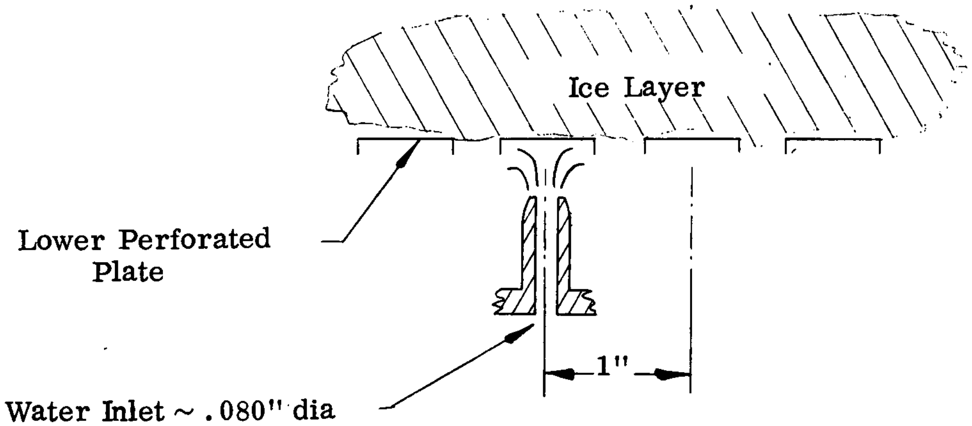
$$(2L * 1) = \frac{0.00221}{0.01052}$$

$$(2L * 1) = .210 \text{ ft}^2$$

where $2L$ = 2.52 inches (width of sublimator)

POWER FOR PUMP IN WATER LOOP

The water pump circulates the water through an enclosed chamber in the sublimator covered by the lower perforated plate. The water loop is pressurized to supply sufficient force to maintain close contact between the sublimating ice layer and the upper perforated plate. Nozzles located beneath the lower plate provide impingement cooling of the plate. If the freezing point of the water is chemically depressed by only 2 or 3 degrees, for example, impingement cooling aids in the formation of ice crystals in the stagnant area above the lower plate. One typical nozzle is shown below.



Assume nozzles are located on a 1-inch grid; that is, each unit area of the sublimator (12" x 3") contains 22 nozzles. (A unit area will be required for each square foot of refrigerator interior aluminum sheet.) Also assume a 0.2 psi drop across the nozzle. The flow required of 22 nozzles is expressed as

$$Q = A\sqrt{2g_c \Delta p/\gamma}$$

$$Q = \frac{\pi}{4} (.080)^2 \left[2\ (32.2)\ (0.2)/62.4\right]^{.5} (22)$$

$$Q = 3.26\ \text{ft}^3/\text{min}$$

Assume that an orifice in the water line upstream of the pump causes a back pressure in the water chamber of 1.0 psi; thus, the pump must circulate 3.26 ft^3 per minute against a 1.20 psi head. The power for the water pump, assuming .50 efficiency, is expressed as

$$\text{Power} = (3.26\ \text{ft}^3/\text{min})\ (1.20\ \text{psi})\ (.0226\ \frac{\text{watts}}{\text{ft-lb-min}^{-1}})\ 1/.5\ (144)$$

$$\text{Power} = 26.0\ \text{watts per ft}^2 \text{ of internal refrigerator sheets}$$

Recall that each square foot of internal refrigerator sheet intercepts 2.07 Btu per hour. An 80% duty cycle effectively increases this rate to 2.59 Btu/hr. Thus,

$$Q_{\text{locker heat loss}} = \left(\frac{2.07}{.80} \right) * (\text{sheet area in ft}^2)$$

or,

$$A_{\text{sheets}} = \frac{\text{locker heat losses (see Figure 2.1.6(a))}}{2.59}$$

$$\boxed{A_{\text{sheets}} = 0.386 \text{ (locker losses)}} \text{ ft}^2$$

Now, the power to drive the water pump can be expressed in terms of the locker heat losses as

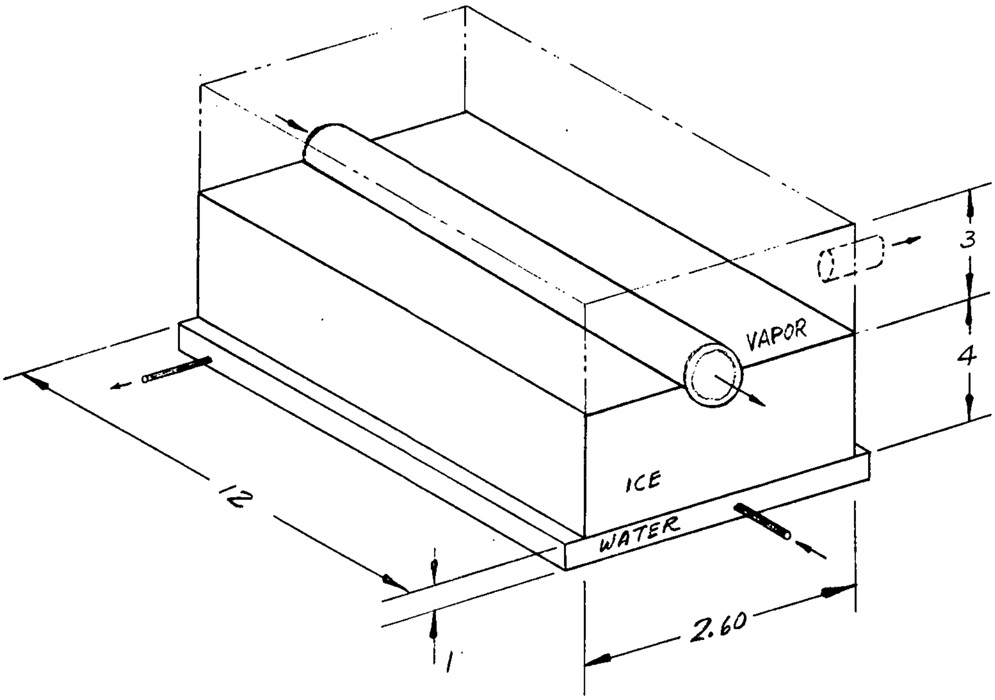
$$\text{Power} = \frac{26 \text{ watts}}{\text{ft}^2} * 0.386 \text{ (locker losses)}$$

$$\boxed{\text{Power} = (10.04) * (\text{locker losses})^{**}}$$

(**See Figure 2.1.6(a))

SUBLIMATOR WEIGHT

(Per square foot of internal refrigerator sheets.)



Component Weights:

Coolant Tube	$= \pi D t L \rho = \pi (.250) (.064) 12 (.10) =$	0.06
Ice Chamber	$= 2 \left[(4 \times 2.6) + (4 \times 12) + (12 \times 2.35) \right] .032 (.10) =$	0.56
Water Chamber	$= \left[2 (1 \times 3) + 2 (1 \times 12) + (3 \times 12) \right] .032 (.10) =$	0.29
Vacuum Chamber	$= \left[2 (3 \times 2.6) + 2 (3 \times 12) + (12 \times 2.6) \right] .032 (.10) =$	0.38
Ice	$= 4 (2.6) 12 (58) 1/1728 =$	4.20
Water	$= 12 (1) 3.0\ 62.4/1728 =$	1.30

Total sublimator weight per ft^2 of internal refrigerator sheet structure

<u>Wt = 6.80 lbs</u> (per ft^2)

Equating the weight to the locker losses

$$Wt = (6.80)\ .386\ \text{(locker losses)}$$

$$\boxed{Wt = 2.62\ \text{(locker losses)}^{*}}\ \text{lbs} \qquad \text{(*See Figure 2.1.6(a))}$$

Likewise, the expression for the volume is

$$\boxed{Vol = .068\ \text{(locker losses)}^{*}}\ ft^3 \qquad \text{(*See Figure 2.1.6(a))}$$

STORAGE WEIGHT AND VOLUME PENALTY OF SUBLIMATED FLUID

Because a hard vacuum is required for the sublimation process to occur, two alternative techniques may be used as a vacuum sink: a vent line to space, or an evacuated storage vessel. The storage vessel alternative would require a vacuum or ion pump to continuously evacuate the products of sublimation entering the vessel. Also, the capacity of the evacuated vessel must be sufficient so that the internal pressure (or the lack of pressure) would not be sensitive to perturbations in the flows entering or leaving the vessel. In addition, the starting transient resulting from the initial priming of the sublimator unit would require a vacuum sink capable of ingesting any large transient flow rates. The consequence of the starting transient would require an overboard vent line to space. If the sublimated water was to be recovered and recycled, a centrifugal-like condensor would be required also.

However, it is highly expedient to use a vent line to space as the primary vacuum sink even though the water vapor could not be recovered. Thus, sufficient water must be set aside solely for the sublimation process. Water for the entire mission may be stored in tanks or it can be reclaimed from the water content in the daily rations comprising the frozen and refrigerated food.

The following analysis will determine whether the water reclaimed from the daily food rations is greater than or less than the water required to operate the sublimation refrigerator concept.

The daily water requirements for any size sublimating refrigerator are:

$$\frac{\text{lbs required}}{\text{day}} = \left(.00221\frac{\text{lbs}}{\text{hr ft}^2}\right)(.386\ \text{locker losses})\ (24\ \text{hrs/day})$$

$$\frac{\text{lbs required}}{\text{day}} = .0204\ \text{(locker losses)}$$

The daily amounts of water freed from the food rations consumed by any size crew are:

$$\frac{\text{lbs freed}}{\text{day}} = (\text{men in crew})\left(\alpha,\ \frac{\text{lb water}}{\text{lb food}}\right)\left(\beta,\ \frac{\text{lb food}}{\text{man day}}\right)$$

The values for α and β can be found in Volume I - Final Report, Section III, Functional Subsystem 1.0 (Provide For Food), Figures III-10 through III-45. These figures present details on the food weight, volume, and water content for each mission. Examination of the figures will reveal that no special water storage requirements are warranted when water is reclaimed from both frozen and refrigerated food rations. In addition, the sublimator requirements can be wholly sustained from the daily consumption of refrigerated rations alone, save for the following five missions tabulated below.

Mission	Sublimator Requirements (lbs/day)	Water Released* (lbs/day)	Daily Shortage (lbs/day)	Mission Shortage (lbs)	Mission Shortage (gallons)
25	3.74	2.85	.89	80.0	10
27	2.82	1.63	1.19	107.0	13 1/2
29	1.82	0.84	1.00	90.0	11 1/4
33	3.74	3.25	.49	44.1	5 1/2
35	2.48	1.68	.80	72.0	9

*Considering the water content of refrigerated rations only.

A sample Data Sheet used to tabulate the various parameters associated with each particular refrigerator follows.

Values for "β" to be used in sample Data Sheet are as follows:

Diet	Number of Men: 6	12	25	50
20/80 B	2.85	5.71	11.95	23.8
C	7.78	15.5	32.4	64.8
60/40 B	1.63	3.25	6.78	13.55
C	4.06	8.11	16.9	33.9
85/15 B	0.84	1.68	3.50	7.0
C	1.76	3.52	7.31	14.65

$\beta\left(\frac{\text{lbs } H_2O}{\text{day}}\ \text{freed}\right)$

DATA SHEET: WATER SUBLIMATION REFRIGERATOR CONCEPT

Mission Number ______________

(____ Men and ____ Days)

Diet Mix: 20/80 B C
60/40 B C
85/15 B C

Note: Locker losses appear on Figure 2.1.6(a)

	Weight (lbs)	Power (watts)	Volume (ft^3)
1. Weight of locker only (see Figure 2.1.6(b)) =	☐	-	-
2. Weight of sublimator unit only = 2 (locker losses)	☐	-	-
3. Daily water requirement for refrigerator = .0204 (locker losses) = ____ lbs required			
4. Daily water amount freed from food rations = (crew size) (lbs water freed/man-day) = "R", see above = _____ lbs freed			
5. Is Line 3 greater than Line 4? Yes enter line 3 minus line 4: _____ No skip to line 7			
6. Water weight penalty = (line 5) (days in mission)=	☐	-	-
7. Water volume penalty = (line 6) $\left(\frac{ft^3}{62.4\ lbs}\right)$	-	-	☐
8. Volume of locker only (see Figure 2.1.6(c)) =	-	-	☐
9. Volume of sublimator unit only = .068 (locker losses) =	-	-	☐
10. Power for pump = 10.04 (locker losses) =	-	☐	-
TOTALS	☐	☐	☐

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.1.6 Title: Space Radiator Freezer

Assumptions:

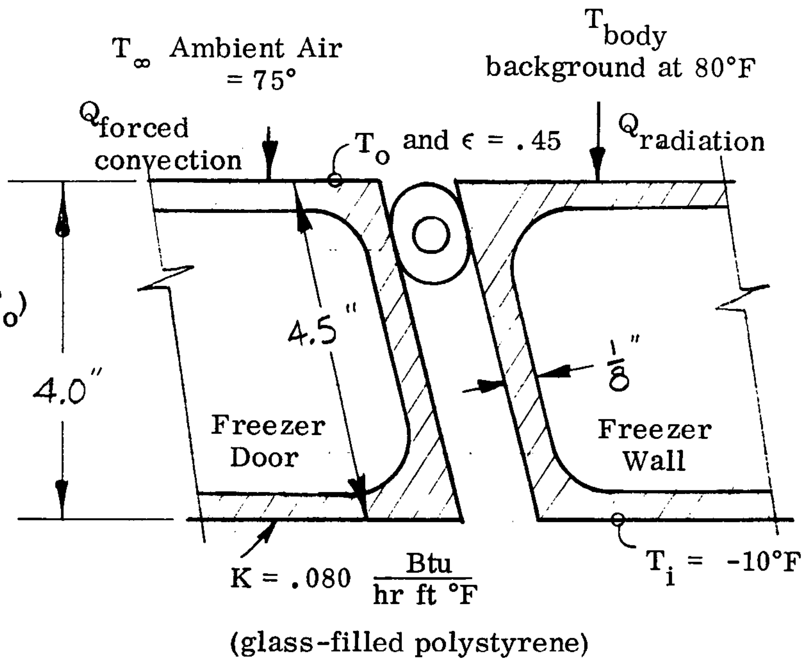
Formulae:

Significant Factors:

General Information:

References:

THERMAL ANALYSIS OF FREEZER DOOR SEAL LEAKAGE



$Q_{forced\ convection} = hA(T_\infty - T_o)$

$h \approx 2.0 \frac{Btu}{hr\ ft\ °F}$

$A \equiv 2\,(.125/12 * L)\ ft^2$

$T_\infty = 75°F$

$Q_{radiation} = \epsilon A \left[\sigma T_{body}^4 - \sigma T_o^4\right]$

$\epsilon = .45$

$A \equiv 2\,(.125/12 * L)\ ft^2$

$T_{body} \equiv 80°F$

$Q_{seal\ convection} = \frac{KA}{\Delta X}(T_o - T_i)$

$K = .080 \frac{Btu}{hr\ ft^2\ °F}$

$A \equiv 2\,(.125 * L)$ in.ft.

$\Delta X = 4.50$ inch

$T_i = -10°F$

now Assume $T_o = 69°F$

$Q_{radiation} = .00936\,(L)\,[145.7 - 134.22] = .108$ Btu/hr

$Q_{convection} = .04165\,(L)\,(75 - 69) = .250$ Btu/hr

where $Q_{total} = .358$ Btu/hr

$Q_{seal\ conduction} = .00445\,(L)\,(69 + 10) = .351$ Btu/hr

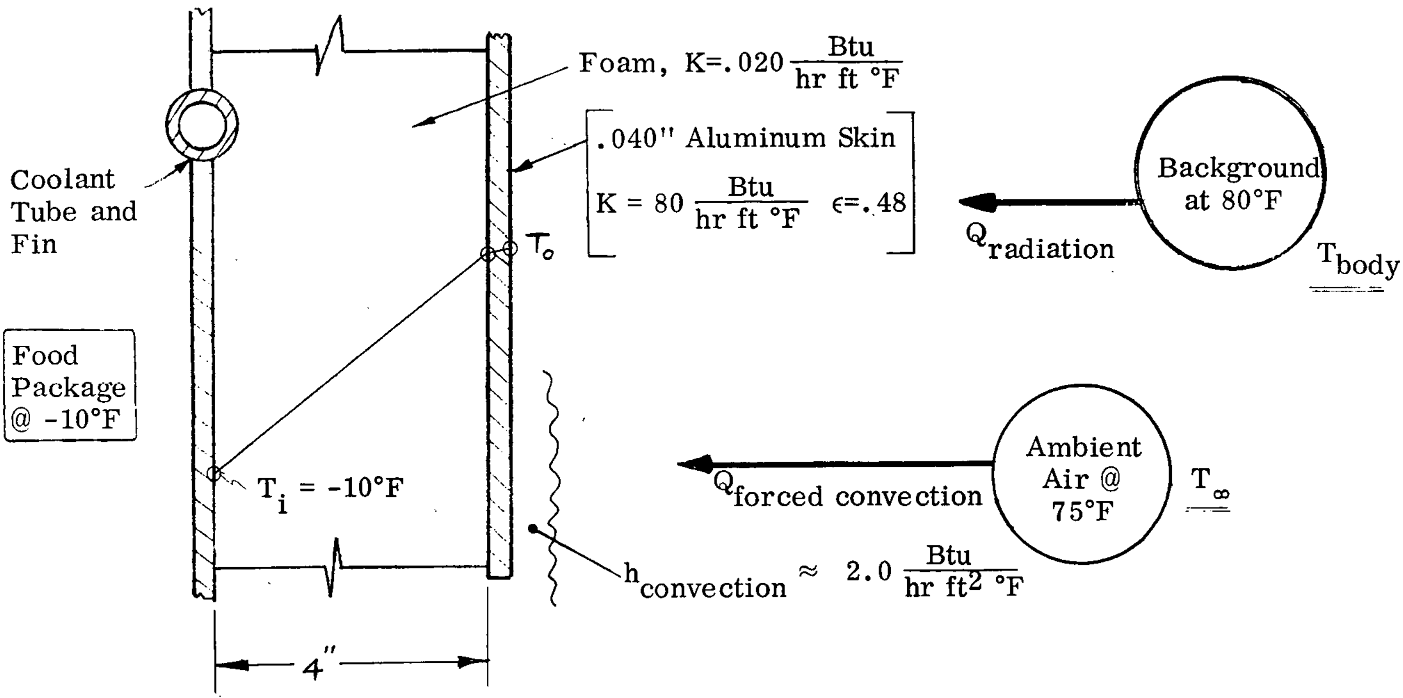
Therefore $Q_{radiation} + Q_{convection} = Q_{conduction}$.

So that $T_o = 69°F$ and

$Q_{door\ seal\ losses} = .351(L)$

where L is length of door seal circumference in feet.

THERMAL ANALYSIS OF FREEZER WALL (INSULATION LOSS)



Assume $T_o = 74°F$

$$Q_{convection} = hA(T_\infty - T_o) = 2.0(1.0)\ (75-74)$$

$$= \underline{\underline{2.00\ \text{Btu/hr}}}$$

$$Q_{radiation} = \epsilon A\left[\delta T_{body}^4 - \delta T_o^4\right] = .48(1.0)\left[145.7 - 139.3\right]$$

$$= \underline{\underline{3.04\ \text{Btu/hr}}}$$

$$U_{\substack{overall\\ T_o \to T_i}} = \frac{1}{\frac{\Delta X}{K} + \frac{\Delta X}{K}}$$

$$= \frac{1}{\frac{.040/12}{80} + \frac{4.0/12}{.020}}$$

$$U_{T_o \to T_i} = .06\ \frac{\text{Btu}}{\text{hr ft}^2\ °\text{F}}$$

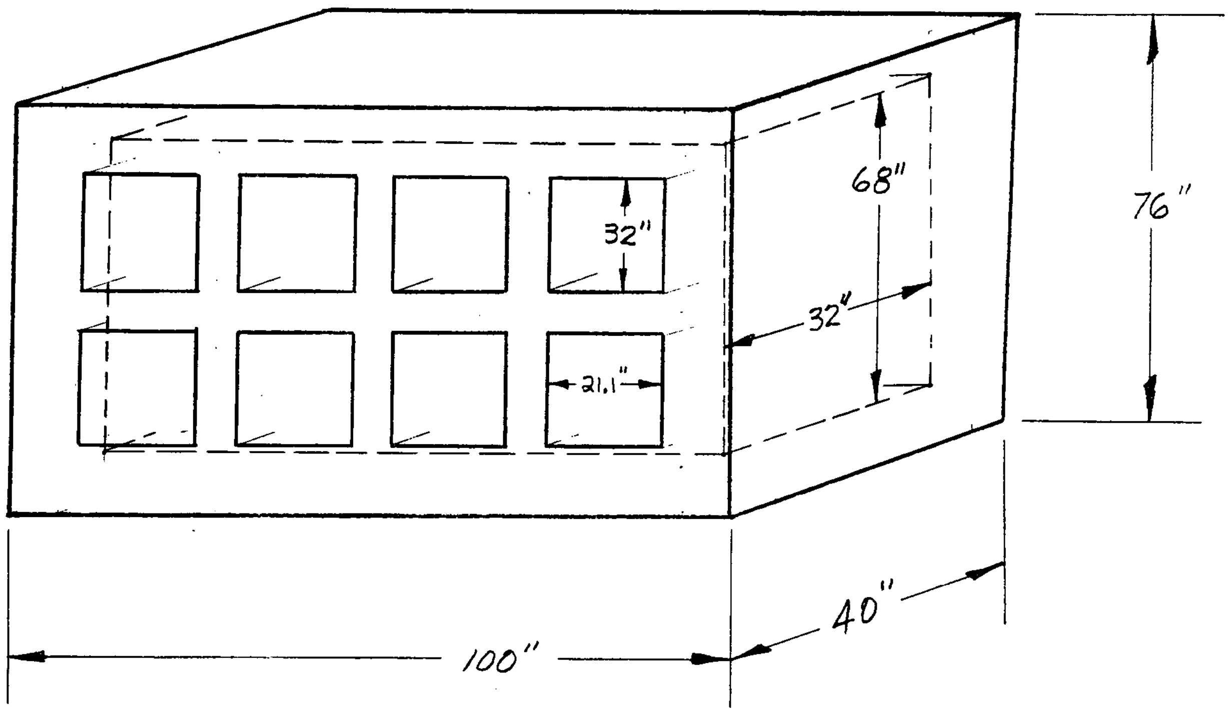
check...

$$Q_{insulation} = UA\ (T_o - T_i) = .06(1.0)(74+10) = \boxed{5.04\ \frac{\text{Btu}}{\text{hr}}\ \text{per ft}^2\ \text{of freezer wall}}$$

and $\left[T_o = 74°F\right]$

THERMAL ANALYSIS OF FOOD LOCKER (FROZEN OR REFRIGERATED)

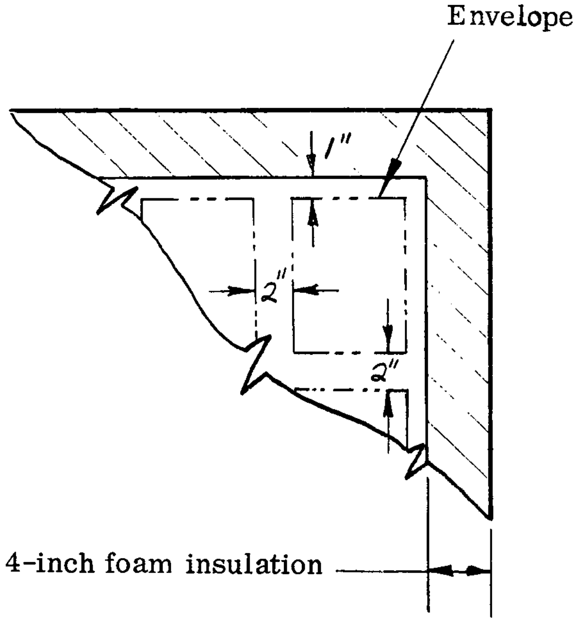
Typically: Analysis for 100 ft^3 food locker...



Volume of food in freezer locker = 100 ft^3

Use 4-inch polyurethane foam insulation in all external walls and doors.

Allow 1- and 2-inch spacing between compartments for packaging, structure, insulation, finger clearance.



It is assumed that the foam envelope enclosing the frozen food will remain cubical in shape to minimize surface area losses; this rationale is valid only to the extent that the width does not exceed 40 inches or the height does not exceed 76 inches. A total width of 40 inches will permit a crewmember to span 36 inches to food packages at the rear of the freezer compartment. A total height of 76 inches will facilitate the installation of the freezer unit within the deck-to-deck dimension.

Total heat losses associated with the frozen food locker:

a) Surface Area Loss
b) Door Seal Loss
c) Conduction (Structural) Loss
d) Door Opening Loss

Surface Area Loss

Because the surface losses depend on both radiation and forced convection mechanisms operating upon the external locker surfaces, the exact loss through the walls depends upon the particular installation of the freezer locker within the vehicle. That is, if a freezer wall is butted against a deck or bulkhead, the radiation mechanism associated with that wall may vary unpredictably while the convection mechanism may drop to zero, altogether. To account for this, it is assumed that no heat leaks exist in the rear wall of the freezer locker. Now, for the case of the 100 ft^3 food locker...

$$\text{Effective Loss Area} = 2\,(40 * 76) + 2\,(40 * 100) + (76 * 100) = 150\ ft^2$$

$$\text{Surface Area Loss} = (150)\ 5.04 = 756.\ Btu/hr$$

Door Seal Loss

$$\text{Circumference of door seals} = \frac{8}{12}(32 + 21.1)\ 2 = 70.8\ ft$$

$$\text{Door Seal Loss} = (70.8)\ .351 = 24.9\ Btu/hr$$

Conduction (Structural) Loss

Assume structural conduction losses can be designed not to exceed 6% of surface and seal losses.

$$\text{Loss} = 0.06\ (756 + 24.9) = 47\ Btu/hr$$

Door Opening Loss

Door opening losses rarely exceed 4% of total heat rate loss. A loss based on 4.5% will be assumed.

$$\text{Loss} = .045\ (828) = 37.3\ Btu/hr$$

Thus, total heat loss leaking into freezer interior is

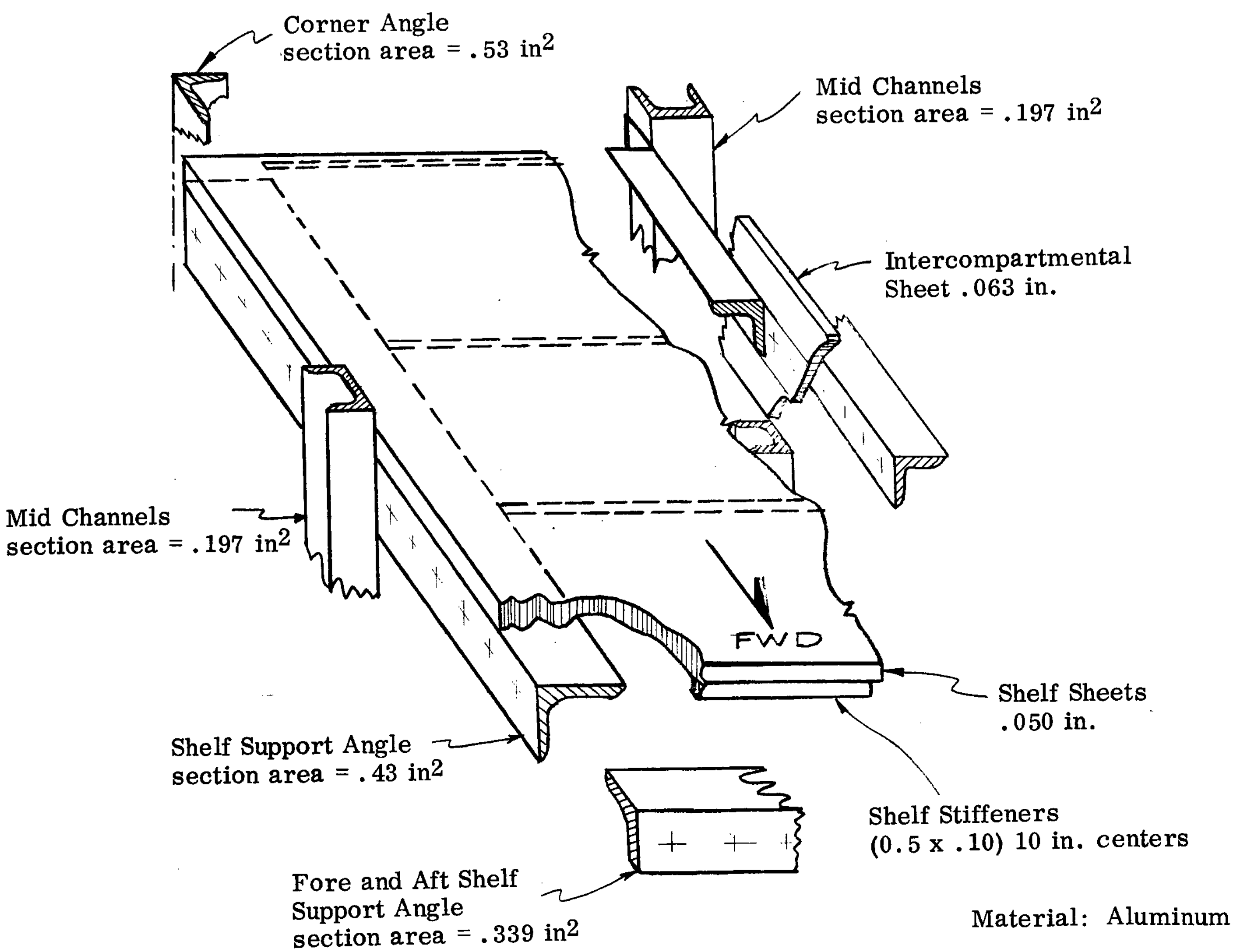
$$756. + 24.9 + 47. + 37.3 = 865 \text{ Btu/hr}$$

- for the freezer containing 100 ft^3 of food.

Figure 2.1.6(a) gives the total heat losses versus food capacity retained in freezers or refrigerators.

STRUCTURAL ANALYSIS OF FOOD LOCKER (FREEZER OR REFRIGERATOR)

Shown: Typical structural support of food shelves (100 ft^3 capacity). Retention devices and insulation not shown.



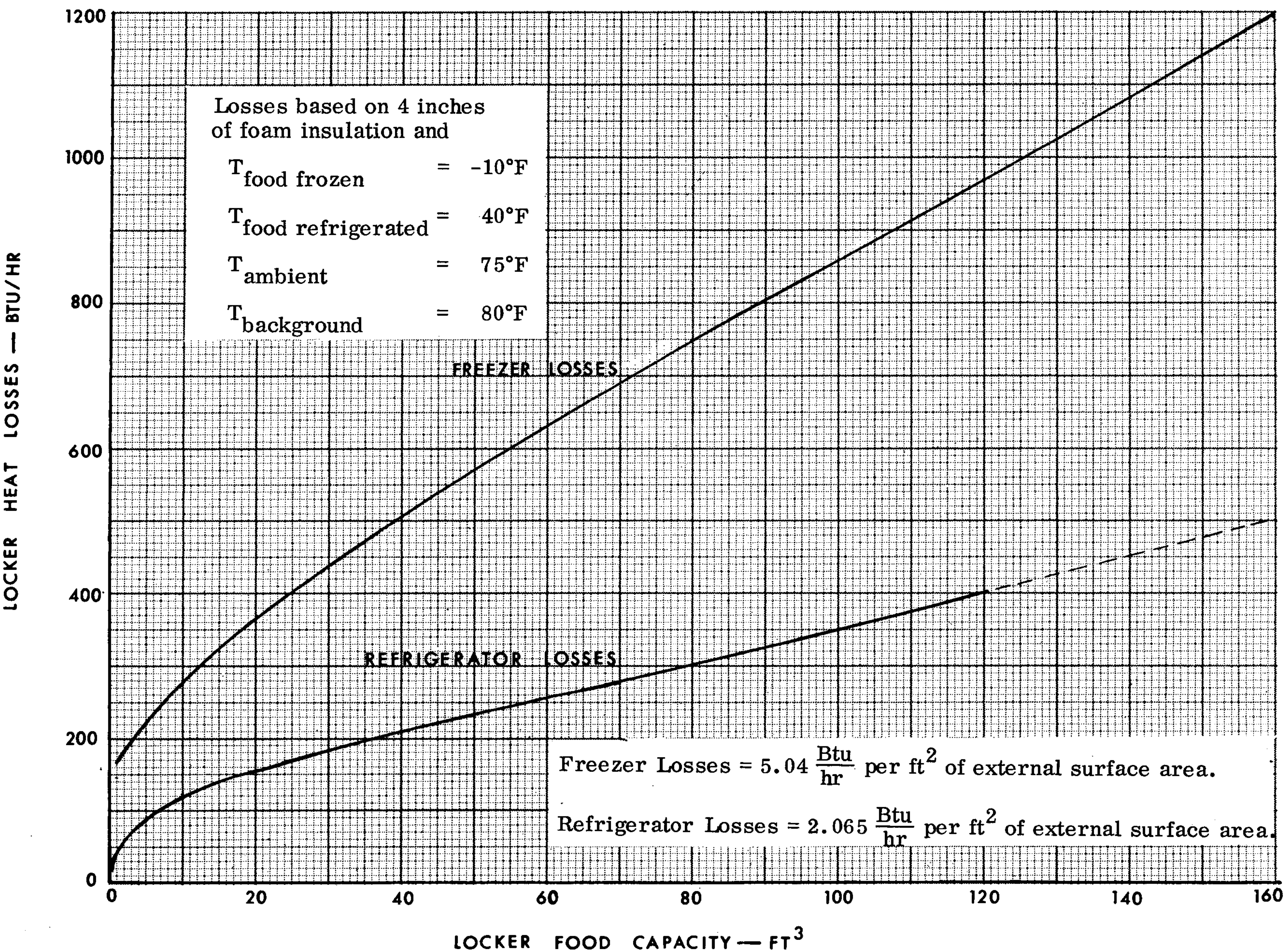
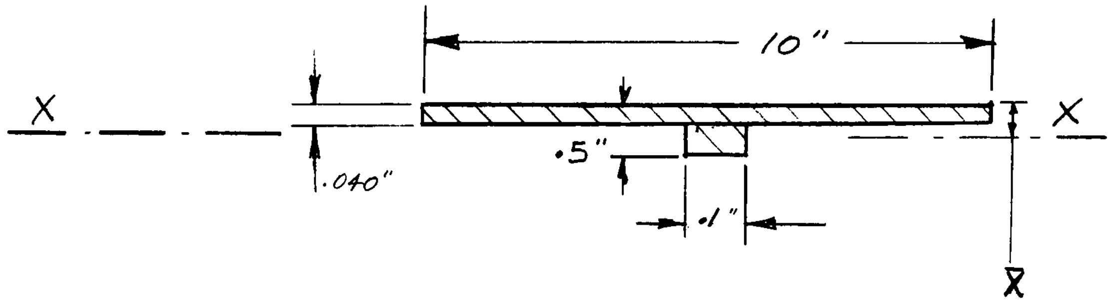


Figure 2.1.6(a). Food Locker Heat Losses Through Insulation Versus Packaged Food Capacity

SHELF SHEET AND STIFFENER



$$\bar{X} = \frac{.5(.10)(.29) + 10(.04)(.02)}{.5(.10) + 10(.04)} = .272 \text{ in.}$$

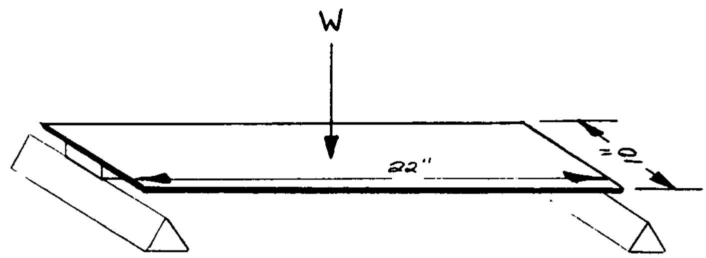
$$I_{XX} = 1/12\ (.10)(.5)^3 + .05(.018)^2 + 1/12\ (10)(.040)^3 + .40(.252)^2 = .0265 \text{ in}^4$$

A) Deflection of Shelf Sheets

$$\delta = \frac{5 W \ell^3}{384\ EI}$$

$$= \frac{5(208.2)\ (22)^3}{384(10.7 \times 10^6).0265}$$

$$\delta = .01016 \text{ inch}$$



$$W = \frac{\text{Food Weight}}{\text{Number Shelves}} * \frac{\text{Shelves}}{\text{Sheets}}$$

$$W = \frac{5000}{8} * \frac{1}{3}$$

$$W = 208.2 \text{ pounds}$$

B) Stress in Shelf Sheets

$$\sigma = \frac{Mc}{I} = \frac{W\ell}{4}\ \frac{C}{I} = \frac{208.2}{4}(22)\ \frac{.272}{.0265}$$

$$\sigma = 11{,}900 \text{ psi}$$

$$(\text{F.S.} = \frac{53}{11.9} = 4 +)$$

WEIGHT OF STRUCTURAL MEMBERS

1) Shelf Support Angles

Wt = (area) (length) ρ = (.43) (36) (.10) 16 = 24.80 pounds

2) Shelf Sheets and Stiffeners

(sheet) Wt = (32 * 23) .050 (.10) 8 = 29.40 pounds

(stiffener) Wt = (.50 * .10) 19.0 (.10) 32 = 3.04 pounds

Total: 32.44 pounds

3) Vertical Supports

(corner angles) Wt = (area) length ρ = (.53) (76) (.10) 4 = 16.1 pounds

(mid-channels) Wt = (.197) (76) (.10) 11 = 16.5 pounds

Total: 32.60 pounds

4) Intercompartmental Sheets

Wt = (72 * 36) (.063) (.10) 3 = 48.90 pounds

5) Fore and Aft Support Angles

Wt = (area) (length) ρ = (.339) (100.) (.10) 4 = 13.60 pounds

6) Structural Support Required for Vehicle Installation/Integration

Assume ~ 25% of structural weight of locker.

Wt = 0.25 (24.80 + 32.44 + 32.60 + 48.90 + 13.60)

Wt = 0.25 (152.3) = 38.10 pounds

7) Total Structural Weight

Wt = (24.80 + 32.44 + 32.60 + 48.90 + 13.60 + 38.10)

Wt = 190 pounds

WEIGHT ANALYSIS OF FOOD LOCKER

(Using 100 ft^3 capacity locker for typical analysis)

Total weight of locker consists of weights for:

1)	External Sheet	(83.30 pounds)
2)	Internal (Fin) Sheet	(113.50 pounds)
3)	Foam Insulation	(186.50 pounds)
4)	Structural Support	(190.00 pounds)*

Total Weight of (100 ft^3) Locker = 573.30 pounds

Figure 2.1.6(b) gives the total weights of the food locker versus the capacity of the locker. The capacity is based on ft^3 of packaged food.

---

*See structural analysis of food locker.

1. Weight of External Sheets

External Area = (40 * 76) 2 + (100 * 76) 2 + (100 * 40) 2 = 27,760 in^2

Weight = (area) (thickness) (density)
= (27,760) (.030) (.10) = 83.30 pounds

2. Weight of Internal (Fin) Sheets

Internal Area = (92 * 32) 2 + (92 * 68) 2 + (32 * 68) 2 = 22,720 in^2

Weight = (area) (thickness) (density)
(22,720) (.050) (.10) = 113.50 pounds

3. Weight of Foam Insulation

Weight = (area) (thickness) (density)

$$= (\text{internal area} + 16 \{ L_o + W_i + H_i \}) \frac{4}{1728} (3.0)$$

$$= (22{,}720 + 16 \{ 100+92+68 \} \frac{4}{1728} (3.0) = 186.50 \text{ pounds}$$

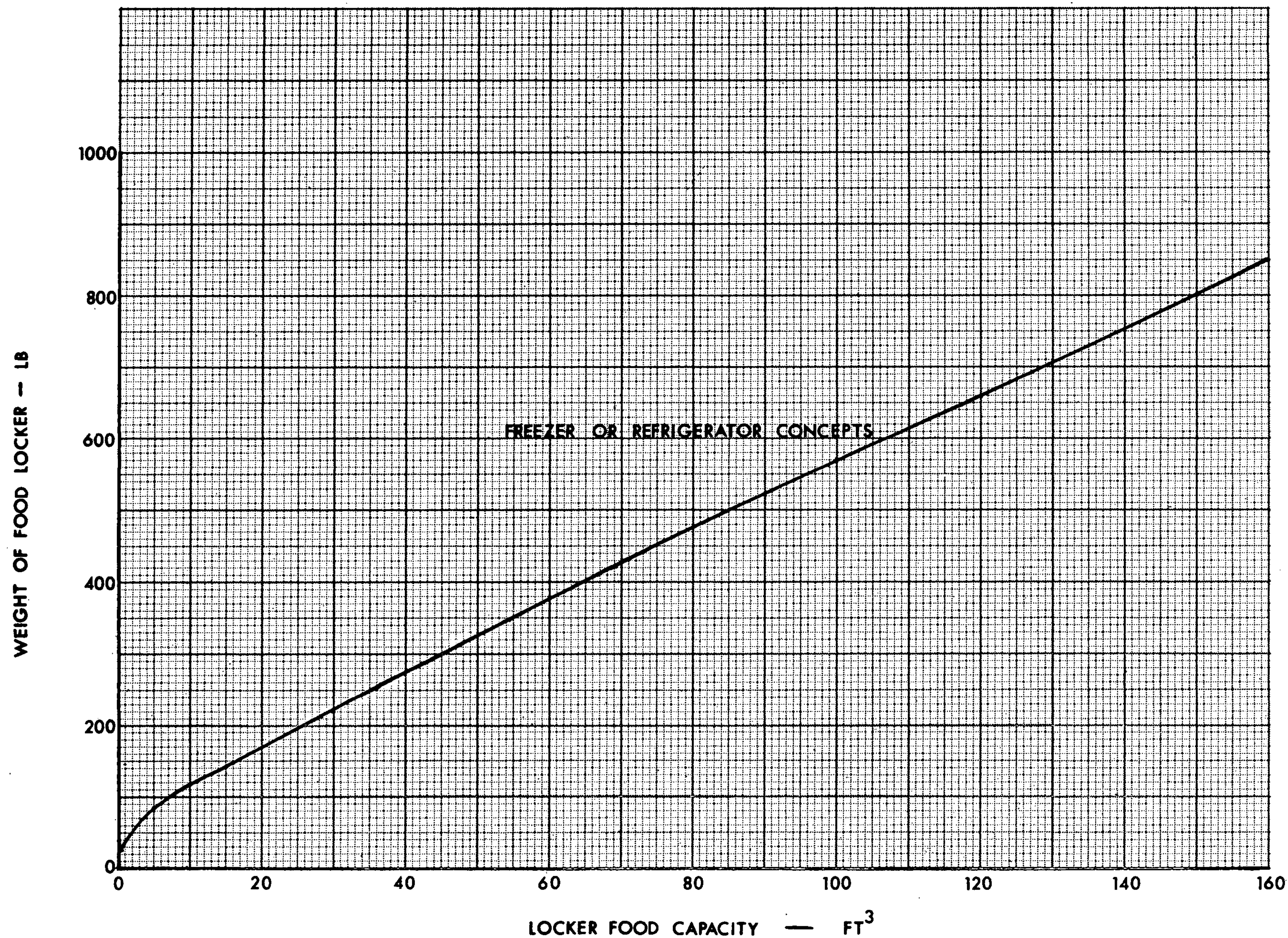
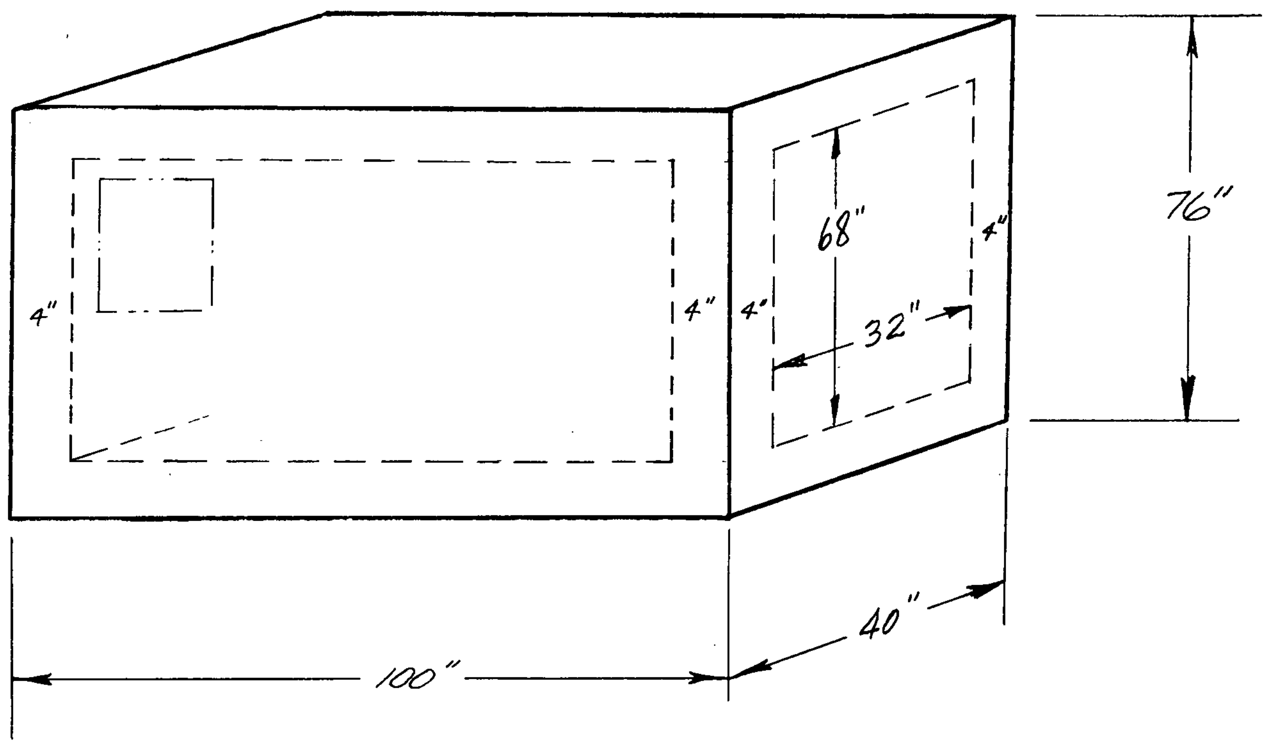


Figure 2.1.6(b). Installed Dry Weight of Food Locker Versus Packaged Food Capacity

VOLUME ANALYSIS OF FOOD LOCKER

(Food Capacity = 100 ft^3)



Installed Volume = 100 * 40 * 76 = 304,000 in^3

Figure 2.1.6(c) gives total volume of food locker versus food capacity in ft^3.

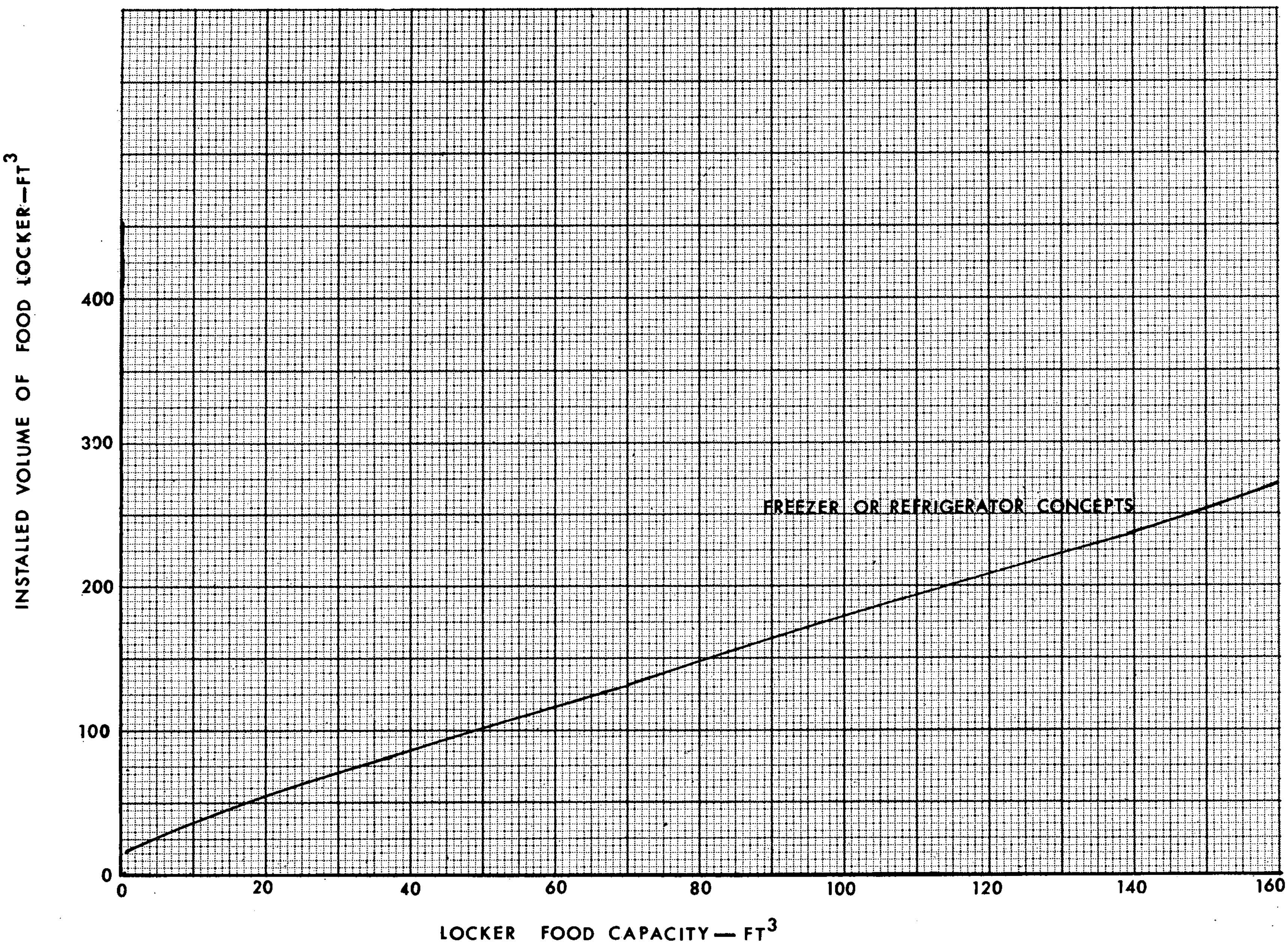
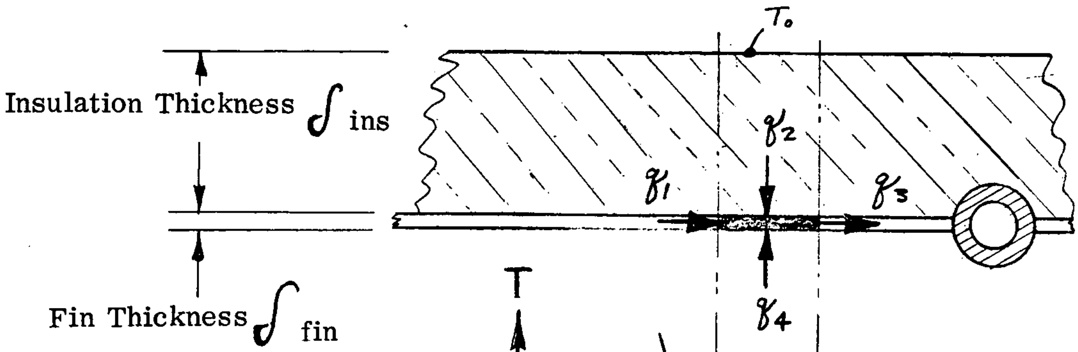
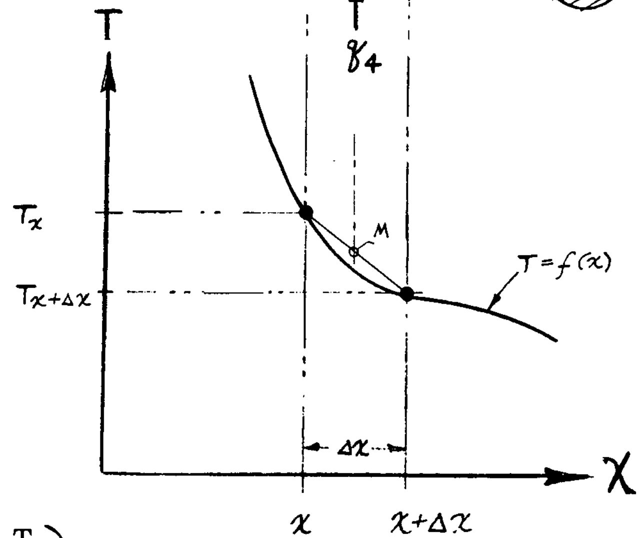


Figure 2.1.6(c). Installed Dry Volume of Food Locker Versus Packaged Food Capacity

The following analysis refers to the fin and associated coolant tubes; the fin is physically the internal aluminum sheet structure that isolates the frozen food compartment from the inner surface of the foam insulation. The inner surface of the foam is lined with the fin and tube configuration. The coolant tube is a continuous duct that is integral with the aluminum sheet or fin. The fin intercepts heat flows leaking through the foam insulation while the coolant flowing through the tube collects the heat flows and directs it away from the freezer or refrigerator locker.

FIN ANALYSIS





Definition:

$$\left(\frac{dT}{dx}\right)_M = \frac{1}{\Delta X}\left(T_x - T_{x+\Delta x}\right)(-1)$$

$$(-1)\left(\frac{dT}{dx}\right)_M \Delta X = T_x - T_{x+\Delta x}$$

$$(-1)\quad \frac{d}{dx}\left(\frac{dT}{dx}\right)_M \Delta X = \left(\frac{dT}{dx}\right)_x - \left(\frac{dT}{dx}\right)_{x+\Delta x}$$

or...

$$\left(\frac{dT}{dx}\right)_{x+\Delta X} = \left(\frac{dT}{dx}\right)_x + \left(\frac{d^2T}{dx^2}\right)_M \Delta X$$

Heat Balance on Fin Element:

$$q_1 + q_2 + q_4 = q_3$$

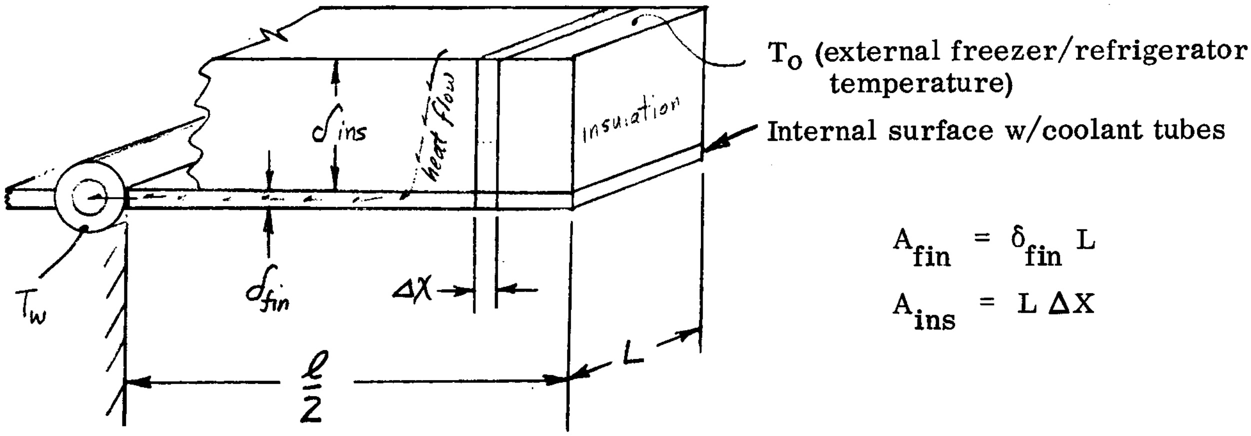
now...
$$-KA)_{fin}\left(\frac{dT}{dx}\right)_x + \left(\frac{KA}{\delta}\right)_{ins}(T_o - T_M) + 0 = -KA)_{fin}\left(\frac{dT}{dx}\right)_{X+\Delta X}$$

$$-KA)_{fin}\left(\frac{dT}{dx}\right)_x + \frac{KA}{\delta})_{ins}(T_o - T_M) = -KA)_{fin}\left(\frac{dT}{dx}\right)_x - KA)_{fin}\left(\frac{d^2T}{dx^2}\right)_M \Delta X$$

(the terms $-KA)_{fin}\left(\frac{dT}{dx}\right)_x$ are struck through on both sides)

$$\frac{d^2T}{dx^2} = \beta^2 (T - T_o) \qquad (1)$$

where $\beta^2 \equiv \left(\frac{KA}{\delta}\right)_{ins} * \left(\frac{1}{KA}\right)_{fin} (1/\Delta X)$



$$A_{fin} = \delta_{fin} L$$

$$A_{ins} = L \Delta X$$

$$\therefore \ \beta^2 = \left(\frac{KA}{\delta}\right)_{ins} * \frac{1}{\Delta X \, (KA)_{fin}} = \frac{K_{ins}}{K_{fin}\, \delta_{fin}\, \delta_{ins}}$$

Thus the general solution to the ordinary second order linear differential equation (1) . . .

$$T - T_o = C_1 e^{\beta X} + C_2 e^{-\beta X} \tag{2}$$

where C_1 and C_2 are constants of integration to be determined from boundary conditions below.

Boundary Condition: at $x = 0$, $T = T_W$

thus equation (2) $$T_W - T_o = C_1 + C_2 \tag{3}$$

Boundary Condition: at $x = \frac{\ell}{2}$, $\frac{dT}{dx} = 0$

Thus differentiating equation (2) $\frac{dT}{dX} = \beta C_1 e^{\beta X} - C_2 \beta e^{-\beta X}$

now. . .

$$0 = C_1 E^{\beta \ell/2} - C_2 e^{-\beta \ell/2} \tag{4}$$

$$\underline{C_2 = C_1 e^{\beta \ell}}$$

from equations (3) and (4) $C_1 = \left(\frac{T_W - T_o}{1 + e^{\beta \ell}} \right) \quad C_2 = \left(\frac{T_W - T_o}{1 + e^{-\beta \ell}} \right)$

Thus, the complete solution to equation (1) is...

$$T - T_o = (T_W - T_o) \left[\frac{e^{\beta X}}{1 + e^{\beta \ell}} + \frac{e^{-\beta \ell}}{1 + e^{-\beta \ell}} \right] \quad \text{OR}$$

in simplified form...

$$\frac{T - T_o}{T_W - T_o} = \frac{\cosh \beta \left(\frac{\ell}{2} - X \right)}{\cosh \left(\beta \frac{\ell}{2} \right)} \qquad (5)$$

Now, the heat flow from the fin root into the coolant tube wall...

$$q_{fin/wall} = -KA \left. \frac{dT}{dx} \right|_{x=0} \quad \text{where} \qquad (6)$$

$$\frac{dT}{dx} = (T_W - T_o) \, \beta \left[\frac{e^{\beta X}}{1 + e^{\beta \ell}} - \frac{e^{-\beta \ell}}{1 + e^{-\beta \ell}} \right]$$

$$\left. \frac{dT}{dx} \right|_{x=0} = (T_W - T_o) \, \beta \tanh \left(\beta \frac{\ell}{2} \right) \qquad (7)$$

now equation (6)...

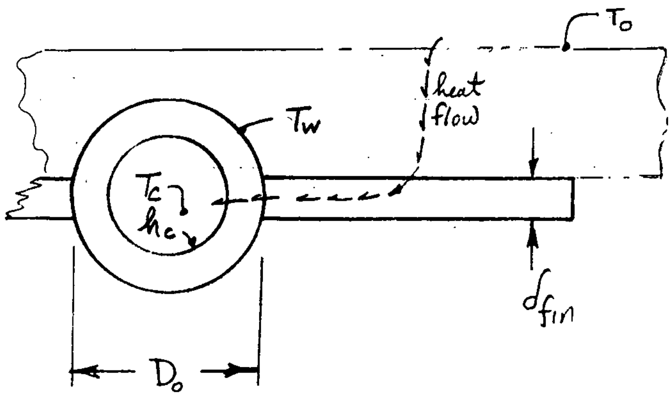
$$q_{fin/wall} = -K A \left.\frac{dT}{dx}\right|_{x=0} = \left(K_{fin}\ \delta_{fin}\ L\ \beta\right) \tanh\left(\beta \frac{\ell}{2}\right) (T_o - T_W) \tag{6A}$$

or, rearranging...

$$q_{fin/wall} = \left(\frac{K}{\delta}\right)_{ins} L \frac{\ell}{2}\ \eta_f\ (T_o - T_W) \qquad \text{where} \qquad \eta_f = \frac{\tanh\left(\beta \frac{\ell}{2}\right)}{\beta \frac{\ell}{2}} \tag{6B}$$

Double this value for a fully developed fin; i.e., half a fin is attached to either side of the coolant tube.

This expression is unity when temperature profile on fin is constant.



Coolant Tube Analysis

Assume:

1) $\bar{D} = D_o - \frac{\delta_{fin}}{2}$

2) $\bar{T}_c = \frac{1}{2} (T_{c_i} + T_{c_o})$

3) T_W is constant

thus... $q_{wall/coolant} = h_c \pi \bar{D} L (T_W - \bar{T}_c)$ (8)

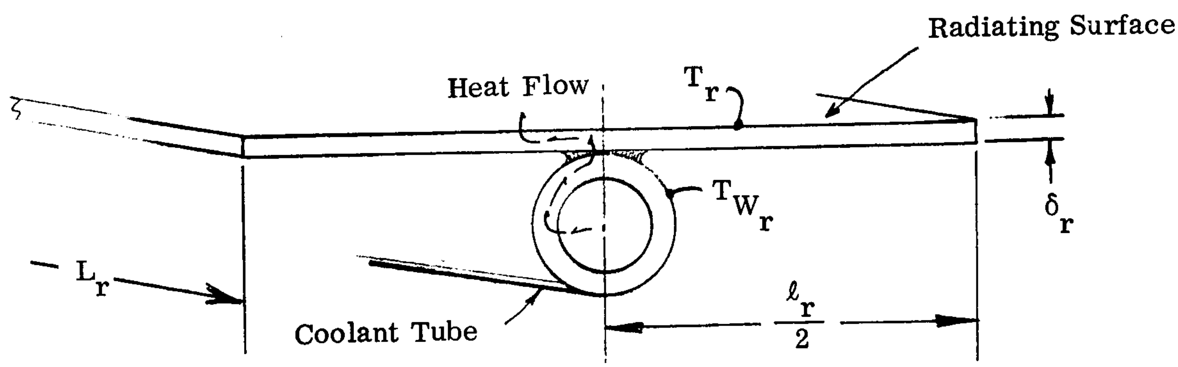
also... $q_{c_{wall/coolant}} = \omega_c Cp_c (T_{c_o} - T_{c_i})$ or $= 2 \omega_c Cp_c (\bar{T}_c - T_{c_i})$ (9)

and from equation (6B)

$$h_c \pi \bar{D} L (T_W - \bar{T}_c) = \left[(\frac{K}{\delta})_{ins} L \frac{\ell}{2} \eta_f (T_o - T_W) \right] * 2 \qquad (10)$$

Two half fin requires per unit tube length.

RADIATOR ANALYSIS



as per analysis of internal fin...

$$K_r \, \delta_r \, \frac{d^2 T_r}{dx^2} + \bar{h}_r \, (T_\infty - T_r) = 0 \qquad T_\infty \equiv \text{Space Temp}$$

so... at $X = 0$, $T_r = T_{W_r}$ (assumed constant)

at $X = \frac{\ell_r}{2}$, $\frac{dT_r}{dx} = 0$

$$T - T_\infty = (T_{W_o} - T_\infty) \, \frac{\cosh \gamma \left(\frac{\ell_r}{2} - X \right)}{\cosh \gamma \left(\frac{\ell_r}{2} \right)}$$

where $\gamma^2 = \frac{\bar{h}_r}{K_r \, \delta_r}$

at $X = 0$, the heat transferred to the fin from the wall of tube...

$$\boxed{q_{wall/rad} = h_r \, L_r \, \frac{\ell_r}{2} \, \eta_r \, (T_{W_r} - T_\infty)} \qquad (11)$$

where $\eta_r = \frac{\tanh \gamma \frac{\ell_r}{2}}{\gamma \frac{\ell_r}{2}}$

likewise...

$$h_{c_r} \pi \bar{D}_r L_r \left(\bar{T}_c - T_{W_r} \right) = \left[h_r L_r \frac{\ell_r}{2} \eta_r (T_{W_r} - T_\infty) \right] * 2 \qquad (12)$$

and... $$2 \omega Cp_c \left(\bar{T}_c - T_{c_i} \right) = h_{c_r} \pi \bar{D}_r L_r \left(\bar{T}_c - T_{W_r} \right) \qquad (13)$$

In Summary:

I) $$2 \omega_c Cp_c \left(\bar{T}_c - T_{c_i} \right) = h_c \pi \bar{D} L \left(T_W - \bar{T}_c \right)$$

II) $$h_c \pi \bar{D} \left(\bar{T}_c - T_W \right) + \left(\frac{K}{\delta} \right)_{ins} \ell \eta_f \left(T_o - T_W \right) = 0$$

III) $$h_{c_r} \pi \bar{D}_r \left(\bar{T}_c - T_{W_r} \right) + h_r \ell_r \eta_r \left(T_\infty - T_{W_r} \right) = 0$$

IV) $$2 \omega_c Cp_c \left(\bar{T}_c - T_{c_i} \right) = h_{c_r} \pi \bar{D}_r L_r \left(\bar{T}_c - T_{W_r} \right)$$

Let

T_{C_i} = -29°F

T_∞ = -460°F

T_o = 75°F

T_W = -10°F

K_{ins} = .025 Btu/hr ft °F

K_{fin} = 90 Btu/hr ft °F

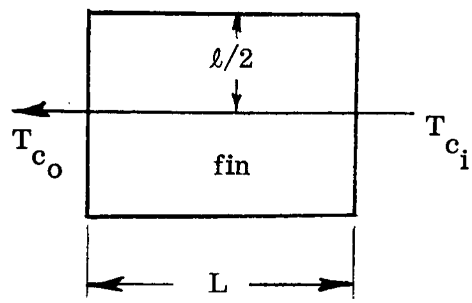
δ_{ins} = 4 inches (.333 feet)

δ_{fin} = .032 inches

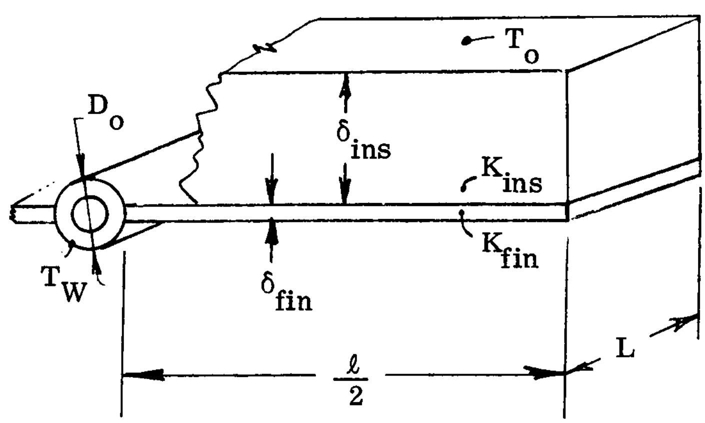
D_o = .250 inches

$\bar{D}$ = .234 inches

$\ell/2$ = 6.0 inches



use L = unity



Properties of 80% Ethylene Glycol at -10°F (-20°F) { -30°F }

K_c = .205 Btu/hr ft °F (.205)

C_{ρ_c} = .53 Btu/lb °F (.52)

μ_c = 246 lb/hr ft (383.) {627. }

ρ_c = 70.2 lb/ft^3 (70.5) { 70.6 }

Solve for coolant internal film coefficient...
from McAdams, equation 9-23b

$$\frac{hc\ Di}{K_c} = \frac{2}{\pi}\ \frac{\omega\, Cp_c}{K_c L}\ \frac{1 - 8\,\psi\,(\eta_1)}{1 + 8\,\psi\,(\eta_1)} \qquad \text{where} \quad \eta_1 = \frac{\pi}{4}\ \frac{K_c\ L}{\omega\ Cp_c}$$

for $\dfrac{\omega\, Cp_c}{K_c\ L} \leq 3$ (which is the expected range), the function $\psi\,(\eta_1) \approx 0$

so... $$\frac{hc\ Di}{K_c} = \frac{2}{\pi}\ \frac{\omega\, Cp_c}{K_c\ L}$$

internal film coefficient for coolant (14)

$$h_c = \frac{2}{\pi\, D_i\ L}\ \omega\ Cp_c$$

now solve for Fin effectiveness...

$$\eta_f = \frac{\tanh\ (R\,\frac{\ell}{2})}{R\,\frac{\ell}{2}} \qquad \text{where} \quad R\,\frac{\ell}{2} = \frac{K_{ins}}{K_{fin}\ \delta_{fin}\ \delta_{ins}} \left(\frac{\ell}{2}\right)$$

$$= \frac{.025\ (.5)}{90\ (.032/12)\ .333} = .1563\ ft^{-1}$$

$$\eta_f = \frac{.155}{.1563} = .993$$

A value close to unity indicates that the distribution of temperature on the fin is nearly constant.

Solve for freezer parameters...

from equations I) and 14...

$$2\ \omega\ Cp_c\ (\bar{T}_c - T_{c_i}) = 2\ \omega\ Cp_c\ \frac{\bar{D}}{D_i}\ (T_W - \bar{T}_c)$$

$$\bar{T}_c - T_{c_i} = \frac{\bar{D}}{D_i}\ (T_W - \bar{T}_c)$$

$$T_c \left(1 + \frac{\bar{D}}{D_i}\right) = T_{c_i} + \frac{\bar{D}}{D_i}\ T_W \qquad (15)$$

so...

$$\bar{T}_c = \left[-29 + \frac{.234}{.218}\ (-10)\right] \frac{1}{1 + \frac{.234}{.218}} = -19.2°F$$

$$T_{c_o} = 2\ \bar{T}_c - T_i = 2\ (-19.2) + 29 = -9.4\ °F$$

} coolant temperatures

from equations II) and 14...

$$\frac{2\ \omega Cp_c}{L}\ \frac{\bar{D}}{D_i} \left(\bar{T}_c - T_W\right) = \left(\frac{K}{\delta}\right)_{ins} \ell\ \eta_f \left(T_W - T_o\right)$$

so...

$$W = \frac{1}{Cp_c} \left(\frac{K}{\delta}\right)_{ins} \ell\ \eta_f\ L\ \frac{D_i}{2\ \bar{D}} \left(\frac{T_W - T_o}{\bar{T}_c - T_W}\right) \qquad (16)$$

now...

$$W = \frac{1}{.52} \left(\frac{.025}{.333}\right) 1\ (.993)\ \frac{.218}{2\ (.234)}\ \frac{(-10\ -75)}{(-19.2 + 10)} =$$

.616 pph/ft^2 of freezer interior fin area

Recall equation (14)

$$h_c = \frac{2\ \omega\ Cp}{\pi\ D_i\ L} = 11.95\ \frac{Btu}{hr\ ft^2\ °F}$$

Solve for radiator parameters for freezers

Derive value for h_r, the overall radiation coefficient associated with surface of radiator...

simply...

$$h_r A (T_t - T_\infty) = \epsilon A \left[\sigma T_r^4 - \sigma T_\infty^4\right]$$

$$h_r = \frac{\epsilon \sigma T_r^4}{T_r + 460} = \underline{\underline{.133}} \text{ (assuming } T_t = -18°F) \quad \frac{\text{Btu}}{\text{hr ft}^2 °F}$$

where...
$\epsilon = .90$
$T_\infty = -460°F$
$\eta_r = 1.0$, so that radiator surface is isothermal.

now, let

$$\ell_r \equiv \ell = 1.0 \text{ foot} \qquad h_{c_r} \equiv h_c = 11.95 \text{Btu/hr ft}^2 \, °F$$

$$\bar{D}_r \equiv \bar{D} = .234 \text{ inch}$$

$$D_{r_i} \equiv D_i = .218 \text{ inch}$$

$$\eta_r \equiv 1.0 \rightarrow T_r = T_{W_r}$$

from equations III) and 14...

$$\left(h_{c_r}\right) \pi \bar{D}_r \left(\bar{T}_c - T_{W_r}\right) + h_r \ell_r \eta_r \left(T_\infty - T_{W_r}\right) = 0$$

$$\left(\frac{2 \omega C_p}{L} \frac{\bar{D}}{D_i}\right) \bar{T}_c - \left(\frac{2 \omega C_p}{L} \frac{\bar{D}}{D_i}\right) T_{W_r} - h_r \ell_r \eta_r (T_{W_r}) = 0$$

so...

$$T_{W_r} = \frac{\left(2 \frac{\omega Cp}{L} \bar{D}/D_i\right) \bar{T}_c}{2 \frac{\omega Cp}{L} \bar{D}/D_i + h_r \ell_r \eta_r} \qquad (17)$$

now...

$$T_{W_r} = \frac{2.065 (-19.2)}{2.065 + .533} = \underline{\underline{-16.02°F}}$$ temperature of radiator surface for freezer concept.

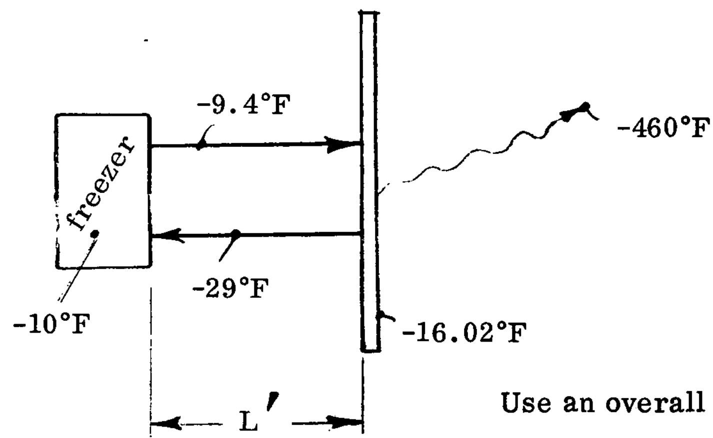
now, from equation (11)...

$$Q_{\text{radiator heat flow}} = 58.8 \frac{\text{Btu}}{\text{hr ft}^2}$$

and from equation (6B)...

$$Q_{\text{freezer fin heat flow}} = 6.32 \frac{\text{Btu}}{\text{hr ft}^2}$$

Conclusion: Use .1076 ft^2 radiator surface per 1.0 ft^2 freezer fin surface.



Use an overall L′ = 100 feet

POWER FOR COOLANT PUMP (FREEZER)

Pressure drop through 100 foot lines...

$$\Delta P = \frac{128\,\mu\,\omega\,L'}{\rho\,g\,\pi\,D_i^4} = \frac{128 * 627\,(.154)\,100}{70.6 * 32.2\,\pi\,\left(\frac{.218}{12}\right)^4}\left(\frac{1}{3600}\right)^2$$

$$\Delta P = 122.5\ \text{lb/ft}^2$$

$$\text{Power} = \Delta P * \frac{\omega}{\rho} = \frac{122.5}{70.6}\,(.616)\,\left(3.76 \times 10^{-4}\ \frac{\text{watts}}{\text{ft lb/hr}}\right)$$

now...

Watts = 1.00×10^{-4} watts/ft^2 of freezer fin surface

Neglect pumping power but assume that controls, valves, sensors and illumination uses 50 watts momentarily.

WEIGHT ANALYSIS FOR SPACE RADIATOR HARDWARE

(Analysis based on a "per ft^2 of interior freezer fin")

For the previously calculated values of...

Coolant coefficient, $h_c = 2.81$ Btu/hr ft^2 °F

Coolant flow rate, $\omega = 0.154$ lb/hr

Coolant tube ID, $D_i = 0.218$ inch

...the coolant velocity within the tube is

$$V = \frac{\omega}{\rho} \frac{4}{\pi D_i^2}$$

$$V = (.616)\ (1.70.5)\ \left(\frac{4}{\pi}\right) \left(\frac{1}{.218}\right)^2 * \left(\frac{12 \text{ inch}}{\text{ft}}\right)^2 * \left(\frac{1 \text{ hr}}{60 \text{ min}}\right)$$

$$V = .564 \text{ ft/min}$$

This velocity shall be maintained regardless of the size of the space radiator freezer concept; therefore,

$$\omega = V \rho \frac{\pi}{4} D_i^2$$

$$\boxed{\omega = 13.0\, D_i^2} \tag{18}$$

where ω is the coolant flow in lb/hr.

Because the coolant flow pump will operate on an 80% to 90% duty cycle, the effective flow rate must increase accordingly, while the coolant tube diameter varies as equation (18). From the thermal analysis of the locker wall, heat at 5.04 Btu/hr penetrates each square foot of freezer surface. However, use 125% of this value to account for other leaks and the duty cycle requirements.

Thus, on the per-square-foot basis, 0.616 lb/hr of coolant will remove 6.30 Btu/hr of locker heat losses. So, the total coolant flow required for any size freezer is...

$$\omega_{total} = \frac{(.616 \text{ lb/hr})}{(6.30 \text{ Btu/hr})} \{ \text{locker heat losses (see Figure 2.1.6(a), Btu/hr} \}$$

Recalling equation (18) and rearranging

$$D_i = \sqrt{\frac{\omega_{total}}{13.0}}$$

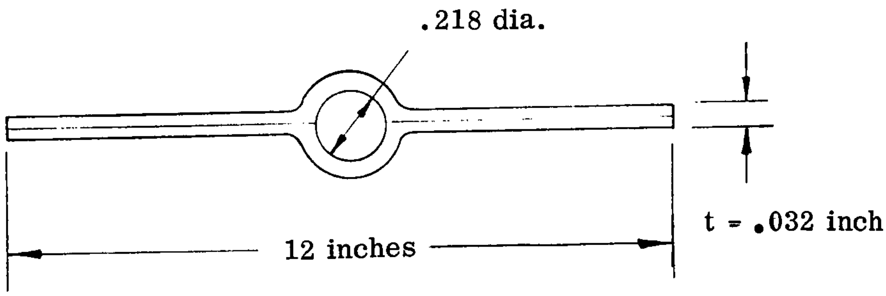
$$D_i = \sqrt{\frac{1}{13.0} * \frac{.616}{6.30} \{\text{ locker heat losses }\}}$$

$$\boxed{D_i = .0866 \sqrt{\{\text{ locker losses }\}}}$$

Thus, for any size freezer locker, the locker losses will determine the internal diameter of the coolant transport tube that connects the locker circulation system to the external space radiator assembly.

Figures 2.1.6(d) and 2.1.6(e) present the weight and volume of space radiator hardware: 200 feet of coolant tube, 2 diverter valves, 1 coolant pump and motor. The weight and volume of the valves, pump, and motor were estimated from commercially available units. However, the weight and volume of the space radiator configuration was calculated using Fairchild Hiller internal design criteria for space radiators. For the cross-section shown below, a radiator panel weight (per square foot) was found to be

$$\boxed{\frac{0.47 \text{ lbs total}}{\text{ft}^2 \text{ of surface}}}$$



Material: Aluminum

Now, from the conclusion of radiator parameters for freezer concepts...

$$A_{radiator} = (.1076)\ A_{freezer\ fin}$$

and from previous considerations, each square foot of freezer fin intercepts approximately 6.30 Btu/hr; that is,

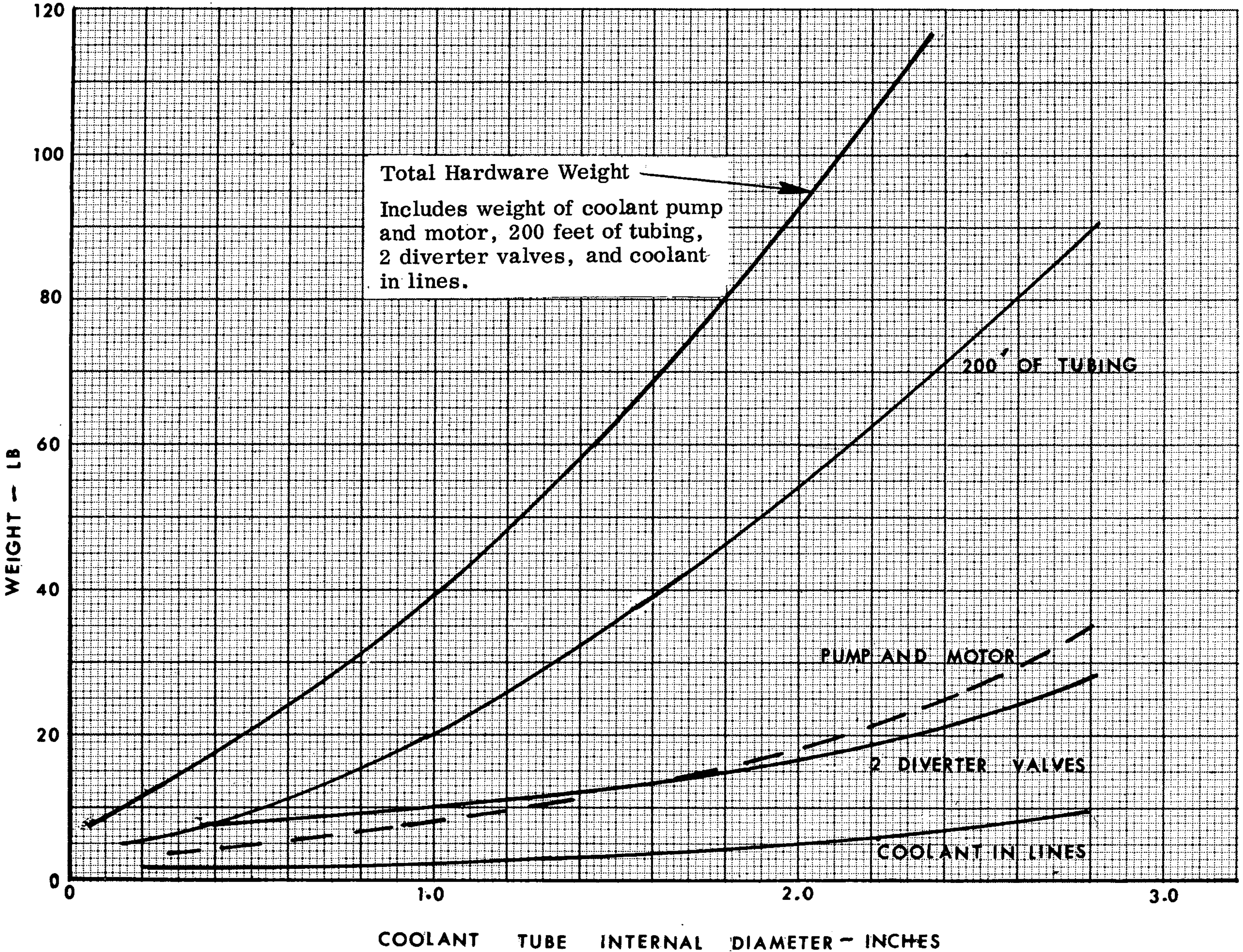


Figure 2.1.6(d). Total Hardware Weight (For Space Radiator Concept) Versus Coolant Tube Internal Diameter

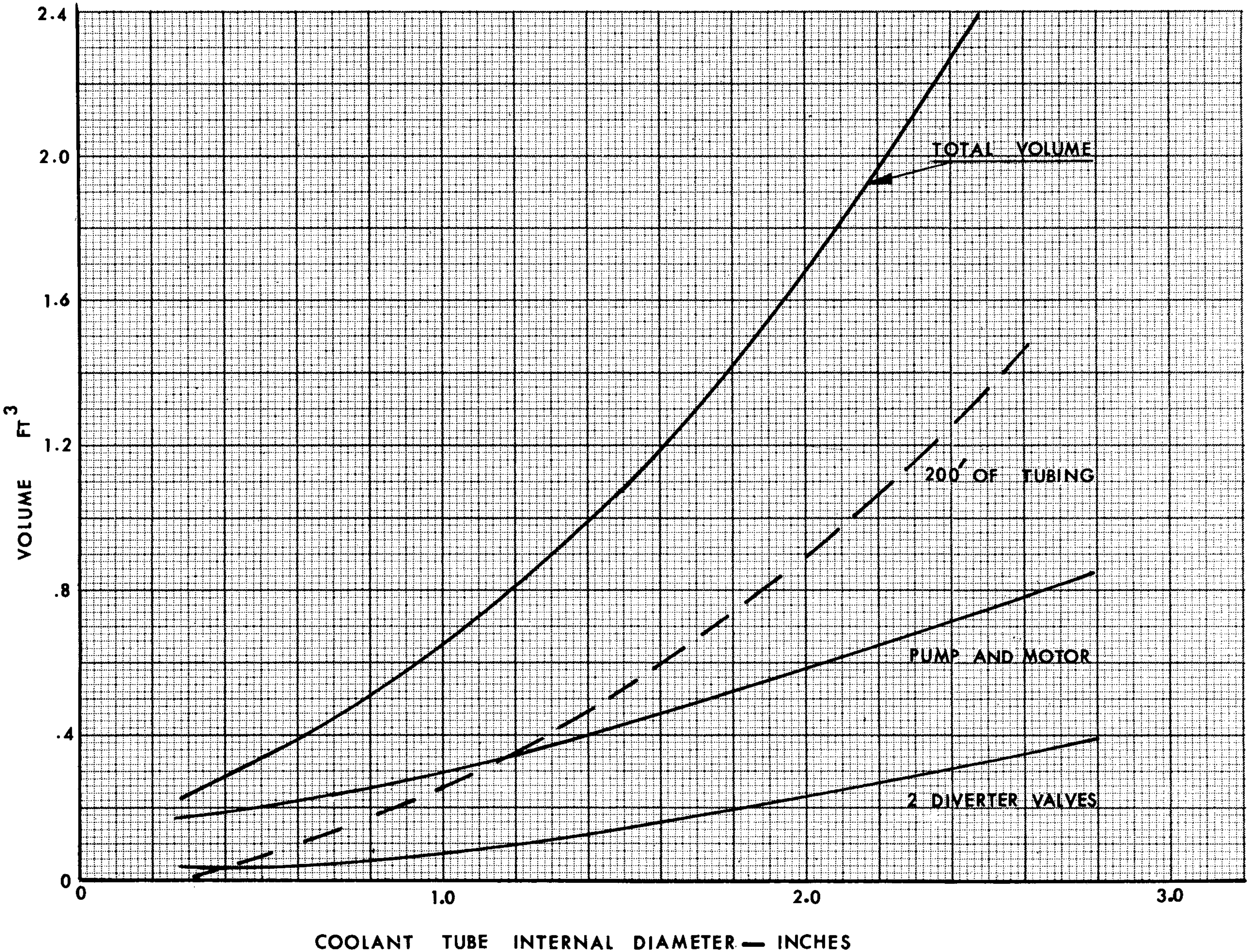


Figure 2.1.6(e). Total Hardware Volume (For Space Radiator Concept) Versus Coolant Tube Internal Diameter

$$A_{\text{freezer fin}} = \frac{1}{6.30} \{ \text{locker heat losses, Btu/hr (see Figure 2.1.6(a))} \}$$

wherein,

$$A_{\text{radiator}} = \frac{.1076}{6.30} \{ \text{locker heat losses} \}$$

but

$$Wt_{\text{radiator}} = (.47 \frac{\text{lbs}}{\text{ft}^2}) \ (\frac{.1076}{6.30}) \ \{ \text{locker heat losses} \}$$

$$\boxed{Wt_{\text{radiator}} = .0087 \{ \text{locker heat losses, Btu/hr} \}}$$

Two radiators would double this weight value.

VOLUME OF SPACE RADIATOR

Assume the effective volume of the radiator assembly is a rectangular envelope around the unit. Thus, for each square foot...

$$\text{Vol} = (12 \text{ inch}) \ (12 \text{ inch}) \ (.25 \text{ inch})$$

$$\text{Vol} = .0208 \text{ ft}^3$$

$$V_{\text{radiator}} = (\frac{.0208 \text{ ft}^3}{1 \text{ ft}^2}) \ (\frac{.1076}{6.30}) \ \{ \text{locker heat losses} \}$$

$$\boxed{V_{\text{radiator}} = .000356 \{ \text{locker heat losses, Btu/hr} \}}$$

Two radiators would double this volume value.

Thus, a typical data sheet for the Space Radiator Freezer concept would appear as...

DATA SHEET: SPACE RADIATOR FREEZER CONCEPT

Mission Number ____________________

(_____ Men and _______ Days)

Diet Mix: 20/80 B C
60/40 B C
85/15 B C

Note: Locker losses appear on Figure 2.1.6(a)

	Weight (lbs)	Power (watts)	Volume (ft^3)
1. Weight of locker (see Figure 2.1.6(b)) =	☐	-	-
2. Coolant pipe dia, $D_i = .0866 \sqrt{\text{locker losses}}$ D_i = ____________ inch			
3. Weight of hardware (see Figure 2.1.6(d)) =	☐	-	-
4. Weight of radiator: W = .0174 {locker losses} = .0174 { } =	☐	-	-
5. Volume of locker (see Figure 2.1.6(c)) =	-	-	☐
6. Volume of hardware (see Figure 2.1.6(e)) =	-	-	☐
7. Volume of radiator: V = .00036 {locker losses} = .00036 { } =	-	-	☐
8. Power: Watts = $\frac{10^{-4}}{6.30}$ {locker losses} =	-	☐	-
TOTALS	☐	☐	☐

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.1.7 Title: Thermoelectric Freezer

Assumptions:

It is assumed that the frozen food will be maintained at -10°F using a locker insulated with four inches of foam. The heat leaking into the locker will be removed using commercially available thermoelectric devices operating as heat pumps.

Formulae:

Significant Factors:

General Information:

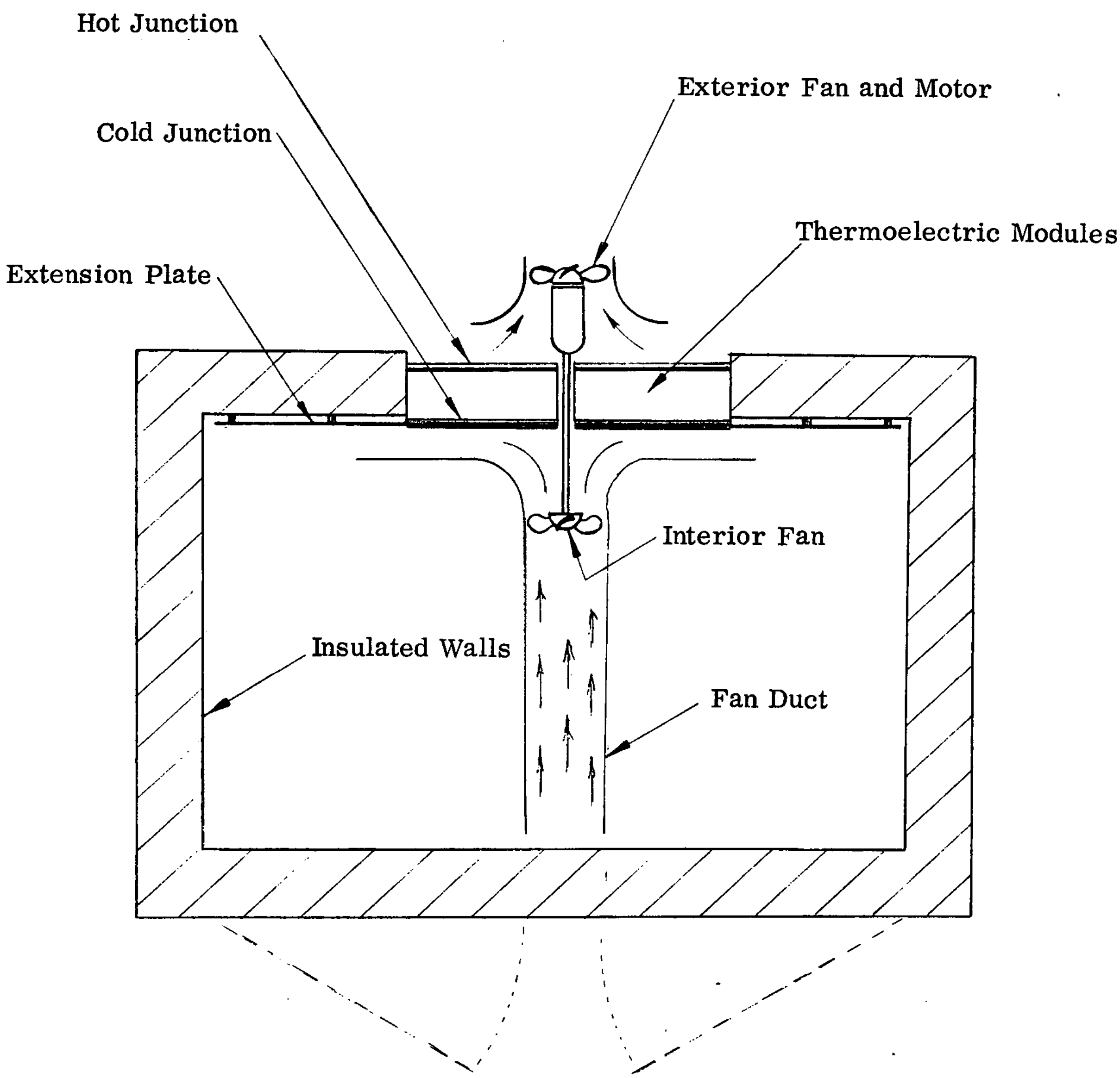
References:

1. Cambridge Thermionic Corporation, Cambridge, Massachusetts.
2. TIA Electric Company, Princeton, New Jersey.
3. Borg-Warner Thermoelectrics, Des Plaines, Illinois.

The thermoelectric freezer concept relies entirely on the thermoelectric module. 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 or refrigerator locker interior (see the plan view of the freezer below). 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 locker.

The references provided catalogs and other information that yielded sufficient data to plot the curves of power, weight, and volume for thermoelectric modules used for freezer and refrigerator concepts. The curves, shown below, are plotted for locker heat losses penetrating the four inches of insulation. Commercial catalog data was adjusted for the four-inch configuration assuming that commercially available units are insulated with 1.25 inches of foam. A sample data sheet used to tabulate the various parameters associated with each particular freezer is included below.



Plan View Thermoelectric Freezer or Refrigerator Concept

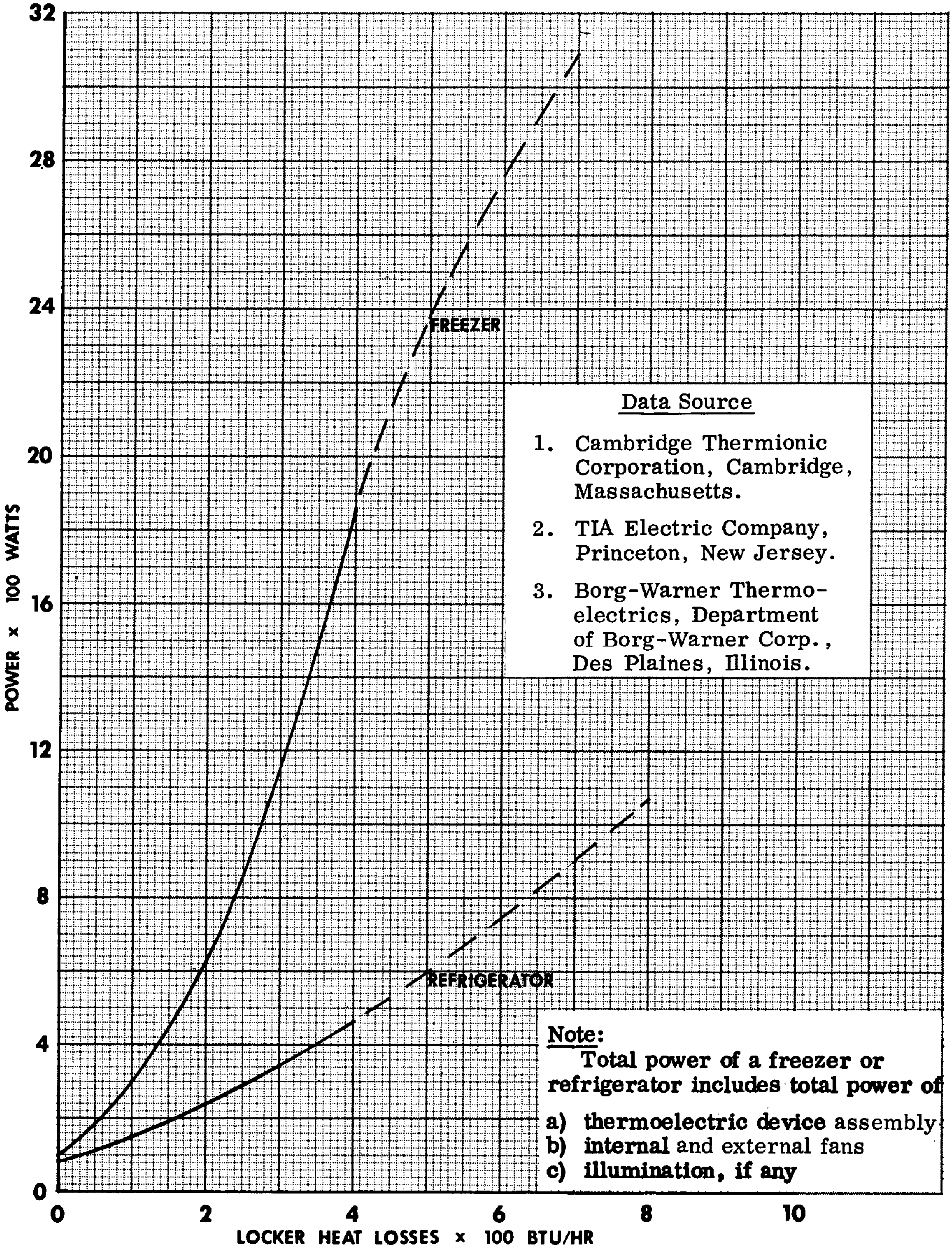


Figure 2.1.7(a). Power For Thermoelectric Device Assembly Versus Locker Heat Losses For Thermoelectric Freezer and Refrigerator Concepts

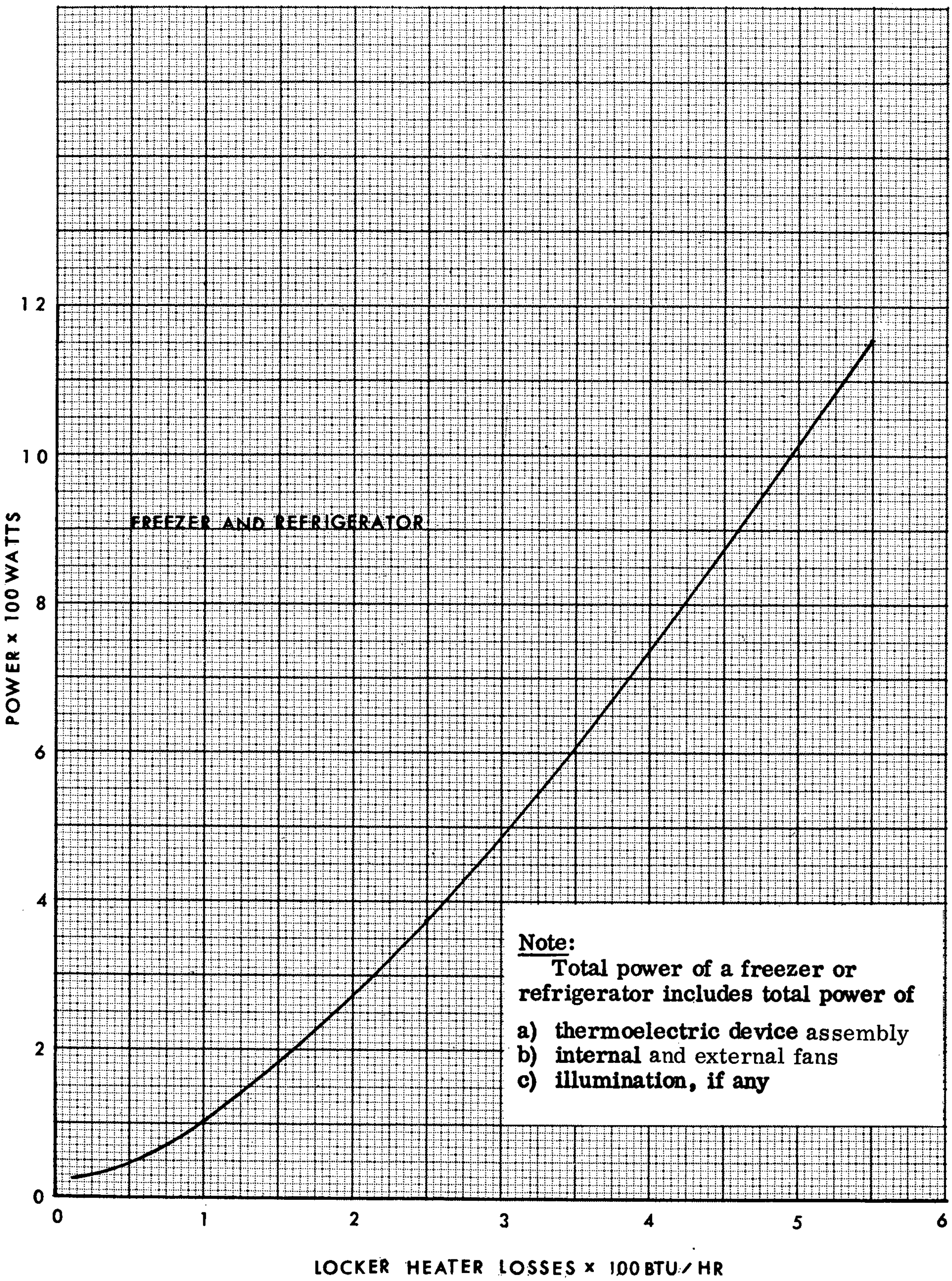


Figure 2.1.7(b). Fan Power For Internal and External Convection Cooling Versus Locker Heat Losses For Thermoelectric Concepts

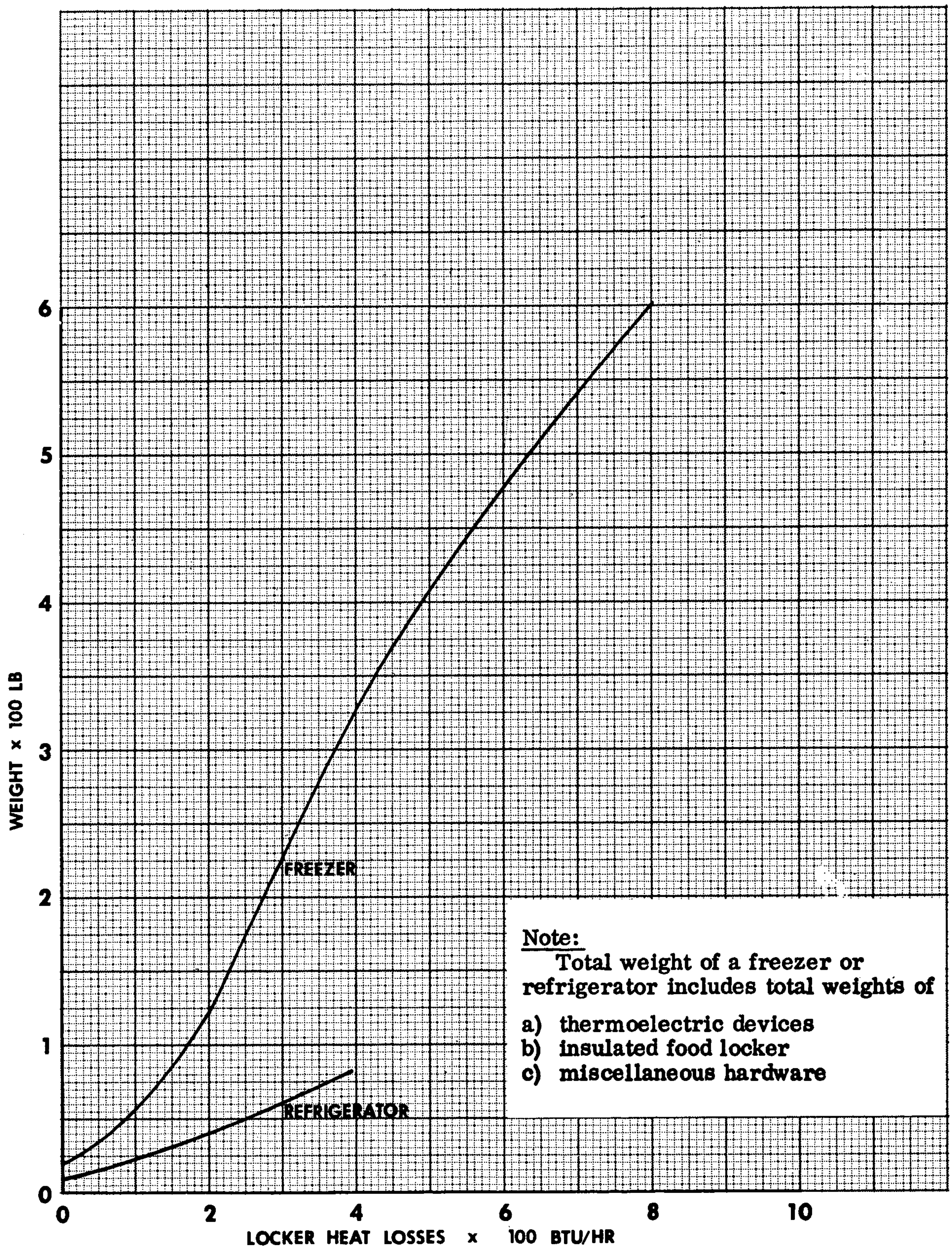


Figure 2.1.7(c). Weight of the Thermoelectric Devices For Thermoelectric Freezer and Refrigerator Concepts

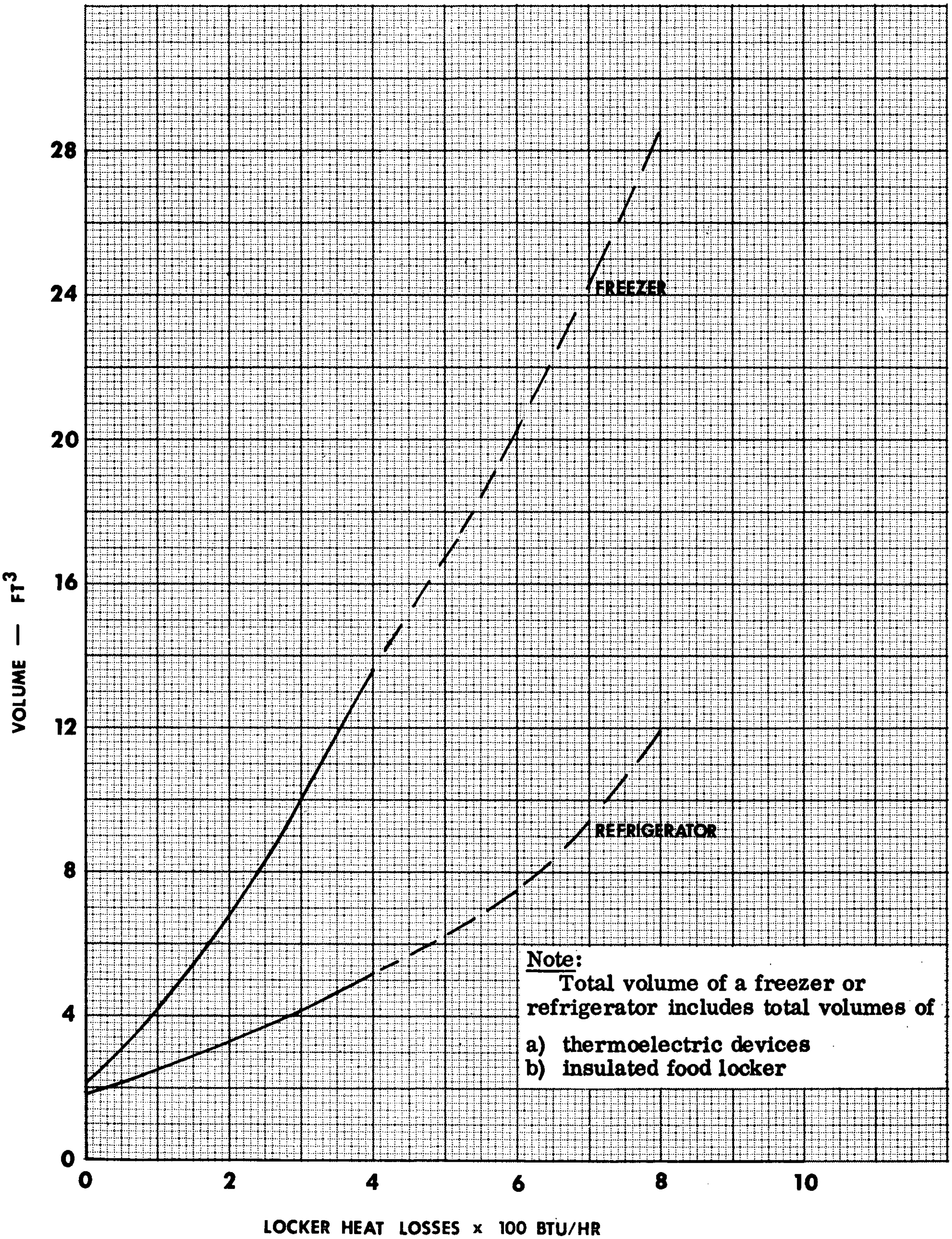


Figure 2.1.7(d). Volume of Thermoelectric Devices For Thermoelectric Freezer and Refrigerator Concepts

DATA SHEET: THERMOELECTRIC FREEZER CONCEPT

Mission Number ______________

(_____ Men and _____ Days)

Diet Mix: 20/80 B C
60/40 B C
85/15 B C

Note: Locker losses appear on Figure 2.1.6(a)

	Weight (lbs)	Power (watts)	Volume (ft^3)
1. Weight of locker only (see Figure 2.1.6(b)) =	☐	-	-
2. Weight of Thermoelectric Devices (Figure 2.1.7(c))	☐	-	-
3. Volume of freezer locker (see Figure 2.1.6(c)) =	-	-	☐
4. Volume of Thermoelectric Devices (see Figure 2.1.7(d))	-	-	☐
5. Power of Thermoelectric Devices (see Figure 2.1.7(a))	-	☐	-
6. Power of Cooling Fans (see Figure 2.1.7(b))	-	☐	-
TOTALS	☐	☐	☐

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.1.8 Title: Turbo-Compressor/Air Cycle Freezer

Assumptions:

See Concept Back-Up Information Sheet for Concept 2.2.8 (Turbo-Compressor/ Air Cycle Refrigerator) for technical discussion of air cycle machinery.

Formulae:

Significant Factors:

General Information:

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.2.4 Title: Water Sublimation Refrigerator

Assumptions:

See Concept Back-Up Information Sheets for Concept 2.1.4 (Water Sublimation Freezer) for the technical discussion of the refrigerator concept included therein.

Formulae:

Significant Factors:

General Information:

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.2.7 Title: Thermoelectric Refrigerator

Assumptions:

See Concept Back-Up Information Sheet for Concept 2.1.7 (Thermoelectric Freezer Concept) for technical discussion of thermoelectric refrigerator.

Formulae:

Significant Factors:

It is assumed that the refrigerated food will be maintained at 40°F using a locker insulated with four inches of foam. The heat leaking into the locker will be removed using commercially available thermoelectric devices operating as heat pumps.

General Information:

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.2.8 Title: Turbo-Compressor/Air Cycle Refrigerator

Assumptions:

Formulae:

Significant Factors:

General Information:

References:

(1) Keenan and Kaye, Gas Tables, published by John Wiley & Son, 1948.

(2) David Mooney, Mechanical Engineering Thermodynamics, published by Prentice-Hall, Inc., 1953.

The air cycle refrigerator technique uses air as the circulating refrigerant. To illustrate the operation of this system and its components, a thermodynamic analysis is presented for a typical air cycle refrigerator. For the analysis, a refrigerator capacity of 56 ft^3 of food was selected. This represents the refrigerated food compliment for 25 crewmembers on a 90-day mission using the 20/80 diet mix. Consequently, the heat leakage rate associated with the refrigerator locker was 248 Btu/hr or 73 watts leakage.

The 73 watts are continuously removed from the locker with an airflow circulating at 30 lbs/min. On Figures 2.2.8(a) and 2.2.8(b), air at ambient pressure P_o is compressed to pressure P_2. A rotating compressor operating at a pressure ratio between 2.5 and 3.0 and air efficiency of 70% is typically employed in systems of this size. Figure 2.2.8(a) indicates two separate compressors only to illustrate that the motor power enters the system through the compression process and that the compression process also loads the expansion turbine. In the process between states 2 and 3, heat is removed with almost no drop in pressure. The cooled air then enters the turbine where it expands to near-ambient pressure levels; the turbine supplies power to the compressor and delivers air to the refrigerator locker at a lower enthalpy (temperature) level, state point 4. The analysis was conducted using the air tables found in the appendix of Reference 2 (David Mooney, Mechanical Engineering Thermodynamics, published by Prentice-Hall, Inc., 1953).

This analysis can be used to analyze freezer concepts noting that the assumed value for T_4 must be changed to -10°F internal freezer temperature.

THERMODYNAMIC ANALYSIS OF AIR CYCLE REFRIGERATOR

At state point 3

A trial value of T_3 = 140°F will be assumed,

at T_3 = 140°F, in Air Tables we read...

$$h_3 = 143.5 \text{ Btu/lb}$$

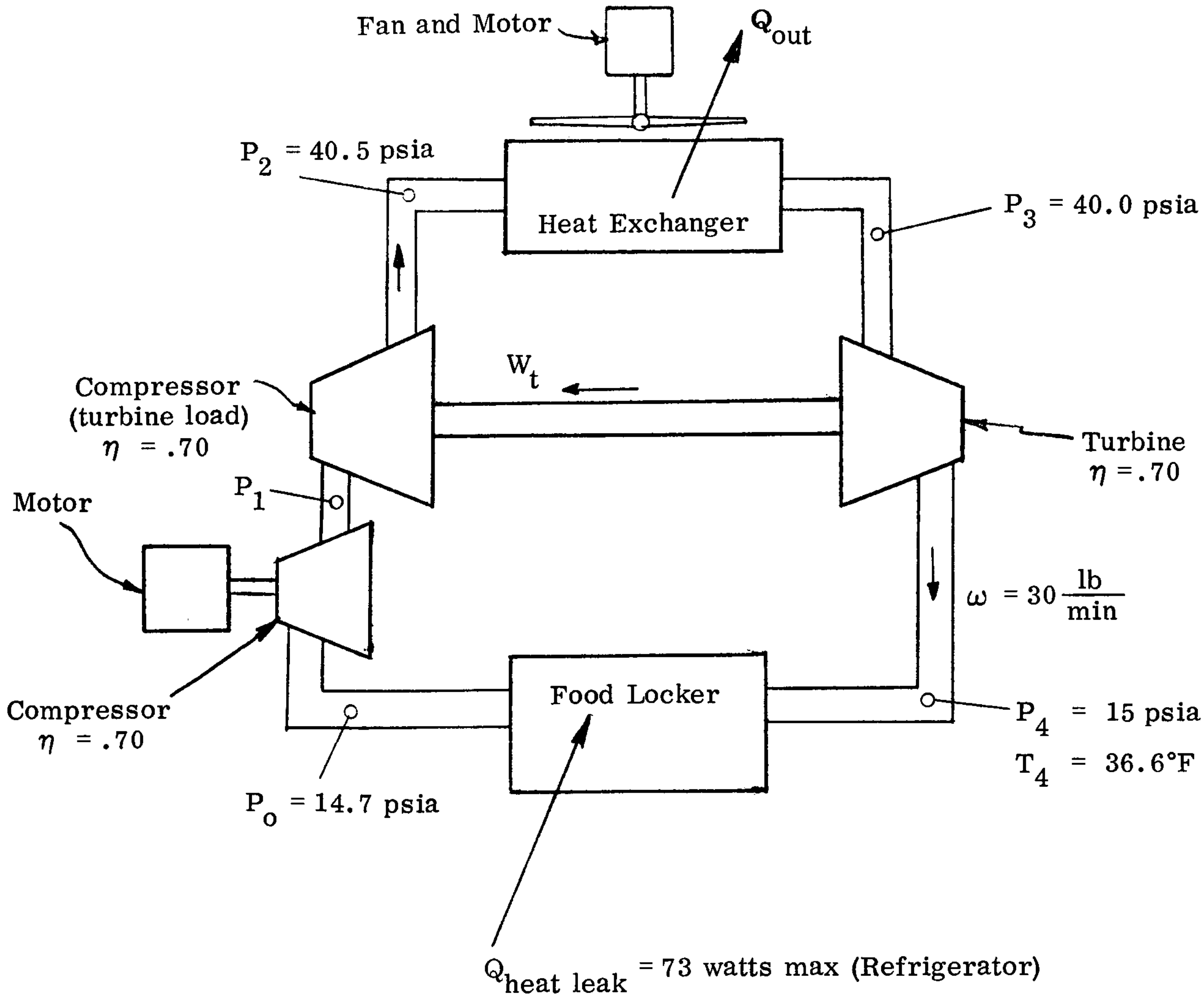
$$P_{r_3} = 2.00$$

now...

$$P_{r_4} = P_{r_3} \left(\frac{P_4}{P_3}\right)$$

$$P_{r_4} = 2.00 \left(\frac{15}{40}\right)$$

$$P_{r_4} = .750$$



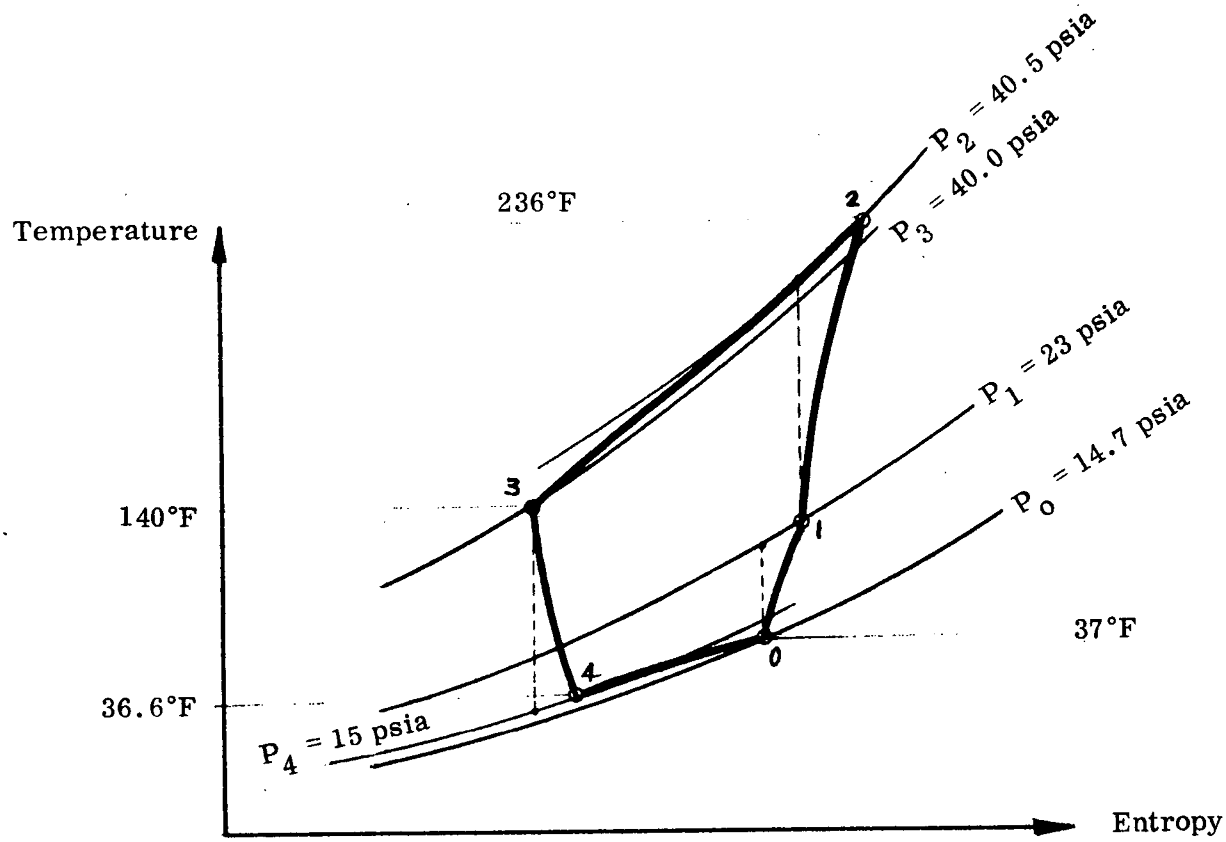
Assumed Values:

P_o	=	14.7 psia
P_4	=	15.0 psia
$(P_2 - P_3)$	=	0.5 psia
T_4	≈	40°F
ω	=	30 lb/min
$\eta_{compressor}$	=	.70
$\eta_{turbine}$	=	.70

$$2.5 < \left(\frac{P_2}{P_o}\right) < 3.0$$

$$2.5 < \left(\frac{P_3}{P_4}\right) < 3.0$$

Figure 2.2.8(a). Air Cycle Schematic



State Point	Pressure (psia)	Temperature (°F)	Enthalpy (Btu/lb)
0	14.7	37.0	119.2
1	23.0	133.7	141.9
2	40.5	236.8	166.7
3	40.0	140.0	143.5
4	15.0	36.6	118.8

Figure 2.2.8(b). Temperature-Entropy Plot of Air Cycle Refrigerator

at P_{r_4} = .750, in Air Tables we read...

$$h_{4_s} = 108.16 \text{ Btu/lb} \quad (\text{"s" denotes isentropic state point})$$

$$T_{4_s} = -7.75°F$$

where $(T_3 - T_4) = .70\,(T_3 - T_{4_s})$

$$T_4 = T_3 - .70\,(T_3 - T_{4_s})$$

$$T_4 = 140 - .70\,(140 + 7.75)$$

$$T_4 = 36.6°F \quad (\text{temperature of air entering refrigerator})$$

If the resulting value for T_4 is unsuitable for refrigeration purposes, then the trial value of T_3 should be modified until the calculated value of T_4 is closer to 40°F.

and $(h_3 - h_4) = .70\,(h_3 - h_{4_s})$

$$h_4 = h_3 - .70\,(h_3 - h_{4_s})$$

$$h_4 = 143.5 - .70\,(143.5 - 108.16)$$

$$h_4 = 118.80 \text{ Btu/lb} \quad (\text{enthalpy entering refrigerator})$$

energy balance on turbine

$$\omega h_3 = W_t + \omega h_4$$

$$W_t = \omega\,(h_3 - h_4)$$

now

$$W_t = (30 \text{ lb/min})\,(60 \text{ min/hr})\,(143.5 - 118.8)$$

$$W_t = 44,500 \text{ Btu/hr}$$

energy balance on refrigerator locker

$$\omega\ C_p\ T_4 + Q_{heat\ leak} = \omega\ C_p\ T_o$$

$$(60\ \text{min/hr})\ (30\ \text{lb/min})\ (.240)\ (36.6) + (73\ \text{watts})\ (3.413) = (60)\ (30)\ (.24)\ T_o$$

$$T_o = \frac{15800 + 248}{432}$$

$$T_o = 37°F \text{ (temperature of air leaving refrigerator)}$$

at $T_o = 37°F$, in Air Tables we read...

$$h_o = 118.78\ \text{Btu/lb}$$

$$P_{r_o} = 1.038 \text{ (properties of air leaving the refrigerator)}$$

now, ASSUME: $P_1 = 23$ psia:

$$P_{r_1} = P_{r_o}\ \left(\frac{P_1}{P_o} \right)$$

$$P_{r_1} = 1.038\ \left(\frac{23}{14.7} \right)$$

$$P_{r_1} = 1.621$$

at $P_{r_1} = 1.621$, in Air Tables we read...

$$h_{1_s} = 135.0\ \text{Btu/lb}$$

$$T_{1_s} = 104.56°F$$

now, assuming the compressor has an efficiency of .70

$$(h_1 - h_o) = 1/.70\ (h_{1_s} - h_o)$$

$$h_1 = h_o + 1.43\ (h_{1_s} - h_o)$$

$$h_1 = 118.78 + 1.43\ (135.0 - 118.78)$$

$$h_1 = 141.98\ \text{Btu/lb}$$

energy balance on compressor connected to turbine:

$$\omega h_1 + W_t = \omega h_2$$

and also $$(h_2 - h_1) = 1/.70\ (h_{2_s} - h_1)$$

$$h_{2_s} = h_1 + W_t\ (.70/\omega)$$

$$h_{2_s} = 141.98 + 44{,}500\ (.70)\ \frac{1}{60 * 30}$$

$$\underline{h_{2_s} = 159.23 \text{ Btu/lb}} \quad \text{(based on assumption of } P_1 = 23 \text{ psia)}$$

now, to check the assumption of $P_1 = 23$ psia...

$$P_{r_2} = P_{r_1}\ (\frac{P_2}{P_1})$$

$$P_{r_2} = 1.621\ (\frac{40.5}{23})$$

$$P_{r_2} = \underline{2.86}$$

at $P_{r_2} = 2.86$, in Air Tables we read...

$$\underline{h_{2_s} = 158.78 \frac{\text{Btu}}{\text{lb}}}$$

The value of 158.78 is comparable to the aforementioned value of 159.28 Btu/lb; however, the trial value of P_1 was modified several times until the agreement of the enthalpy (h_{2_s}) values was sufficiently close. Therefore, P_1 is 23.0 psia and

$$\underline{T_1 = 133.7°F}$$

$$\underline{T_{2_s} = 205.75°F}$$

accordingly,

$$(h_2 - h_1) = 1/.70\ (h_{2_s} - h_1)$$

$$h_2 = 141.98 + 1.43\ (159.28 - 141.98)$$

$$\underline{h_2 = 166.73 \text{ Btu/lb}}$$

likewise, $\underline{T_2 = 236.8°F}$

Determine the power required to drive the compressor between state points 0 and 1:

an energy balance on compressor shows...

$$W_{in} = \omega\ (h_1 - h_o)$$

$$W_{in} = (30\ \text{lb/min})\ (60\ \text{min/hr})\ (141.98 - 118.78)$$

$$W_{in} = 41,750\ \text{Btu/hr}$$

Using an overall motor/drive efficiency of 90%, the power of the motor is...

$$W_{motor} = \frac{41,750}{3.413}\ \left(\frac{1}{.90}\right)$$

$$W_{motor} = 13,650\ \text{watts}\ \ (18.3\ \text{Hp})$$

Energy balance on entire system

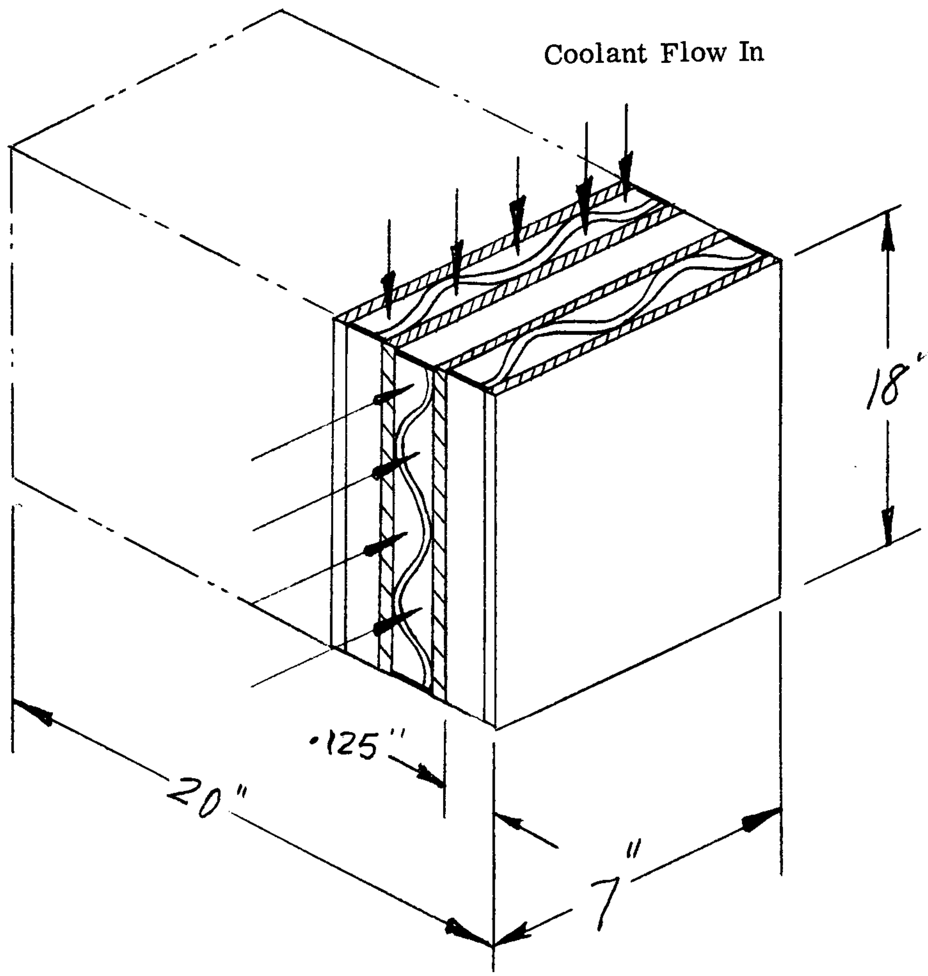
Energy in = Energy out

$$Q_{in} + W_{motor} = \omega\ (h_2 - h_3)$$

$$(73\ \text{watts})\ 3.413 + 41,750\ \text{Btu/hr} = (30\ \text{lb/min})\ (60\ \text{min/hr})\ (166.73 - 143.50)$$

$$41,999 \cong 41,850\ \ \text{(Check)}$$

HEAT EXCHANGER ANALYSIS



A_c: Coolant free-flow area = 8 (7 in. * .100 in.) = 5.60 in^2

f: Friction factor, mean $\cong$ .040

ΔP_c: Pressure drop, coolant passages $\equiv$ 2.0 psia

ϵ : Overall heat exchanger effectiveness $\cong$ .60

From the definition of effectiveness for a heat exchanger

$T_{c_\sigma} = T_{c_i} + \beta \epsilon \ \Delta T_{max}$ where

T_{c_σ} = coolant temperature out

T_{c_i} = coolant temperature in $\cong$ 76°F

$\beta = (m\ C_p)_{air} / (m\ C_p)_{coolant} = \frac{30}{\omega_c}$

$\epsilon = .60$

$\Delta T_{max} = T_{hot\ air\ in} - T_{coolant\ in} = (237 - 76) = 161°F$

ω_c = coolant flow rate, lbs/min

so that,

$$T_{c_\sigma} = 76 + \left(\frac{30}{\omega_c}\right)(.60)(161)$$

$$\boxed{T_{c_\sigma} = 76 + \frac{2900}{\omega_c}}$$

However, before T_{c_σ} can be evaluated, a value for ω_c must be determined:

$$\Delta P_c = \frac{f\,G^2}{2 g_c\,\rho}\ \frac{4\,L}{D_h}$$

where $\Delta P_c \equiv 2.0$ psia

$f = .04$

$g_c = 32.2$ ft/sec^2

$\rho = .071$ lb/ft^3

$L = 18$ inches

D_h = hydraulic diameter $= \frac{4A}{P_{wet}} = \frac{4\ (7 * .10)\ 8}{2\ (7.10)} = 1.57$ inches

$$G \equiv \frac{\omega_c}{A_c} = \frac{\omega_c}{5.6}\left(\frac{1\ min}{60\ sec}\right)\left(\frac{12\ in}{ft}\right)^2 = .429\ \omega_c \quad \frac{lb}{ft^2\text{-sec}}$$

ω_c = coolant flow rate, lb/min

now...

$$G^2 = (\Delta P_c)\, 2\, g_c\, \rho\, D_h * \frac{1}{4\, f\, L}$$

$$G^2 = (.02)\, 2\, (32.2)\, (.071)\, (1.57) * \frac{144}{4\,(.04)\,(18)}$$

$$G^2 = 718.$$

$$G = 26.8 \frac{lb}{ft^2\text{-sec}}$$

but

$$G = .429\, \omega_c$$

$$.429\, \omega_c = 26.8$$

$$\boxed{\omega_c = 62.5 \frac{lb}{min}}$$ fan driven coolant flow in heat exchanger

now, evaluate T_{c_σ} ...

$$T_{c_\sigma} = 76 + \frac{2900}{625}$$

$T_{c_\sigma} = 122°F$ Temperature of coolant flow leaving heat exchanger

SUMMARY

Power

a) Compressor Motor		13,650
b) Fan Motor		800
	Total Power	14,450 watts

Weight

a) Turbine and Compressor (estimated)		10.0
b) Heat Exchanger (estimated)		18.0
c) Compressor Motor (estimated)		150.0
d) Fan and Motor (estimated)		40.0
e) Air Ducts (estimated)		12.0
f) Food Locker		375.5
	Total Weight	587.5 pounds

Volume

a)	Turbine and Compressor	0.60
b)	Heat Exchanger w/Fan, Motor	3.08
c)	Compressor Motor (estimated)	2.94
d)	Air Ducts (estimated)	2.80
e)	Food Locker	106.0
	Total Volume	115.4 ft^3

The following curves show estimated levels for power, weight, and volume for the air cycle refrigerator and freezer.

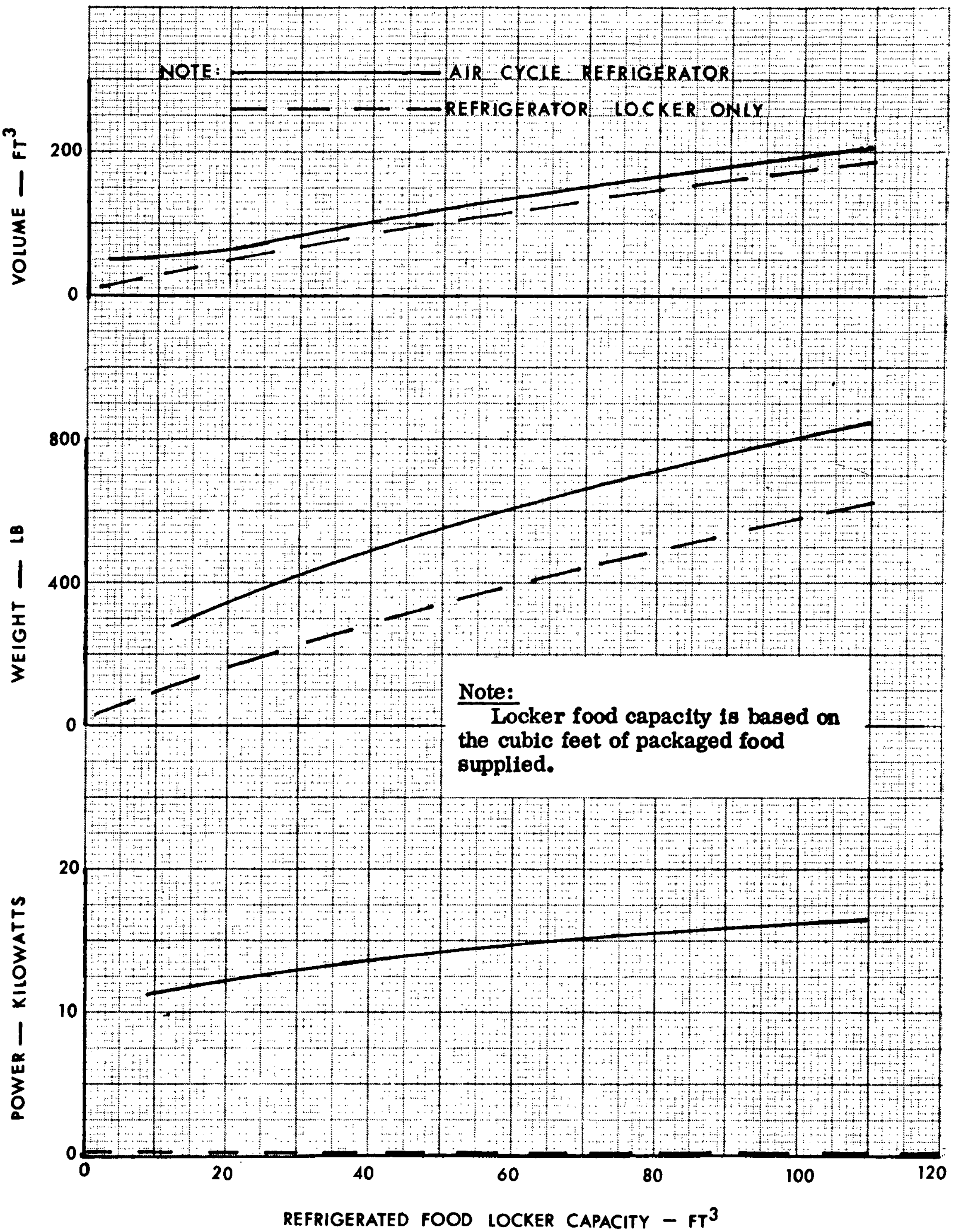


Figure 2.2.8(c). Total Estimated Power, Weight, and Volume Versus Locker Food Capacity Air Cycle Concept - Refrigerator Only

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.3.1 Title: Ambient Storage - Rigid Concept

Assumptions:

1. That the shape of the storage concept will be cubical to minimize size.

Formulae:

Significant Factors:

See Structural Analysis of Food Locker, Back-Up Information Sheet, Concept 2.1.6 for component weights of shelving structure.

General Information:

The ambient storage (rigid concept) relies on a shelving structure for food arrangement, support, and retention. A structural weight ratio of 26.3 pounds of food per pound of structure will be used to determine the weight penalty of the storage concept. The installed volume requirements were based on the cubical dimension of the food with 2 inches added to the length, width, and height.

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 2.3.2 Title: Ambient Storage - Flexible Concept

Assumptions:

1. That the weight of the netting and fastening hardware is 1/10 the weight of the comparable rigid concept.

Formulae:

Significant Factors:

General Information:

The concept consists of an elastic netting material fastened to a bulkhead in the storage area. The netting will be fastened at multiple locations so that the empty configuration lies close against the bulkhead. Food retrieval will be conducted through the extensible openings of the netting.

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 3.2.1 Title: Hot Air Convection Heating Oven

Assumptions:

Formulae:

Significant Factors:

General Information:

References:

PRELIMINARY ASSUMPTIONS

To calculate the weight, volume, and power requirements of an oven used to warm food from -10°F to 160°F, a simplifying assumption will be introduced. That is, the warming oven shall be sized to accommodate a frozen food mass based on 80% of the food consumed during the largest daily meal. The consequence of this assumption results in a food warming oven that is sized for the bulk and power requirements of 1.27 pounds of food per man (each day). This value was determined from Figure III-5 (Volume I, Section 1.0); using the 20/80C mix, 1.591 pounds of food per man-day constitutes the largest daily meal (lunch). The product of (80%) * (1.591) is 1.27 lbs food/man-day. It is further assumed that a food warming oven based on the 1.27 lbs food/man-day will be equally useful for the 60/40 and 85/15 diet mixtures also tabulated in Figure III-5. To qualify this assumption: Information in Section 1.0 indicates that for diet mixtures 20/80, 60/40, and 85/15, the (average) percentage of frozen constituents in these diets decreases from 40% to 30%, and to 15%, respectively. That is, for even the most austere of diet mixtures (85/15 for example), a warming oven based on 1.27 will suffice; however, because of the inherent dearth of frozen supplies in the austere diets, the oven would be utilized only once every 3 days when sufficient frozen supplies would have accumulated. Likewise, the 60/40 diet may require the warming oven every second day.

The analysis of a Hot Air Convection Warming Oven for a crew of 12 follows.

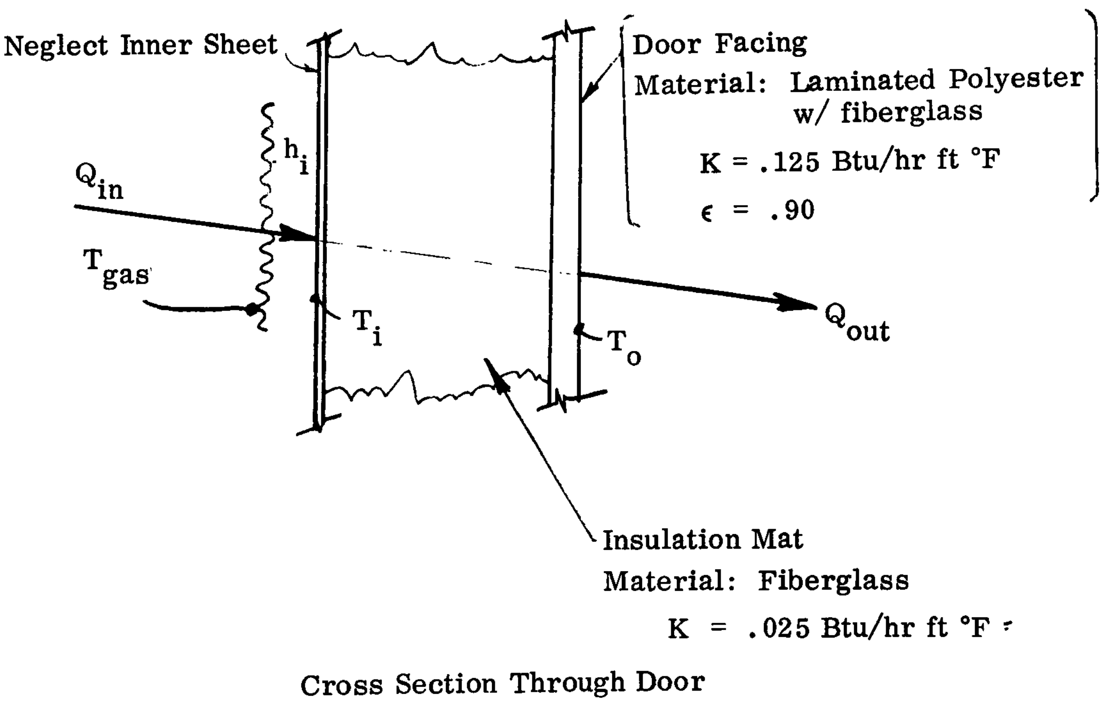
The hot air convection heating oven raises the temperature of food to about 160°F from the frozen state of -10°F in 30 minutes. A fan located in the rear of the food compartment increases the circulation of the heated air over the food mass. A typical analysis of the hot air convection oven is presented below. After the amount of food to be warmed is determined, the arrangement of food within the oven can be fixed. Figure 3.2.1(a) shows twelve sample food packages located within the food compartment envelope. A typical spacing between packages and compartment walls is indicated in the figure.

Figure 3.2.1(b) illustrates how insulation mats and vented control areas enclose the food compartment envelope. The analysis starts by restricting the maximum tactile temperature of the oven (door) to 140°F.

ASSUME

1. Surface temperature $T_o \lesseqgtr 140°F$.
2. $h_i \approx 6.70$ Btu/hr ft^2 °F (based on quick calculations).
3. Door facing is .125 inch thick.
4. Door insulation is .75 inch thick.
5. Radiation heat transfer mechanism predominate at T_o.

DETERMINE T_{gas} so that $T_o \lesseqgtr 140°F$ ...



Cross Section Through Door

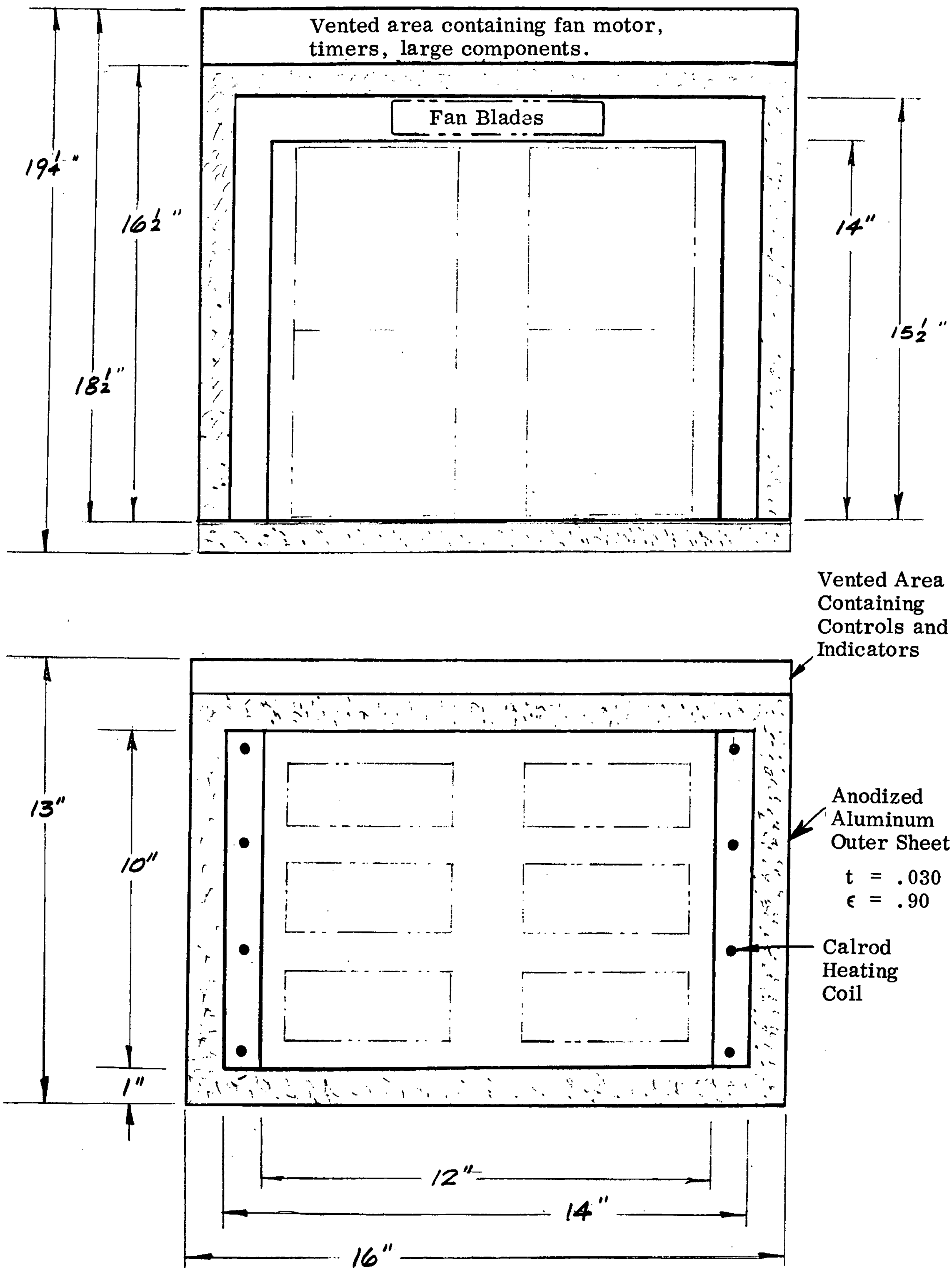


Figure 3.2.1(b). Cross-Sectional View of Oven

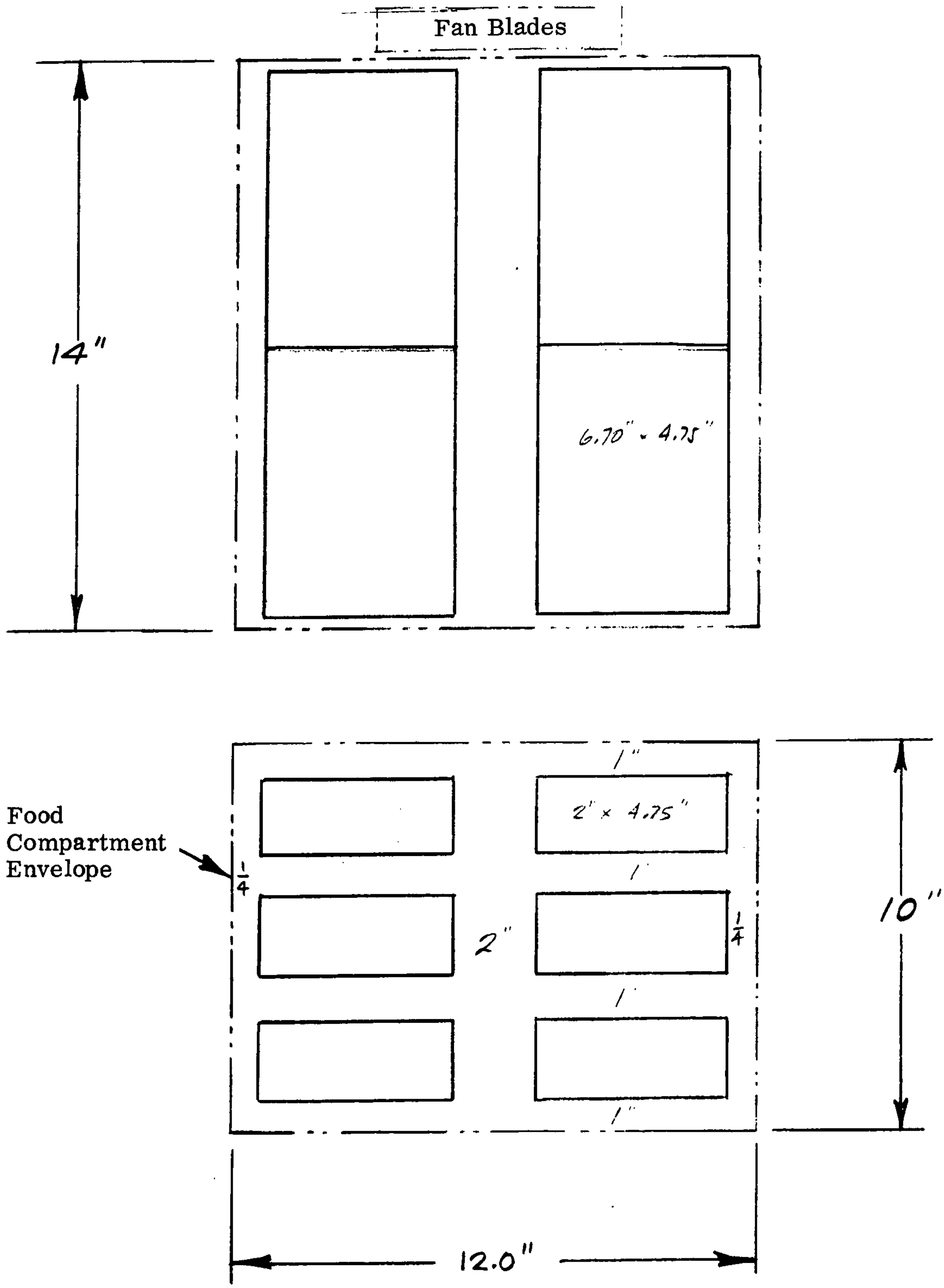


Figure 3.2.1(a). Food Package Arrangement

$Q_{in} = Q_{out}$

$$UA\,(T_g - T_o) = A\,\epsilon_o\,[\sigma T_o^4 - \sigma T_\infty^4]$$

$$\frac{(T_g - 140)}{\frac{.125}{.125\,(12)} + \frac{.75}{.025\,(12)} + \frac{1}{6.7}} = .90\,(222 - 130)$$

Note: $Tg \equiv T_{gas}$

$T_{gas} = 366°F$

also...

$$h_i\,A\,(T_g - T_i) = A\,\epsilon_o\,(\sigma T_o^4 - \sigma T_\infty^4)$$

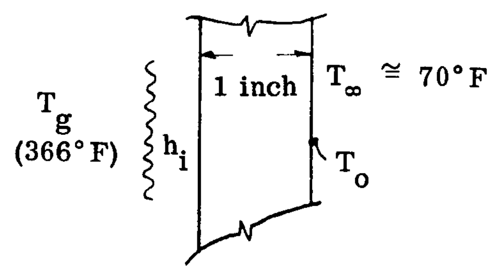
so...

$T_i = 354°F$

STEADY STATE LOSSES (WORST CASE)

Losses Through Top Surface

$$UA\,\Delta T = \frac{(T_g - T_o)\,A}{\frac{1}{.025\,(12)} + \frac{1}{6.7}} = .90\,A\,[\sigma T_o^4 - 135]$$



$$\frac{366 - T_o}{3.49\,(.90)} = \sigma T_o^4 - 135$$

$T_o = 131°F$

$$LOSS = \epsilon\,A\,[\sigma T_o^4 - \sigma T_\infty^4]$$
$$= .90\,(17 * 16)\,1/144\,[74]$$
$$= 126\ Btu/hr$$

Losses Through Bottom Surface

LOSS = 126 Btu/hr

Losses Through Rear Surface

$$\frac{(T_g - T_o)\,A}{\frac{1}{.025(12)} + \frac{1}{9.25}} = .90\,A\,[\,\sigma T_o^4 - 135\,]$$

$$\frac{366 - T_o}{(3.45)\,.90} = \sigma T_o^4 - 135$$

$$T_o = 132°F$$

$$\text{LOSS} = \epsilon A\,[\sigma T_o^4 - \sigma T_\infty^4]$$

$$= .90\,(14 * 10)\,[75.5]\,\frac{1}{144}$$

$$= 67 \text{ Btu/hr}$$

Losses Through Sides

$$Q = \epsilon A\,[\sigma T_o^4 - \sigma T_\infty^4]$$

$$= .90\,[15.5 * 10]\,2\,[75.5]\,\frac{1}{144} = 146.5 \text{ Btu/hr}$$

Losses Through Door

$$Q = \epsilon A\,[\sigma T_{140}^4 - \sigma T_\infty^4]$$

$$= .90\,(14 * 10)\,(87)\,\frac{1}{144} = 76 \text{ Btu/hr}$$

Surface	Area	Maximum Temperature	Heat Loss
Top	272 in^2	131°F	126 Btu/hr
Bottom	272 in^2	131°F	126 Btu/hr
Sides	155 in^2	132°F	146.5 Btu/hr
Rear	140 in^2	132°F	67 Btu/hr
Door	140 in^2	140°F	76 Btu/hr
			541.5 Btu/hr

TRANSIENT POWER REQUIRED

This power is defined as the energy needed to raise the oven constituents to steady values:

a) Oven structural casing and door from 65°F to ~ 132°F.

b) Insulation from 65°F to 243°F; $\{1/2\ (\bar{T}_i + \bar{T}_o) = 1/2\ (354 + 132) = 243°F\}$.

c) Plenum liners from 65°F to 354°F.

d) Food compartment liners from 65°F to 354°F.

e) Food mass from -10°F to 160°F.

f) Food containers from -10°F to 265°F; $\{1/2\ (T_{food} + T_{gas}) = 265°F\}$

The heating capacity is sized for above losses plus steady state leakage from surfaces.

Neglect thermal capacity of air in oven.

CALCULATIONS OF TRANSIENT POWER REQUIRED

a) Oven Structural Casing

$$Wt = \rho\ t\ Area = (.10)\ (.030) \left[(12 * 16.5) + (16.5*15) + \frac{(10.5*14.5)}{2} \right] 2 = 3.3 \text{ lbs.}$$

$$Q = m\ C_p \frac{\Delta T}{\Delta \theta} = (3.13)\ (.23)\ (132 - 65) \frac{1}{.5} = \underline{\underline{96.5 \text{ Btu/hr}}}$$

Oven Door (Polyester Facing)

$$Wt = \rho\ t\ A = (.070)\ (.125)\ [10.5 * 14.5\ ] = 1.332 \text{ lbs.}$$

$$Q = (1.332)\ .30\ \left(\frac{67}{.5}\right) = \underline{\underline{53.5 \text{ Btu/hr}}}$$

b) Insulation Mat

$$Wt = \rho\ t\ Area = \left(\frac{2.40}{1728}\right) (1.0) \left[(12*16.5) + (16*16.5) + (16*12) \frac{1.75}{2} \right] 2$$

$$Q = (1.75)\ .12\ (354 - 65) \frac{1}{.5} = \underline{\underline{121 \text{ Btu/hr}}}$$

c) Plenum Liners

$$Wt = \rho\, t\, Area = (.29)\,(.020)\left[(10*14) + \frac{(12*10)}{2} + (12*14)\right]2 = 4.27 \text{ lbs.}$$

$$Q = (4.27)\,(.12)\,(354 - 65)\,\frac{1}{.5} = \underline{\underline{297 \text{ Btu/hr}}}$$

d) Food Compartment Liners

$$Wt = \rho\, t\, Area = (.29)\,(.020)\left[(10*15.5) + \frac{(15.5*14)}{2} + (1*14)\,2 + (14*1.5)\right]2 = 3.62 \text{ lbs.}$$

$$Q = (3.62)\,(.12)\,(289)\,\frac{1}{.5} = \underline{\underline{251 \text{ Btu/hr}}}$$

e) Food Mass

$$Q_{\text{thaw from -10°F to 32°F}} = \frac{m}{\Delta\theta}\left[30\%\, Cp_{food} + 70\%\, Cp_{ice}\right]\Delta T$$

$$= \frac{12\,(1.270)}{.50}\left[30\%\,(.40) + 70\%\,(.501)\right](32 + 10) = \underline{\underline{583 \text{ Btu/hr}}}$$

$$Q \text{ required to change phase @ 32°F} = 12\,(1.270)\left[70\%\right]\frac{144}{.5} = \underline{\underline{2984 \text{ Btu/hr}}}$$

$$Q_{\text{cook from 32°F to 160°F}} = \frac{12\,(1.270)}{.50}\left[30\%\,(.40) + 70\%\,(1.00)\right](160 - 32) = \underline{\underline{3110 \text{ Btu/hr}}}$$

f) Food Containers

Assume weight of the individual container as .25 pounds.

$$\Sigma\, Wt = 12\,(.25) = 3.0 \text{ pounds}$$

$$Q = \frac{(3.0)\,(.20)}{.50}\,(265 + 10) = \underline{\underline{330 \text{ Btu/hr}}}$$

Oven Component	Weight (Pounds)	Power Required (Btu/hr)	Power Required (Watts)
Structural Sheets	4.46	150.0	
Insulation	1.75	121.0	
Plenum Liners	4.27	297.0	
Component Liners	3.62	251.0	
Food Mass	14.80	6677.0	
Food Containers	3.0	330.0	
Ambient Leak	-	541.5	
TOTAL	31.9*	8367.0	2450 Watts

Use 2800 watt capacity heater

* 31.9 pounds
5.0 fan/motor
2.0 heater/supports
1.0 controls/timers

40.0 pounds Overall Weight

SIZE FAN AND MOTOR

Surface Area in Plenum Regions

$$A_{\substack{plenum\\overall}} = 4\,(1*15\ 1/2) + 2\,(1\text{-}1/2 * 12) + 2\,(10 * 16\text{-}1/2) + 2\,(10*14) + 10\,(12+14)$$

$$= 968\ in^2 \qquad \text{but...}$$

...since the flow splits equally, the effective surface of the plenum exposed is...

$$A_{plenum} = 1/2\,(968)\ 1/144 = \underline{\underline{3.36\ ft^2}}$$

Surface Area of Food Compartment

$$A_{\substack{food\\compartment\\liners}} = 2\left[(14 * 12) + (10 * 14) + (12 * 10)\right] +$$

$$A_{packages} = 12\left[2\,(6.70 * 4.75) + 2\,(6.70 * 2) + 1\,(4.75 * 2)\right]$$

This area consists of the surface areas of the liners, the inner door, and food packages.

$$A_{\substack{food\\compartment}} = (856 + 1200)\ 1/144 = \underline{\underline{14.28\ ft^2}}$$

For Turbulent Flow in a Duct

$$h = .023\ \frac{K}{d}\left(\frac{d\ \omega}{\mu\ A}\right)^{.8} P^{1/3}$$

where...

K (thermal conductivity)	=	.019 Btu/hr ft °F
μ (viscosity)	=	1.61×10^{-5} lb/ft-sec
A (flow area)	=	(see below) ft^2
Cp (specific heat)	=	.243 Btu/lb °F
P (Prandtl Number)	=	.71
ω (flow rate)	-	(TBD) lb/sec

All evaluated at $T_{film} = 1/2\,(T_g + T_i) = 300°F$

for the plenum, determine flow area (for above expression)

$$\text{Flow area of plenum only} = \frac{2\ (10 * 1)\ 14 + 1\ (14 * 1.5)\ 14}{2 * 14 + 14} = 13.7\ \text{in}^2 = .095\ \text{ft}^2$$

$$D_{equiv.} = \frac{4\ A}{P_{wet}} = \frac{4\ (.095)}{2\ (1 + 10)\ \frac{1}{12}} = \underline{\underline{.207\ \text{ft.}}}$$

$$h_{in\ plenum} = .023\ \frac{.019}{.207} \left[\frac{.207\ \omega/2}{1.61 \times 10^{-5}\ (.095)} \right]^{.8} (.71)^{1/3} = \underline{\underline{13.75\ \omega^{.8}\ \frac{\text{Btu}}{\text{ft}^2\ \text{hr}\ °\text{F}}}}$$

$$\text{Flow Area of Food Compartment Only} = (10 * 12) - 6\ (4.75 * 2.0) = 63\ \text{in}^2 = \underline{\underline{.438\ \text{ft}^2}}$$

$$D_{equiv} = \frac{4\ A}{P_{wet}} = \frac{4\ (.438)\ 12}{(10 * 12) + 12\ (4.75 + 2 + 2)} = \underline{.0934\ \text{ft}}$$

$$h_{food\ compartment} = .023\ \frac{.019}{.0934} \left[\frac{.0934\ \omega}{1.61 \times 10^{-5}\ (.438)} \right]^{.8} (.71)^{1/3} = 8.27\ \omega^{.8}\ \frac{\text{Btu}}{\text{ft}^2\ \text{hr}\ °\text{F}}$$

HEAT BALANCE ON INTERNAL SURFACES (SIZE FAN)

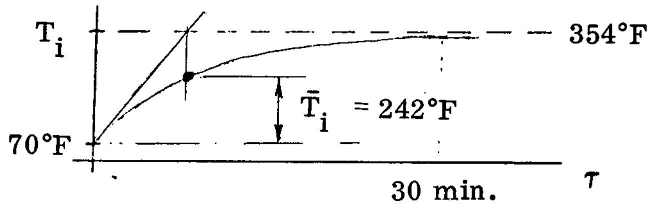
$$Q_{heater} = Q_{into\ surfaces}$$

$$2800\ \text{watts} = 9560\ \text{Btu/hr} = hA_{plenum}\ (T_{gas} - \bar{T}_i) + hA_{food\ compartment}\ (T_{gas} - \bar{T}_i)$$

$$9560 = \left[13.75\ \omega^{.8} * 3.36 + 8.27\ \omega^{.8} * 14.28 \right] (366 - 242)$$

where... $\omega^{.8} = .47$

$$\underline{\underline{\omega = .394\ \text{lb/sec} = 308\ \text{scfm}}}$$



Use $\bar{T}_i$ as an average surface (internal) temperature in initial calculations.

SUMMARY

Total Weight = 31.9 + 5.0 (fan and motor) + 2.0 (heater and supports) + 1.0 (controls and timers) = 40 pounds

Installed Volume = 16 x 13 x 19-1/4 (inches) = 2.55 ft^3

Total Power = 2800 (heater) + 130 (motor) + 70 (controls and lights) = 3000 watts

Heat Rejected = Q from (Oven[1] and Food Surfaces[2])
= 159 + 470 + 87 = 716 watts

1) Oven losses occur during cooking period + 1.5 hours.

2) Assume food cools from 160°F to 100°F in 20 minutes = 470 watts
Assume containers cool from 265°F to 100°F in 20 minutes = 87 watts

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 3.2.2 Title: Microwave Warming Oven

Assumptions:

In Back-Up Information Sheets for Concept 3.2.1, Hot Air Convective Heating Oven, see Preliminary Assumptions for the generalized approach to sizing food warming concepts.

Formulae:

Significant Factors:

General Information:

Recent reports from the reference source show that the electrical efficiency of current microwave generator/power supplies is close to 50% overall. This will be the value used in the following evaluation.

References:

Litton Industries, Atherton Division, 2530 North Second Street, Minneapolis, Minnesota 55411.

The microwave oven relies on the magnetron tube to generate high frequency waves necessary to penetrate and warm the food. The microwaves are ducted from the generation region into the tuned food cavity where a suitable wave mixer is used to preclude hot and cold spots in the food.

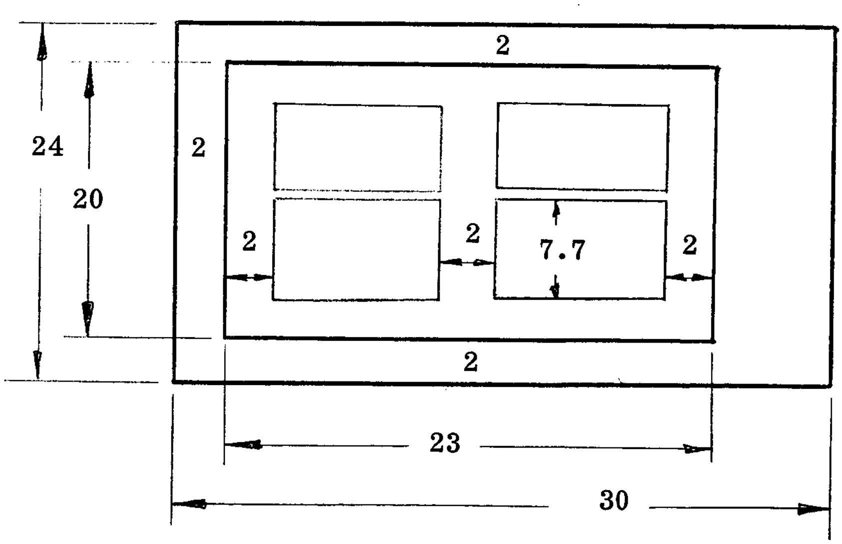
The power supply will be designed as a solid state unit for maximum reliability. A fan is used to remove heat from the power supply and magnetron region and rejects it to ambient. The door configuration will be of the swing-down type and incorporate a seal designed to attenuate thermal and RF energy. Glass or ceramic plates, located 1 inch from the interior surfaces of the oven, will be used to retain the food being heated; also, the interior configuration will be designed to avoid entrapment of food particles and permit ease of cleaning.

The oven will be designed to heat frozen or partially cooked foods suitable for the preparation of meals and snack items with minimum crew interaction and maximum convenience. The oven will raise the temperature of food from -10°F to 160°F serving level uniformly throughout.

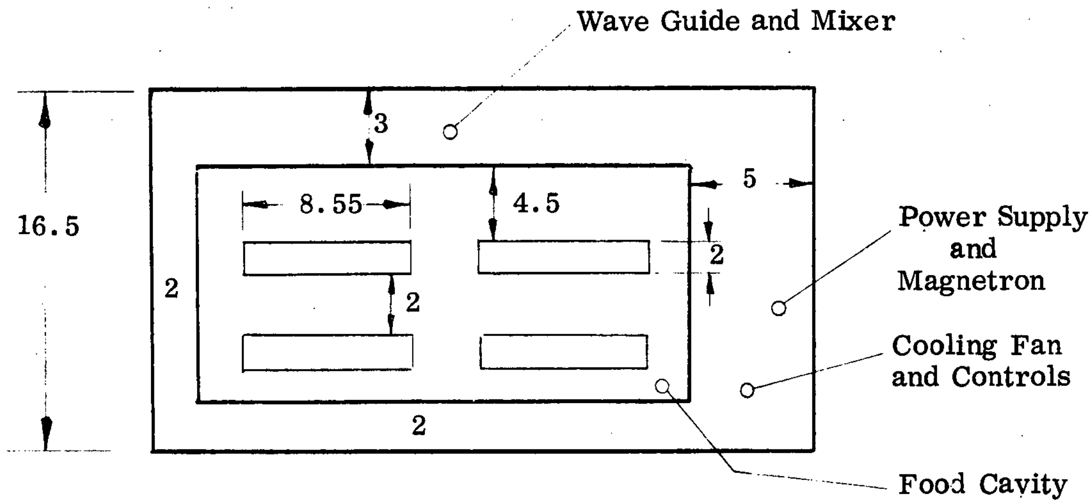
The analysis of the microwave heating oven is primarily concerned with determining the power required to raise the food temperature as well as determining the power losses that exist during the warming process. The following analysis will determine the requirements of an oven capable of heating food for 12 crewmembers. The oven will be sized for 1.27 pounds food per man-day. The validity of this number is qualified in a detailed discussion found in the Back-Up Information Sheets for Concept 3.2.1 under Preliminary Assumptions.

Using a frozen food density of 50 lb/ft^3, the size of the food packages for 12 crewmembers can be described. For this analysis, four standard packages will be used. Each package measures 2.0 * 7.7 * 8.55.

The arrangement of the food packages within the food cavity envelope is illustrated below. A general rule is to limit the total vertical food thickness to 4 inches so wave penetration is not severely attenuated.



PLAN VIEW



FRONTAL VIEW

The power required to warm supplies for 12 men will be presented in three steps assuming 70% of the wet food mass is water.

-10°F to 32°F

$$Q_1 = \frac{m}{\Delta\theta}\left[70\%\ Cp_{ice} + 30\%\ Cp_{food}\right]\Delta T$$

$$Q_1 = \frac{12\ (1.27)}{0.5}\left[.70 * .501 + .30 * .40\right]\ 42$$

$$Q_1 = \underline{\underline{602\ \text{Btu/hr}}}$$

32°F to 32°F Δphase

$$Q_2 = (70\%)\ m\ \frac{\Delta H}{\Delta\theta}$$

$$Q_2 = (.70)\ 12\ (1.27)\ \frac{144}{0.5}$$

$$Q_2 = \underline{\underline{3070\ \text{Btu/hr}}}$$

32°F to 160°F

$$Q_3 = \frac{m}{\Delta\theta}\left[70\%\ Cp_{water} + 30\%\ Cp_{food}\right]\Delta T$$

$$Q_3 = \frac{12\ (1.27)}{0.5}\left[.70 * 1.0 + .30 * .40\right]\ 128$$

$$Q_3 = \underline{\underline{3190\ \text{Btu/hr}}}$$

$$Q_{food\ heating} = 602 + 3070 + 3190 = 6862\ \text{Btu/hr}$$

$$Q_{food\ heating} = \underline{\underline{2000\ \text{watts}}}$$

ELECTRICAL POWER REQUIRED TO DELIVER 2000 WATTS

$$\text{Power} = \frac{2000}{\eta}$$

$$\underline{\text{Power} = 4000 \text{ watts}}$$

WEIGHT AND VOLUME CALCULATIONS

The construction of the isolated food cavity is a stainless steel shell. The outer case effectively insulates the control and power supply region and may be a lightweight phenolic. The space between the inner and outer shells are filled with fiberglass insulation only when the microwave oven is augmented with a radiant heating element; otherwise, very little thermal energy is evolved in the food cavity.

The expression for the installed volume is:

$$\text{Vol} = L * W * H$$

$$\text{Vol} = 30 * 24 * 16.5$$

$$\underline{\text{Vol} = 6.90 \text{ ft}^3} \text{ for 12 man oven}$$

Because the dimensions of the above microwave oven concept are similar to a commercial unit of comparable power output (see Litton Models 550 and 850), the installed weight can be estimated at 192 pounds.

HEAT REJECTED INTO THE CABIN ATMOSPHERE

The heat that enters the cabin atmosphere during the preparation (and eating) cycle comes from the inefficiency in the microwave power supply and from the cooling of the meal prior to consumption. Because the overall efficiency of the microwave oven is 50%, a heat rate equal to that supplied to the food leaves the power supply and related equipment. Thus, the overall oven loss is

$$q_{\text{oven loss}} = \underline{2000 \text{ watts}}$$

Now, it is assumed that the food cools from 160°F to 100°F in approximately 20 minutes before completion of eating. The expression for this heat loss is

$$q_{\text{food cool-off}} = m\ Cp\ \frac{\Delta T}{\Delta \theta}$$

$$m = 12 \text{ men} * 1.27\ \frac{\text{lbs food}}{\text{man}}$$

$$C_p = .82 \text{ Btu/lb °F}$$

$$\Delta T = 160 - 100°\text{F}$$

$$\Delta \theta = 20 \text{ minutes}$$

$q_{food\ cool\text{-}off} = 2250$ Btu/hr

$q_{food\ cool\text{-}off} = \underline{660 \text{ watts}}$

Total heat rejected to cabin atmosphere

$Q_{rejected} = 2000 + 660 = \underline{2660 \text{ watts}}$

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 3.2.3 Title: Resistance Heating Oven

Assumptions:

Formulae:

Significant Factors:

The Resistance Heating Oven was based on design features incorporated into the Litton Quartz-Plate Infrared Oven, Model HE-5000.

General Information:

References:

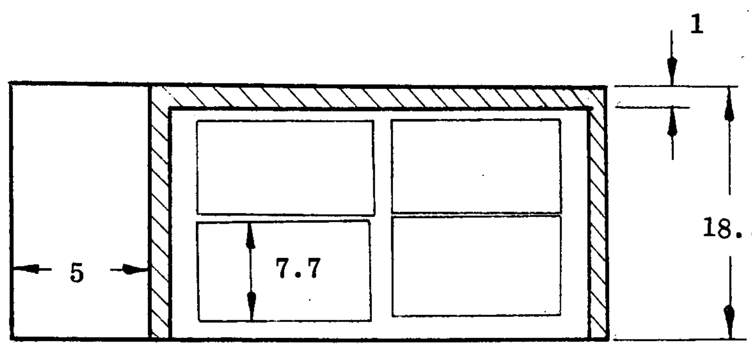
Litton Industries, Atherton Division, 2530 North Second Street, Minneapolis, Minnesota 55411.

The radiant (or resistance) food warming oven relies on an infrared element to introduce heat into the food. The oven features a fused silica plate which transmits high intensity infrared radiant energy.

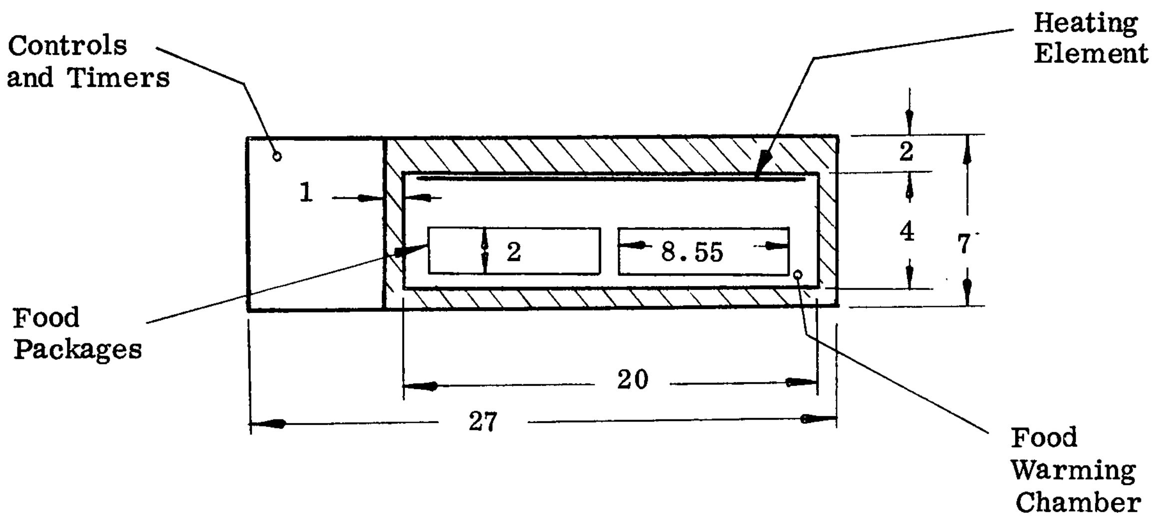
The heating chamber containing the heating element will be 4 inches high and approximately 14 inches deep. The width of the heating chamber will be sized to accommodate the food for any crew size. The chamber is limited to 4 inches in height because food warming efficiency in the radiant oven falls off quickly for food thicknesses greater than 2 inches; that is, heating time and thermal losses increase. Surface scorching of some food products may occur if an excessively thick package is warmed quickly.

The analysis of the radiant warming oven is primarily concerned with determining the power required to raise the temperature of the frozen food from -10°F to the 160°F serving level as well as determining the power losses that exist during the warming process. The following analysis will determine the power, weight, and volume requirements of an oven capable of heating food for 12 crewmembers. The oven will be sized for 1.27 pounds food per man-day. The validity of this number is qualified in a detailed discussion found in the Back-Up Information Sheets for Concept 3.2.1 under Preliminary Assumptions.

Using a frozen food density of 50 lb/ft^3, the size of the food packages for 12 crewmembers can be described. For this analysis, four standard packages will be used; each package measures 2.0 * 7.7 * 8.55 inches. The arrangement of the food packages within the food cavity envelope is illustrated below.



PLAN VIEW



FRONTAL VIEW

The power required to warm the frozen food for 12 men was calculated previously in the Back-Up Information Sheets for Concept 3.2.2; the power amounted to 6862 Btu/hr or approximately 2000 watts input to the food.

For the expression describing the electrical power input necessary to deliver this 2000 watts, an overall operating efficiency for the radiant oven concept must be determined. To ascertain this efficiency using analytical techniques would involve a digital computer program to solve a complex transient radiation analysis; that would involve multiple view factors, radiative couplings, and fixing the geometry associated with individual oven configurations. However, information supplied by the referenced source implies that the efficiency of commercial radiant ovens is slightly superior to the microwave warming principle, but not equal to the hot air forced-convection concept.

This would place the efficiency between 50% and 62%; 60% was the chosen efficiency for the radiant oven. Thus,

$$\text{Power} = \frac{2000}{\eta} = \frac{2000}{.60}$$

$$\underline{\underline{\text{Power} = 3334 \text{ watts}}}$$

WEIGHT AND VOLUME CALCULATIONS

The construction of the oven is stainless steel to minimize cleaning operations. An inch of thermal insulation surrounds the food warming chamber; two inches of insulation is used above the infrared element. Controls and indicators are sufficiently isolated from the heat of the heating chamber. Weight calculations indicate the following values:

Weight of fiberglass = 3.85 lbs

Weight of stainless sheets = 28.1 lbs

Weight of heating element, controls = 9.0 lbs

The total installed weight of radiant oven = 40.95 lbs.

The expression for the installed volume is:

$$Vol = 27 * 18.5 * 7$$

$$Vol = \underline{\underline{2.02\ ft^3}}$$

HEAT REJECTED INTO THE CABIN ATMOSPHERE

The energy that enters the cabin atmosphere during the preparation (and eating) cycle comes from stray radiation in the heating chamber. Approximately 40% of the electrical power supplied to the oven leaves in the form of losses. Thus, 40% of the energy supplied is:

$$q_{oven\ loss} = .40\ (3334)$$

$$q_{oven\ loss} = \underline{\underline{1334\ watts}}$$

If the food cools from 160°F to approximately 100°F in 20 minutes before completion of eating, the expression for the heat rejected to cabin atmosphere is:

$$q_{food\ cool\text{-}off} = m\ Cp\ \frac{\Delta T}{\Delta \theta}$$

$$m = 12\ men * 1.27\ \frac{lbs\ food}{man}$$

$$Cp \approx .82\ Btu/lb\ °F$$

$$\Delta T = 160 - 100°F$$

$$\Delta \theta = 20\ minutes$$

$$q_{food\ cool\text{-}off} = \underline{\underline{660\ watts}}$$

Total heat rejected during warming/eating cycle:

$$Q_{rejected} = 1334 + 660 = \underline{\underline{1994\ watts}}$$

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 3.2.6 Title: Self-Heating Food Packages

Assumptions:

In Concept Back-Up Information Sheets for Concept 3.2.1, the Hot Air Convection Heating Oven, see preliminary assumptions for the generalized approach to sizing food warming concepts.

Formulae:

Significant Factors:

General Information:

References:

Anthony Scott, "Metal Foils That Heat and Cure", Engineering, pp. 421-422, October 17, 1969.

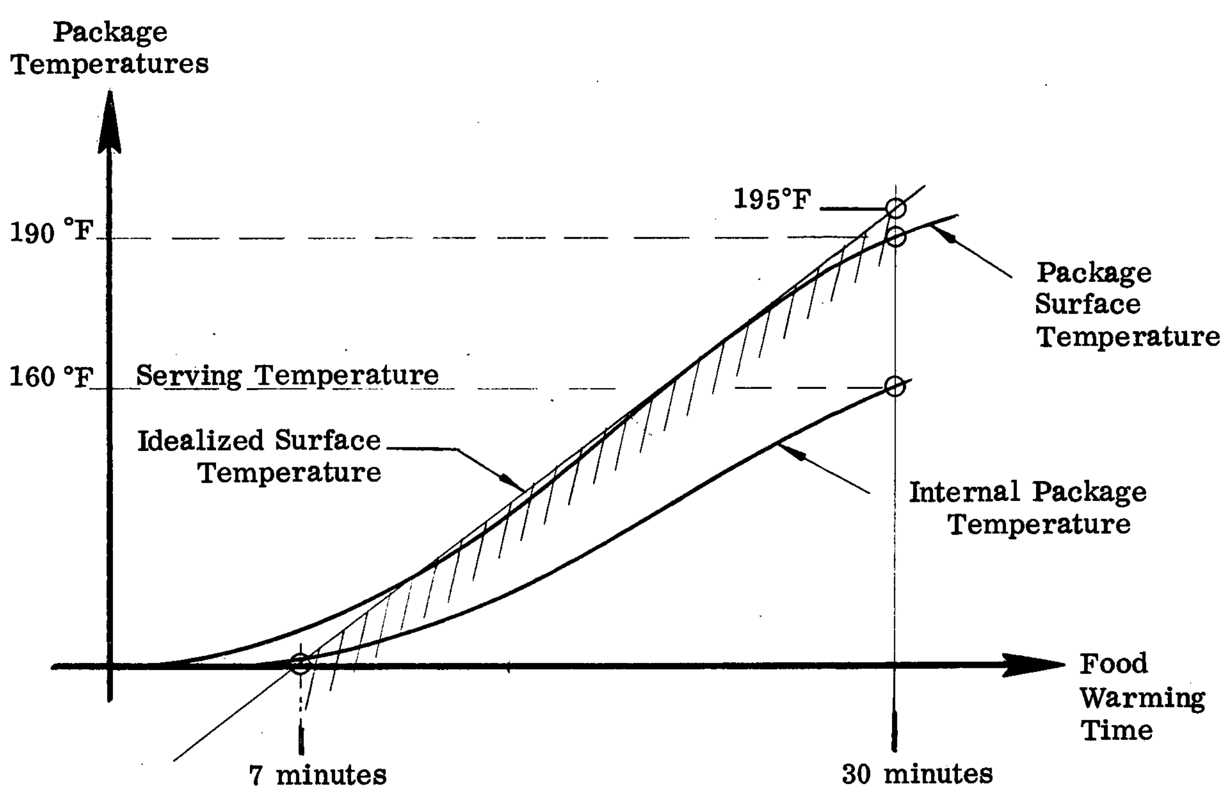
The self-heating package concept relies on the electrical resistivity of aluminum foil to introduce heat into the food. The foil is mechanically slit in a zig-zag pattern to give broad conducting arms with narrow spaces between. The resulting pattern is a series of electrical conduction paths connected to a common buss or terminal. The foil is most usually integrated directly into the food packaging concept, either into the laminates of the polyethylene bag or bonded to the surface of the paperboard package.

The terminals for the electrical circuits are concealed within a convenient peel-up flap located near the edge of the food package concept. To activate the self-heating package, the peel-up flap is extended and inserted beneath a clipboard-like clamp connect to the electrical power supply. The power is controlled by a suitable timing device.

Foils as heating elements have the great advantage (over wire conductors) of giving a very even heat. This is because the area of the thin flat foil must always be greater than that of a wire of equivalent current carrying capacity.

The design analysis of the self-heating food packages is primarily concerned with determining the power required to raise the food temperature to serving levels as well as determining the thermal losses that exist during the warming process.

It is assumed that the internal portion of the food will be heated by conduction from the surface inward to 160°F in 30 minutes. The losses leaving the surface of the food package are primarily radiant. A typical distribution of transient temperatures for the self-heating package is illustrated below.



Transient Temperature Distribution Associated With Warming the Self-Heating Food Package

Note that as the internal package temperature reaches the 160°F serving level, the surface of the package where the heating foil is located will typically be 30°F higher. To simplify the calculations, an idealized linear distribution will be used to approximate the transient temperature response at the surface. Thus, the radiation losses emanating from the surfaces will be based on an idealized temperature that commences to rise 7 minutes after the food warming current is initiated and increases to a peak of 195°F. The expression for the surface losses in Btu/hr is...

$$Q_{loss} = (A * \epsilon)_{surface} (\sigma T_s^4 - \sigma T_o^4)$$

where

A = square feet of package surface area

ϵ = .50, surface emissivity

T_s = 195°F, surface temperature

T_o = ambient wall temperature

The power required to warm the food from -10°F to 160°F is based on the daily food consumption rate of 1.27 pounds food per man. The validity of this number is qualified in a detailed discussion found in the Back-Up Information Sheets for Concept 3.2.1 under Preliminary Assumptions. The power required to warm supplies for 6 men will be presented in three steps below, assuming 70% of wet food mass is water.

-10°F to 32°F

$$Q_1 = \frac{m}{\Delta\theta}\left[70\%\ Cp_{ice} + 30\%\ Cp_{food}\right]\Delta T$$

$$Q_1 = \frac{6\ (1.27)}{0.5}\left[.70 * .501 + .30 * .40\right] 42$$

$$Q_1 = \underline{\underline{301\ \text{Btu/hr}}}$$

32° to 32°F Δphase

$$Q_2 = m\ \Delta H\ (70\%)\ \frac{1}{\Delta\theta}$$

$$Q_2 = 6\ (.127)\ 144\ (.70)\ \frac{1}{0.5}$$

$$Q_2 = \underline{\underline{1535\ \text{Btu/hr}}}$$

32°F to 160°F

$$Q_3 = \frac{m}{\Delta\theta}\left[70\%\ Cp_{water} + 30\%\ Cp_{food}\right]\Delta T$$

$$Q_3 = \frac{6\ (1.27)}{0.5}\left[.70 * 1.0 + .30 * .40\right] 128$$

$$Q_3 = \underline{\underline{1595\ \text{Btu/hr}}}$$

$Q_{food\ heating} = 301 + 1535 + 1595 = 3431$ Btu/hr

$Q_{food\ heating} \doteq \underline{1000 \text{ watts}}$

Now, determine losses from surface of package...

Using a frozen food density of 50 lb/ft^3, the size of the food package for 6 crewmembers is idealized as a package 8.55 inches x 7.70 inches x 4.0 inches; this yields a surface area of

$$A = 2 (L * W) + 2 (L * H) + 2 (H * W)$$

$$A = 2 (8.55 * 4.0) + 2 (8.55 * 7.70) + 2 (7.70 * 4.0)$$

$$A = \underline{1.814 \text{ ft}^2}$$

now,

$$Q_{loss} = (A * \epsilon)_{surface} (\sigma T_s^4 - \sigma T_o^4)$$

$$Q_{loss} = (1.814 * .50) (315 - 157)$$

$$Q_{loss} = \underline{143.2 \text{ Btu/hr}} \text{ (maximum value)}$$

But since the losses act only during the 23-minute interval from 7 minutes to 30 minutes after the electrical current is initiated, the lost energy amounts to

$$Q_{loss} = (143.2 \text{ Btu/hr}) * (23/60 \text{ hour}) * .5$$

$$Q_{loss} = \underline{27.5 \text{ Btu}}$$

Thus, the total energy supplied during the 30-minute warming period is...

$$\text{Energy} = Q_{food\ heating} * 1/2 \text{ hour} + Q_{loss}$$

$$\text{Energy} = (3431) * 0.5 + (27.5)$$

$$\text{Energy} = \underline{1743.5 \text{ Btu}}$$

$$\text{Energy} = \underline{511.1 \text{ watt-hours}}$$

Peak power requirements occur at the end of the heating cycle when losses are maximum. The peak power required for the 6-man self-heating food package concept is...

$$\text{Power (max)} = Q_{\text{food heating}} + Q_{\text{loss (max)}}$$

$$\text{Power (max)} = 3431 \text{ Btu/hr} + 143.2 \text{ Btu/hr}$$

$$\text{Power (max)} = \underline{\underline{3574 \text{ Btu/hr}}}$$

Weight and volume estimates for the self-heating package concept are based on a moderately small housing for the timing devices, switches and indicator lights, and clamp-like electrical terminals.

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 3.2.13 Title: Combination Microwave/Resistance Heating Oven

Assumptions:

The combination microwave and resistance oven concept is simply a microwave warming oven retrofitted with a suitable infrared element above the food. The infrared element introduces to the microwave concept the capability to make meals appear more acceptable by browning the upper surfaces of many food items.

The infrared capability will require additional controls and switching, but this results in a minuscle increase in the installed weight. However, one inch of fiberglass will now be required to insulate the microwave cavity.

Formulae:

Significant Factors:

Power requirements for the combination oven will depend on the individual's choice of either microwave or infrared warming.

The 60% efficiency for the infrared concept is only slightly superior to the 50% microwave technique, resulting in a lower instantaneous power drain.

General Information:

See Back-Up Information Sheets, Concept 3.2.2 for detailed analysis of the Microwave Heating Concept without the resistance heating capability.

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 3.2.14 Title: Combination Hot Air Convection/Resistance Heating Oven

Assumptions:

The Combination Hot-Air Convective/Resistance Oven concept is simply a hot-air convection warming oven retrofitted with a suitable infrared element above the food. The infrared element introduces to the hot-air convection concept the capability to make meals appear more acceptable by quick-browning the upper surfaces of many food items.

The infrared capability will require additional controls and switching, but this results in a minuscle increase in the installed weight.

Formulae:

Significant Factors:

Power requirements for the combination oven will depend on the individual's choice of either hot air convection or infrared warming.

However, because the electrical efficiencies of the hot-air and infrared techniques are practically identical, almost no increase in power results when the warming techniques are employed consecutively.

General Information:

See Back-Up Information Sheets - Concept 3.2.1 for detailed analysis of the Hot Air Convection Heating Concept without the resistance (browning) capability.

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 3.2.15 Title: Electrically Heated Food Tray

Assumptions:

Food warming time to be 30 minutes.

Formulae:

$$\text{Max Power} \; \alpha \; \frac{\text{(Food Mass) (Food Cp) (Temperature Change)}}{\text{(Time To Warm Food)}}$$

Significant Factors:

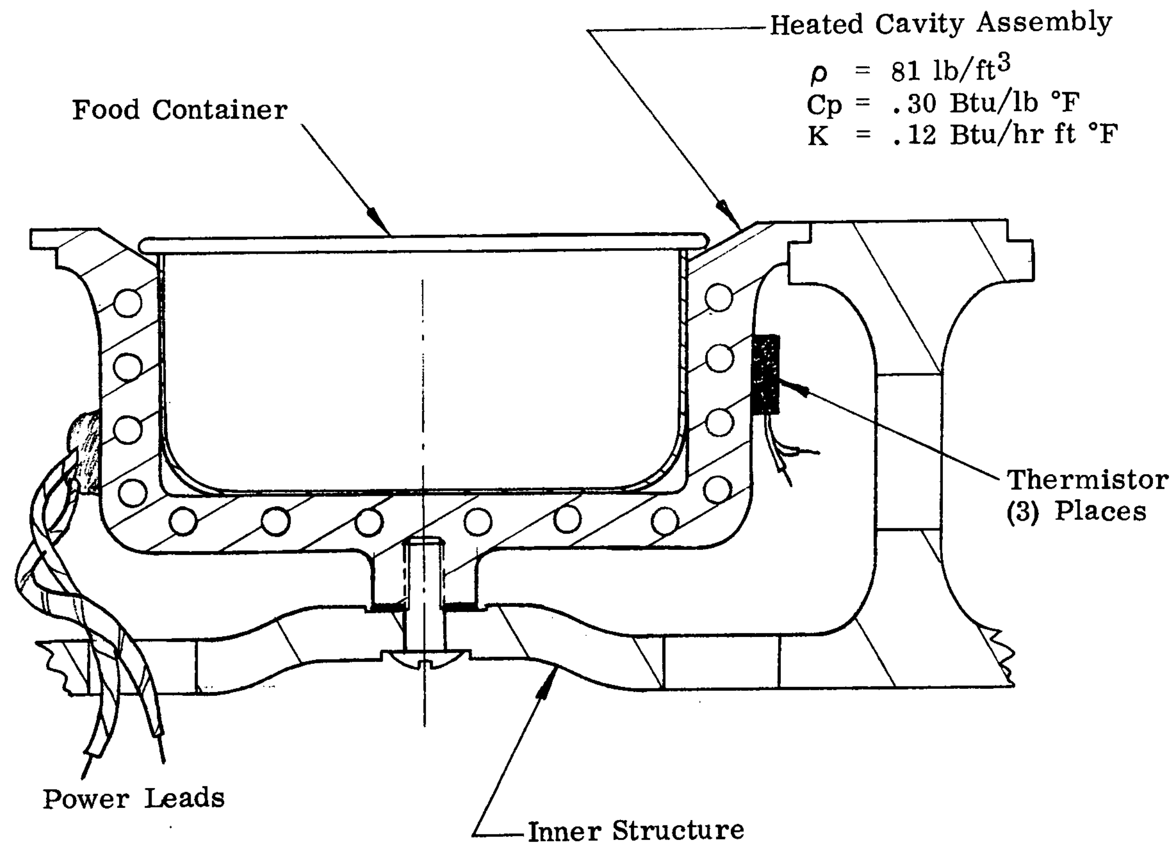
The reference states that one hour is given to the thawing cycle as food is heated from frozen temperature levels; in addition, another one hour period is given to continued heating of food to 150°F serving temperatures. See in formulae above that maximum electrical power is inversely proportional to warming time.

General Information:

References:

"Preliminary Skylab Food Systems Baseline Design," NASA/Manned Spacecraft Center, Houston, Texas, September 8, 1970.

The analysis of the Electrically Heated Food Trays is concerned with the food, the food cavities, and the heat required to raise the temperature of the cavity region. Assume that the size of the cavities accepts two food packages: 4 inches diameter by 1-3/8 deep, and 2.75 inches diameter by 1-3/8 deep. A cross-section of one typical cavity region is shown below.



THERMAL ANALYSIS OF CAVITY FOR LARGER FOOD CONTAINER

$$\text{mass of cavity walls} = \left[\pi D h + \frac{\pi D^2}{4}\right] \rho * t$$

$$= \left[\pi (4.0)(1.75) + \frac{\pi}{4}(4.0)^2\right](.047)(.30)$$

$$= .486 \text{ lbs}$$

Energy required to warm walls from 70°F to 200°F

$$Q = m\ Cp\ \Delta T$$
$$Q = (.486)\ (.30)\ (130)$$
$$Q = 190\ \text{Btu}$$

Mass of Aluminum Can $= \left[\pi D h + \frac{\pi}{2} D^2 \right] \rho * t$

$$= \left[\pi (4.0)(1.375) + \frac{\pi}{2} (4.0)^2 \right] .10\ (.030)$$

$$= .127\ \text{lbs}$$

Energy required to warm aluminum can from -10°F to 180°F

$$Q = m\ Cp\ \Delta T$$
$$Q = (.127)\ (.21)\ (190)$$
$$Q = 5.06\ \text{Btu}$$

Mass of food in 4-inch can

$$\text{Volume of Can} = \frac{\pi}{4} D^2 h = \frac{\pi}{4} (4.0)^2 (1.375) = 17.30$$

$$\text{Food Mass} = (17.30)\ (50\ \frac{\text{lbs food}}{\text{ft}^3})\ (\frac{1}{1728}) = .50\ \text{lbs}$$

Energy required to warm food from -10°F to 160°F

$$Q = Q_{(-10\text{ to }32)} + Q_{\Delta \text{phase}} + Q_{(32\text{ to }160)}$$

$$Q = .50 \left[70\% * .501 + 30\% * .4 \right] 42 + .50\ (70\% * 144) +$$
$$.50 \left[70\% * 1.0 + 30\% * .4 \right] 128$$

$$Q = 9.90 + 50.4 + 52.5 = 112.8\ \text{Btu}$$

Total Transient Energy Required

$$Q_{total} = Q_{walls} + Q_{can} + Q_{food}$$

$$Q_{total} = 190 + 5.06 + 112.8$$

$$Q_{total} = 307.87\ \text{Btu}$$

Assume a steady radiation loss from surface of can

$$Q_{loss} = A\,\epsilon \left[\sigma\, T_c^{\,4} - \sigma\, T_o^{\,4} \right]$$

$$Q_{loss} = (.087)\ (0.5) \left[207.7 - 140.41 \right]$$

$$Q_{loss} = 2.92 \text{ Btu/hr}$$

where $T_c \approx 130°F$
$T_o \approx 75°F$
$\epsilon \approx .50$

Heat required to warm 4-inch food can and cavity in 30 minutes

$$Q_{heater} = Q_{total} + Q_{loss}$$

$$Q_{heater} = \frac{307.87}{.50} + 2.92$$

$$\boxed{Q_{heater} = 608 \text{ Btu/hr}}$$ for each 4-inch cavity

Repeating the analysis for the 2.75-inch food can and cavity, find

$$\boxed{Q'_{heater} = 352 \text{ Btu/hr}}$$ for each 2.75-inch cavity

Determine Max Power required by tray concept, assuming the lunch meal for the 20/80 C diet (1.591 lbs food)

Closest to this food compliment would be three 4-inch cans or two 4-inch cans plus two 2.75-inch cans for a combined food mass of 1.50 pounds.

$$Q_{(4\text{-inch cans})} = 3\ (608 \text{ Btu/hr}) = 534 \text{ watts}$$

$$Q_{(2\,+\,2 \text{ cans})} = 2\ (608) + 2\ (352) = 562 \text{ watts}$$

Thus, maximum theoretical power is $\boxed{562 \text{ watts (per tray)}}$

Weight of Concept

Tray Weight	=	3.98
Electrical Hardware	=	0.52
Total Weight Per Man	=	4.50 pounds

Volume of Concept

Tray Volume	=	L * W * t
	=	16 * 13 * 4.50 in^3
	=	0.541
Electrical Hardware Volume	=	0.059
Total Volume Per Man	=	0.60 ft^3

SUMMARY

Electrically Heated Food Tray

	6 Men	12 Men	25 Men
Peak Power	3380 watts	6750 watts	14,000 watts
Installed Weight	27 lbs	54 lbs	112.5 lbs
Installed Volume	3.60 ft^3	7.2 ft^3	15.0 ft^3
Energy	4050 $\frac{\text{watt-hours}}{\text{day}}$	8100 $\frac{\text{watt-hours}}{\text{day}}$	16,800 $\frac{\text{watt-hours}}{\text{day}}$

FUNCTIONAL SUBSYSTEM AREA 4.0

PROVIDE FOR SERVING OF FOOD

Detail data for this functional subsystem area are presented in Final Report, Volume I, Section III, paragraph 4.0 and in Data Book, Book I, Section II, Functional Subsystem Area 4.0.

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.4.1 Title: Tray With Recesses

Assumptions:

1. The tray will be cleaned after each use and reused at the next meal service.
2. There will be one tray for each crewman.
3. The tray will be mold formed of polyimide S. P. -I.
4. Overall dimensions: 14 x 14 x 1.5 (H) (inches)
5. Useful life of tray is 10 years.

Formulae:

Thickness = .050 inch

Density S. P. -I Polyimide = .051 lb/in^3

Overall Mass Volume = 16.67 in^3 (includes partitions)

$$\text{Mass Volume x Density} = \frac{16.67 \text{ in}^3}{\text{Tray}} \times \frac{.051 \text{ lb}}{\text{in}^3} = 0.85 \text{ lb/tray}$$

Significant Factors:

General Information:

References:

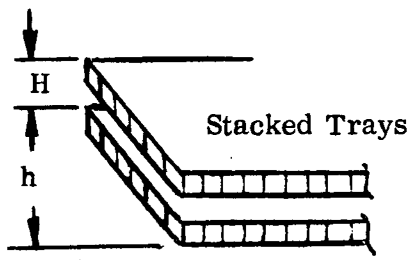
Stacked height of n trays = S

$$S = (n - 1)(H) + h$$

where: n = number of trays

H = distance from top of one tray to top of tray stacked (see drawing below)

h = overall height of individual tray (see drawing below)



Volume of stack - V_s

$$V_s = L \times W \times S$$

where: L = overall length

W = overall width

Installed volume add 1.0 inch to each dimension

$$V_1 = (L + 1'')(W + 1'')(S + 1'')$$

CALCULATION OF INSTALLED VOLUME OF TRAY

$V_{installed} = (L + 1'')\ (W + 1'')\ (S + 1'')$

where L = overall length
W = overall width
S = stack height

6-Man Supply

S = 3.06 in. $V_{installed}$ = 15 x 15 x 4.0 = 900 in^3 = .521 ft^3

12-Man Supply

S = 4.48 in. $V_{installed}$ = 15 x 15 x 5.5 = 1,237 in^3 = .715 ft^3

25-Man Supply

S = 8.99 in. $V_{installed}$ = 15 x 15 x 10 = 2,250 in^3 = 1.30 ft^3

Packaged weight for resupply is assumed to be .1 lb package per pound of tray or 10%.

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 500	$ 500	$ 500
Tooling	750	750	750
Fabrication	130	260	390
Procurement	400	400	400
TOTAL:	$ 1,780	$ 1,910	$ 2,040

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.4.3 Title: Tray With Spiked or Ribbed Surfaces

Assumptions:

1. The tray will be cleaned after each use and reused at the next meal service.
2. There will be one tray for each crewman.
3. The tray will be mold formed of polymide S. P. -I.
4. Overall dimensions: 14 x 14 x 1.5 inches
5. Useful life of tray is 10 years.

Formulae:

Significant Factors:

1. Material thickness = .050 inch
2. Density S. P. -I Polyymide = 0.051 lb/in^3
3. Overall mass volume = 16.67 in^3 (includes partitions)

Mass Volume x Density $\frac{16.67\ in^3}{Tray} \times \frac{.051\ lb}{in^3} = 0.85$ lb/tray

General Information:

Installed weights and volumes are identical to those of Concept 5.4.1 (Tray With Recesses).

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 625	$ 625	$ 625
Tooling	900	900	900
Fabrication	130	260	390
Procurement & Quality Control	400	400	400
TOTAL:	$ 2,055	$ 2,185	$ 2,315

3

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.4.4 Title: Cohesive Menu Components

Assumptions:

The providing of food was not considered as part of this study; however, preliminary estimates were made to establish generalized initial and resupply order of magnitude costs.

Formulae:

Significant Factors:

General Information:

The costs are applicable only to the cohesive menu components of a total food mix.

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

Engineering	$ 250,000	$ 250,000	$ 250,000
Tooling	60,000	60,000	60,000
Procurement	100,000	100,000	100,000
SUB-TOTAL:	$ 410,000	$ 410,000	$ 410,000
Process 14-Day Resupply	13,000	26,000	39,000
Process 90-Day Resupply	84,500	169,000	221,000
TOTAL INITIAL COSTS			
+14-Day Supply	$ 423,000	$ 436,000	$ 449,000
or			
+90-Day Supply	$ 494,000	$ 579,000	$ 631,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.4.5 Title: Pre-Cut Bite-Sized Menu Components

Assumptions:

The providing of food was not considered as part of this study; however, preliminary estimates were made to establish generalized initial and resupply order of magnitude costs.

Formulae:

Significant Factors:

General Information:

The costs are applicable only to the pre-cut bite-sized menu components of a total food mix.

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 75,000	$ 75,000	$ 75,000
Tooling	30,000	30,000	30,000
Procurement	100,000	100,000	100,000
SUB-TOTAL:	$ 205,000	$ 205,000	$ 205,000
Process 14-Day Resupply	13,000	26,000	39,000
Process 90-Day Resupply	84,500	169,000	221,000
TOTAL INITIAL COSTS			
+14-Day Supply	$ 218,000	$ 231,000	$ 244,000
or			
+90-Day Supply	$ 289,500	$ 374,000	$ 426,000

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 5.4.6 Title: Package Containment of Menu Items

Assumptions:

The providing of food was not considered as part of this study; however, preliminary estimates were made to establish generalized initial and resupply order of magnitude costs.

Formulae:

Significant Factors:

General Information:

The costs are applicable only to those individually packaged menu items comprising a total food mix.

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 50,000	$ 50,000	$ 50,000
Tooling	15,000	15,000	15,000
Procurement	100,000	100,000	100,000
SUB-TOTAL:	$ 165,000	$ 165,000	$ 165,000
Process 14-Day Resupply	13,000	26,000	39,000
Process 90-Day Resupply	84,500	169,000	253,000
TOTAL INITIAL COSTS			
+14-Day Supply	$ 178,000	$ 191,000	$ 204,000
or			
+90-Day Supply	$ 249,000	$ 324,000	$ 418,000

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 5.4.7 Title: Meal Tray With Cover

Assumptions:

1. The tray will be disassembled after each use, washed, reassembled, and reused at the next meal service.
2. There will be one tray for each crewman.
3. Useful life for each tray is 10 years.
4. Overall dimensions, cylindrical 9"D x 3"H includes cover.
5. Material, formed S. P. -I Polyimide throughout with exception mylar flap over 1/4 cutout sector of cover.

Formulae:

Significant Factors:

Material Thickness

a) Tray and partitions, .080"
b) Cover, .050"
c) Flap, .015"

General Information:

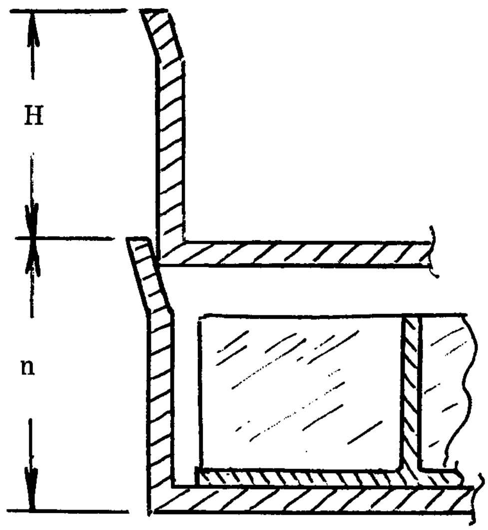
References:

Drawing D5.4.7, Element Concept Data Sheets 5.4.7.1 through 5.4.7.3, Data Book - Book I.

stacked height of n trays = S

$$S = (n - 1)(H) + h$$

where
n = number of trays
H = height of one stack
h = height of the nth tray



Insert Partition

volume of stack V_s

$$V_s = \left(\frac{\pi D^2}{4} \right) S$$

Installed volume, add 1.0" to each dimension

$$V_I = \frac{\pi (D + 1)^2}{4} (S + 1)$$

CALCULATION OF INSTALLED VOLUME OF TRAY

From V_I (on previous page)

$$V_I = \frac{\pi (D+1)^2}{4} (S+1) = \frac{\pi}{4} (D^2 + 2D + 1)(S+1)$$

Constants
$H = 2.75$ in
$h = 3.0$ in
$D = 9.0$ in

<u>6-Man Crew</u>

$S = 5 (2.75) + 3 = 16.75$ in

$$V_I = \frac{\pi}{4} (81 + 18 + 1) (17.75) = (25 \pi) (17.75) = 1{,}393 \text{ in}^3 = .806 \text{ ft}^3$$

<u>12-Man Crew</u>

$S = 11 (2.75) + 3 = 33.25$ in

$$V_I = \frac{\pi}{4} (81 + 18 + 1) (34.25) = (25 \pi) (34.25) = 2{,}689 \text{ in}^3 = 1.556 \text{ ft}^3$$

<u>25-Man Crew</u>

$S = 24 (2.75) + 3 = 69.00$ in

$$V_I = \frac{\pi}{4} (81 + 18 + 1) (70.00) = (25 \pi) (70.00) = 5{,}495 \text{ in}^3 = 3.180 \text{ ft}^3$$

Packaged weight approximately .1 lb pkg per lb of trays.

CALCULATION OF WEIGHT AND VOLUME

	Tray	Partitions	Cover	Flap	Total
Material (lb/in^3)	.051	.051	.051	.051	
Mass Volume (in^3)	11.52	3.84	2.39	.238	17.75
Weight (lb)	0.587	0.196	0.122	0.012	.917

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 10,000	$ 10,000	$ 10,000
Tooling	3,600	3,600	3,600
Procurement	1,600	1,600	1,600
Fabrication	130	260	390
TOTAL:	$ 15,330	$ 15,460	$ 15,590

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 5.4.11 Title: Edible Membranous Coating on Menu Items

Assumptions:

The providing of food was not considered as part of this study; however, preliminary estimates were made to establish generalized initial and resupply order of magnitude costs.

Formulae:

Significant Factors:

General Information:

The costs are applicable only to those menu items compatible with an edible membranous coating.

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 50,000	$ 50,000	$ 50,000
Tooling	0	0	0
Procurement	40,000	40,000	40,000
SUB-TOTAL:	$ 90,000	$ 90,000	$ 90,000
Process 14-Day Resupply	1,300	2,600	3,900
Process 90-Day Resupply	8,450	16,900	22,100
TOTAL INITIAL COSTS			
+14-Day Supply	$ 91,300	$ 92,600	$ 93,900
or			
+90-Day Supply	$ 98,450	$ 105,900	$ 112,100

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 5.5.2A   Title: Closed Liquid Container (Positive Displacement Drinking Device)

Assumptions:

1. The cup will be disassembled (flexible liner and top removed) and cleaned after each meal service.
2. There will be one cup for each crewman.
3. Liner is reusable for the life of the cup (10 years).
4. Materials: (a) collapsible shells, rigid urethane, .051 lb/in^3, (b) drinking and filling valve, itypaton rubber, .040 lb/in^3, (c) flexible liner, Fluoro Elastomer, .051 lb/in^3.

Formulae:

Significant Factors:

Material Thickness:
- a) Shells, .031"
- b) Liner, .010"
- c) Valve, .025"

General Information:

References:

Drawing D5.5.2A, Element Concept Data Sheets 5.5.2.1 through 5.5.2.3, Data Book - Book I.

STACKED HEIGHT OF n CUPS S

$$S = n(h)$$

where h = height of one device in the collapsed configuration

VOLUME OF STACK V_s

$$V_s = \left(\frac{\pi D^2}{4} \right) S$$

where D = the overall outside diameter

INSTALLED VOLUME V_I add 1.0" to each dimension for packaging

$$V_I = \frac{\pi (D + 1)^2}{4} (S + 1) = \frac{\pi}{4} (D^2 + 2D + 1) (S + 1)$$

constants: D = 3.0 in
h = 2.25 in

Crew Size	S	V_I (in^3)	V_I (ft^3)
6	13.5 in	182	.105
12	27.0 in	339	.196
25	56.2 in	705	.408

Packaged weight for resupply is estimated to be 0.1 lb pkg/lb material.

WEIGHT AND VOLUME OF A CLOSED LIQUID CONTAINER

	Liner	Shells	Top	Valves	Total
Material (lb/in^3)	.051	.051	.051	.040	
Mass Volume (in^3)	.354	3.352	.218	.193	4.117 in^3
Weight (lb)	.018	.171	.011	.007	.207 lb

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 10,000	$ 10,000	$ 10,000
Tooling	6,000	6,000	6,000
Fabrication	1,300	2,600	3,900
Procurement	80,000	80,000	80,000
TOTAL:	$ 97,300	$ 98,600	$ 99,900

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 5.5.2C Title: Closed Liquid Container (Negative Pressure Operated Drinking Device)

Assumptions:

1. The cup will be disassembled (flexible liner and top removed) and cleaned as required.
2. There will be one cup for each crewman.
3. Liner is reusable for the life of the cup (10 years).
4. Materials: (a) container, top, and mouthpiece, rigid polyurethane, .051 lb/in^3, and (b) bladder, fluoroelastomer, .051 lb/in^3.

Formulae:

Significant Factors:

General Information:

References:

Element Concept Data Sheets 5.5.2.5 through 5.5.2.8, Data Book - Book I.

Resupply volume is estimated on the basis of the diagonal packing method of cylindrical cups.

$$V = h\,n\,d^2\,(0.866\,m + 0.134)$$

where h = height of container
n = number of containers per tier
d = diameter of one container
m = number of tiers

Crew Size	h (in)	m	n	d^2 (in^2)	V_{in^3}	V_{ft^3}
6	5.6	2	3	6.8	131	.122
12	5.6	6	2	6.8	406	.235
25	5.6	5	5	6.8	850	.491

CALCULATION OF WEIGHT AND VOLUME

	Bladder	Container	Top	Valve	Mouthpiece	Total
Material (lb/in^3)	.051	.051	.051	.051	.040	
Mass Volume (in^3)	.354	.975	.925	.098	.175	2.527
Weight (lb)	.018	.049	.047	.005	.007	.126

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 10,000	$ 10,000	$ 10,000
Tooling	6,000	6,000	6,000
Fabrication	1,300	2,600	3,900
Procurement	40,000	40,000	40,000
TOTAL:	$ 57,300	$ 58,600	$ 59,900

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 5.5.3 Title: In-Package Liquid Restraint

Assumptions:

The providing of food was not considered as part of this study; however, preliminary estimates were made to establish generalized initial and resupply order of magnitude costs.

Formulae:

Significant Factors:

General Information:

The costs are applicable only to the in-package liquid restraint items of a total food mix.

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 5,000	$ 6,000	$ 7,500
Tooling	3,000	3,000	3,000
Procurement	20,000	20,000	20,000
SUB-TOTAL:	$ 28,000	$ 29,000	$ 30,000
Process 14-Day Resupply	1,300	2,600	3,900
Process 90-Day Resupply	8,450	16,900	22,100
TOTAL INITIAL COSTS			
+14-Day Supply	$ 29,300	$ 31,600	$ 34,400
or			
+90-Day Supply	$ 36,450	$ 45,900	$ 52,100

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.6.2 Title: Conventional Eating Utensils (Reusable)

Assumptions:

1. Conventional utensils are knife, fork, and spoon.
2. Size of each utensil is approximately 3/4 standard.
3. The useful life of each utensil is 10 years.
4. There will be no more than one of each type utensil required for each crewman.

Formulae:

Significant Factors:

	Weight (lb)	Volume (ft^3)
Spoon	.050 each	.021/6 units
Knife	.106 each	.004/6 units
Fork	.070 each	.021/6 units

General Information:

References:

Utensils used for this study were Pan Am Airlines "Exclusive" from International Silver Company.

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering	$ 2,500	$ 2,500	$ 2,500
Tooling	1,500	1,500	1,500
Fabrication	130	260	390
Procurement	800	800	800
TOTAL:	$ 4,930	$ 5,060	$ 5,190

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.6.3 Title: Unconventional Eating Utensils (Reusable)

Assumptions:

1. Useful life of each utensil is 10 years.
2. There will be no more than one of each type utensil required for each crewman.
3. Spork is manufactured from 3/4 standard spoon.

Formulae:

Removal of 8% of mass volume from spoon end required to form tines in standard spoon. Therefore, W = .92 x weight of spoon.

Significant Factors:

	Weight (lb)	Volume (ft^3)
Spork	.046 each	.021/6 units
Knife/Fork/Tong	.102 each	.036/6 units

General Information:

Overall dimension of Knife/Fork/Tong: 8.5 in L x 1.0 in W x 1.25 in H

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Engineering			
(Spork)	$ 10,000	$ 10,000	$ 10,000
(Knife/Fork/Tong)	20,000	20,000	20,000
Tooling	9,000	9,000	9,000
Fabrication	195	325	520
Procurement	3,200	3,200	3,200
TOTAL:			
Spork	$ 22,395	$ 22,525	$ 22,720
Knife/Fork/Tong	$ 32,395	$ 32,575	$ 32,720

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.6.4 Title: Disposable Utensils (Conventional)

Assumptions:

1. The useful life of each utensil is one meal.
2. There will be no more than one of each type utensil required for each crewman.

Formulae:

Significant Factors:

General Information:

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows: *

	6-Man	12-Man	25-Man
Engineering	$ 2,000	$ 2,000	$ 2,000
Tooling	9,000	9,000	9,000
Procurement	800	800	800
SUB-TOTAL:	$ 11,800	$ 11,800	$ 11,800
Process 14-Day Resupply	130	260	390
Process 90-Day Resupply	845	1,690	2,535
TOTAL INITIAL COSTS			
+14-Day Resupply	$ 11,930	$ 12,060	$ 12,190
or			
+90-Day Resupply	$ 12,645	$ 13,490	$ 14,335

*Cost for each type utensil (i.e., Knife, Fork, Spoon) is identical.

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.6.5 Title: Disposable Utensils (Unconventional)

Assumptions:

1. The useful life of each utensil is one meal.
2. There will be no more than one of each type utensil required for each crewman.

Formulae:

Significant Factors:

General Information:

Overall dimension of Knife/Fork/Tong: 8.5 in. (L) x 10 in. (W) x 1.25 in. (H)

References:

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

"Spork" Only	6-Man	12-Man	25-Man
Engineering	$ 10,000	$ 10,000	$ 10,000
Tooling	9,000	9,000	9,000
Procurement	3,200	3,200	3,200
SUB-TOTAL:	$ 22,200	$ 22,200	$ 22,200
Process 14-Day Resupply	195	325	520
Process 90-Day Resupply	1,267	2,112	3,380
TOTAL INITIAL COSTS			
+14-Day Supply	$ 22,395	$ 22,525	$ 22,720
or			
+90-Day Supply	$ 23,467	$ 24,312	$ 25,580

Knife/Fork/Tong	6-Man	12-Man	25-Man
Engineering	$ 20,000	$ 20,000	$ 20,000
Tooling	9,000	9,000	9,000
Procurement	3,200	3,200	3,200
SUB-TOTAL:	$ 32,200	$ 32,200	$ 32,200
Process 14-Day Resupply	195	325	520
Process 90-Day Resupply	1,267	2,112	3,380
TOTAL INITIAL COSTS			
+14-Day Supply	$ 32,395	$ 32,525	$ 32,720
or			
+90-Day Supply	$ 33,467	$ 34,312	$ 35,580

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.8.1 **Title:** Magnetized Eating Utensils (Conventional-Reusable)

Assumptions:

1. Size and shape of magnetized conventional eating utensils remains unaltered.
2. The useful life of each utensil is 10 years.
3. There will be no more than one of each type utensil required for each crewman.

Formulae:

Significant Factors:

	Weight (lb)	Volume (ft^3)
Spoon	.055 each	.021/6 units
Knife	.116 each	.004/6 units
Fork	.077 each	.021/6 units

This represents a 10% increase in weight with no accompanying volume increase over non-magnetized utensils.

General Information:

This concept could also be extended to trays and table surfaces.

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 5.9.3 Title: Chair Restraint System

Assumptions:

1. Back strap system consists of one contoured strap 18 in L x 3 in W x .060 in and one attachment device.
2. Lap strap system consists of two contoured straps each 9 in L x 3 in W x .060 in and one attachment device per strap.
3. Strap material, polyimide SP-I (.051 lb/in^3).

Formulae:

Significant Factors:

General Information:

References:

WEIGHT ANALYSIS

	Back Strap	Lap Strap
Straps	1	2
Attachments	1	2
Density Volume	3.24 in^3	3.24 in^3
Strap Weight	.165 lb	.165 lb
Attachment Weight	.162 lb	.324 lb
Total System Weight/Chair	.327 lb	.496 lb

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	6-Man	12-Man	25-Man
Back Strap System			
Engineering	$ 2,000	$ 2,000	$ 2,000
Tooling	3,000	3,000	3,000
Fabrication	260	520	780
Procurement	6,000	6,000	6,000
TOTAL:	$ 11,260	$ 11,520	$ 11,780

	6-Man	12-Man	25-Man
Lap Strap System			
Engineering	$ 5,000	$ 5,000	$ 5,000
Tooling	9,000	9,000	9,000
Fabrication	520	1,040	1,560
Procurement	12,000	12,000	12,000
TOTAL:	$ 26,520	$ 27,040	$ 27,560

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.1.2 Title: Hand-Held Vacuum Cleaner Unit

Assumptions:

Motor sizing criteria was based on unit being developed for Skylab program.

Formulae:

Significant Factors:

General Information:

Interface with space vehicle electrical power system, and general debris processing techniques.

References:

None

DETERMINATION OF RESUPPLY WEIGHTS AND VOLUMES

Collector bag unit weight = .05 lbs; unit volume (folded) 3.0 x 3.0 x .3 inches = 2.7 cu.in. ÷ 1728 = .00156 cu.ft.

Assumed Usage Rates:

(6) and (12) 1 collector bag per day
(25) 2 collector bags per day } plus additional 50% of supply to cover contingencies
(50) 3 collector bags per day

RESUPPLY WEIGHTS

Number Days in Resupply Period		Usage Per Resupply Period		50% Contin- gency		Total Bags Per Resupply		Unit Weight (lbs)		Resupply Weight (lbs)		Number Resupplies in 10 Years		10 Year Resupply Weight (lbs)
(6 and 12)	14	14	+	7	=	21	x	.05	=	1.05	x	260	=	273
	90	90	+	45	=	135	x	.05	=	6.75	x	40	=	270
	180	180	+	90	=	270	x	.05	=	13.50	x	20	=	270
(25)	14	28	+	14	=	42	x	.05	=	2.10	x	260	=	546
	90	180	+	90	=	270	x	.05	=	13.50	x	40	=	540
	180	360	+	180	=	540	x	.05	=	27.00	x	20	=	540
(50)	14	42	+	21	=	63	x	.05	=	3.15	x	260	=	819
	90	270	+	135	=	405	x	.05	=	20.25	x	40	=	810
	180	540	+	270	=	810	x	.05	=	40.50	x	20	=	810

RESUPPLY VOLUMES

Number Days in Resupply Period		Usage Per Resupply Period		50% Contin- gency		Total Bags Per Resupply		Unit Volume (cu.ft.)		Resupply Volume (cu.ft.)		Number Resupplies in 10 Years		10 Year Resupply Volume (cu.ft.)
(6 and 12)	14	14	+	7	=	21	x	.00156	=	.03276	x	260	=	8.518
	90	90	+	45	=	135	x	.00156	=	.21060	x	40	=	8.424
	180	180	+	90	=	270	x	.00156	=	.42120	x	20	=	8.424
(25)	14	28	+	14	=	42	x	.00156	=	.06552	x	260	=	17.035
	90	180	+	90	=	270	x	.00156	=	.42120	x	40	=	16.848
	180	360	+	180	=	540	x	.00156	=	.84240	x	20	=	16.848
(50)	14	42	+	21	=	63	x	.00156	=	.09828	x	260	=	25.553
	90	270	+	135	=	405	x	.00156	=	.63180	x	40	=	25.272
	180	540	+	270	=	810	x	.00156	=	1.26360	x	20	=	25.272

ESTIMATION OF CREW OPERATING TIME

Assume crew time to include preparatory, operational, and post-operative functions associated with this mode of clean-up per meal period:

(6) 6 minutes or .10 hr/meal period x 3 = .30 hrs/day
(12) 9 minutes or .15 hr/meal period x 3 = .45 hrs/day
(25) 12 minutes or .20 hr/meal period x 3 = .60 hrs/day

DETERMINATION OF ELECTRICAL USAGE

Assume motor operates at 80 watts, and that powered operation is one-half of (50%) of the crew operating time:

(6) .30 hrs/day x .5 = .15 hrs/day x 80 W = 12 watt-hrs/day
(12) .45 hrs/day x .5 = .225 hrs/day x 80 W = 18 watt-hrs/day
(25) .60 hrs/day x .5 = .30 hrs/day x 80 W = 24 watt-hrs/day

10 YEAR OPERATING TIME OF EQUIPMENT

Daily operating time is multiplied by 3650 to obtain equipment operating time over a 10-year period:

(6) .30 hrs/day x 3650 = 1095.00 hrs in 10 years
(12) .45 hrs/day x 3650 = 1642.50 hrs in 10 years
(25) .60 hrs/day x 3650 = 2190.00 hrs in 10 years

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	(6)	(12)	(25)
A. Engineering	$ 125,000	$ 125,000	$125,000
B. Tooling	30,000	30,000	30,000
C. Fabrication	15,000	15,000	15,000
D. Qualification	250,000	250,000	250,000
E. Documentation	10,000	10,000	10,000
TOTALS →	$ 430,000	$ 430,000	$430,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.1.3 Title: Guided Transport Vacuum Cleaner Unit

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle electrical power system, structural design, and general debris processing techniques.

References:

None

DETERMINATION OF RESUPPLY WEIGHTS AND VOLUMES

Common size collector bag for (6), (12), and (25); unit weight = .10 lbs; unit volume (folded) 7.0 x 7.0 x .3 inches = 14.7 cu.in. ÷ 1728 = .00793 cu.ft.

Larger collector bag for (50); unit weight = .12 lbs; unit volume (folded) 10.0 x 7.0 x .3 inches = 21.0 cu.in. ÷ 1728 = .01157 cu.ft.

Assumed usage rate is 1 collector bag per day plus additional 50% of supply to cover contingencies.

RESUPPLY WEIGHTS

	Number Days in Resupply Period	Usage Per Resupply Period		50% Contin-gency		Total Bags Per Resupply		Unit Weight (lbs)		Resupply Weight (lbs)		Number Resupplies in 10 Years		10 Year Resupply Weight (lbs)
(6)	14	14	+	7	=	21	x	.10	=	2.1	x	260	=	546
(12)	90	90	+	45	=	135	x	.10	=	13.5	x	40	-	540
(25)	180	180	+	90	=	270	x	.10	=	27.0	x	20	=	540
	14	14	+	7	=	21	x	.12	=	2.5	x	260	=	650
(50)	90	90	+	45	=	135	x	.12	=	16.2	x	40	=	648
	180	180	+	90	=	270	x	.12	=	32.4	x	20	=	648

RESUPPLY VOLUMES

	Number Days in Resupply Period	Usage Per Resupply Period		50% Contin-gency		Total Bags Per Resupply		Unit Volume (cu.ft.)		Resupply Volume (cu.ft.)		Number Resupplies in 10 Years		10 Year Resupply Volume (cu.ft.)
(6)	14	14	+	7	=	21	x	.00793	=	.16653	x	260	=	43.298
(12)	90	90	+	45	=	135	x	.00793	=	1.07055	x	40	=	42.822
(25)	180	180	+	90	=	270	x	.00793	=	2.14110	x	20	=	42.822
	14	14	+	7	=	21	x	.01157	=	.24297	x	260	=	63.172
(50)	90	90	+	45	=	135	x	.01157	=	1.56195	x	40	=	62.478
	180	180	+	90	=	270	x	.01157	=	3.12390	x	20	=	62.478

ESTIMATION OF CREW OPERATING TIME

Assume crew time to include preparatory, operational, and post-operative functions associated with this mode of clean-up per meal period:

(6) 18 minutes or .30 hr/meal period x 3 = .90 hrs/day
(12) 27 minutes or .45 hr/meal period x 3 = 1.35 hrs/day
(25) 36 minutes or .60 hr/meal period x 3 = 1.80 hrs/day

DETERMINATION OF ELECTRIC POWER USAGE

Assume motor operates at 1500 watts, and that powered operation is one-half of (50%) of the crew operating time:

(6) .90 hrs/day x .5 = .45 hrs/day x 1500 W = 675 watt-hrs/day
(12) 1.35 hrs/day x .5 = .675 hrs/day x 1500 W = 1013 watt-hrs/day
(25) 1.80 hrs/day x .5 = .90 hrs/day x 1500 W = 1350 watt-hrs/day

10-YEAR OPERATING TIME OF EQUIPMENT

Daily operating time is multiplied by 3650 to obtain equipment operating time over a 10-year period:

(6) .90 hrs/day x 3650 = 3285.00 hrs in 10 years
(12) 1.35 hrs/day x 3650 = 4927.50 hrs in 10 years
(25) 1.80 hrs/day x 3650 = 6570.00 hrs in 10 years

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 375,000	$ 375,000	$ 375,000
B.	Tooling	200,000	200,000	200,000
C.	Fabrication	150,000	150,000	150,000
D.	Qualification	500,000	500,000	500,000
E.	Documentation	15,000	15,000	15,000
	TOTALS →	$1,240,000	$1,240,000	$1,240,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.1.7 Title: Hand Cleaning With Impregnated Disposable Wipes

Assumptions:

Section area allocations were based on the North American Rockwell "Phase B" Space statinn studies and mock-up for a 12-man crew.

Formulae:

Significant Factors:

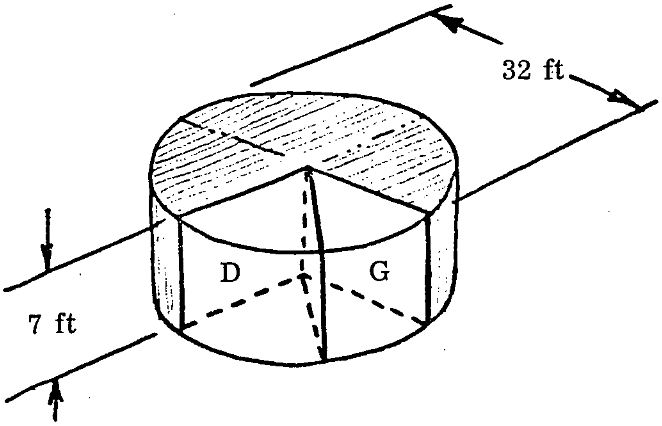
General Information:

Interface with space vehicle environmental control system and general debris processing techniques.

References:

Information predicated upon experimental use of Wash 'n Dri® Towelette manufactured by CANAAN PRODUCTS, Inc. of Canaan, Connecticut (a subsidiary of the COLGATE-PALMOLIVE COMPANY).

ESTIMATION OF SURFACE AREA TO BE CLEANED



Area = 3.1417 x 16^2 = 804.28 sq ft

Circum = 3.1417 x 32 = 100.53 feet

Assume 33 feet diameter vehicle with 6-inch wall thickness; therefore, interior diameter is 32 feet.

Assume 90 degree sector allocation for 6 men Galley/Dining requisites.

Assume 180 degree sector allocation for 12 men.

Assume 270 degree sector allocation for 25 men (50 men same as 25 men; Dining in 2 sessions).

6-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .25 =	175.93 sq.ft.
Sector Surface = 804.28 x .25 = 201.07 sq.ft. x 2 =	402.14 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partition) =	448.00 sq.ft.
Sub Total:	1026.07 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	256.52 sq.ft.
TOTAL:	1282.59 sq.ft.

12-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .50 =	351.86 sq.ft.
Sector Surface = 804.28 x .50 = 402.14 sq.ft. x 2 =	804.28 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partiaion) =	448.00 sq.ft.
Sub Total:	1604.14 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	401.03 sq.ft.
TOTAL:	2005.17 sq.ft.

25-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .75 =	527.79 sq.ft.
Sector Surface = 804.28 x .75 = 603.21 sq.ft. x 2 =	1206.42 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partition)	448.00 sq.ft.
Sub Total:	2182.21 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	545.55 sq.ft.
TOTAL:	2727.76 sq.ft.

FREQUENCY OF CLEANSING/SANITIZING

Assume 25% of total surface to be cleaned on daily basis.

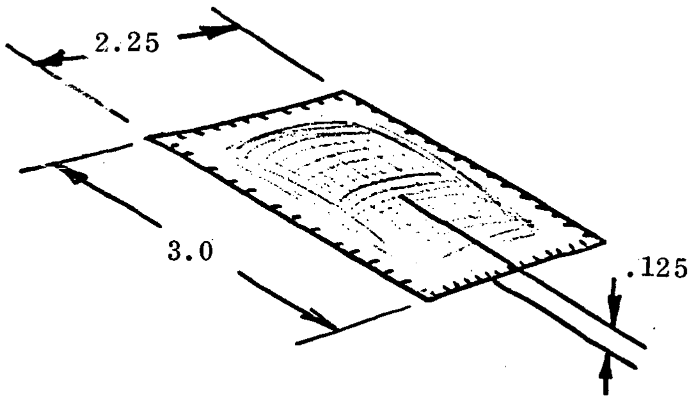
Assume entire surfaces to be cleaned at two-week intervals.

		Surfaces @ 2-Week Intervals				Surfaces Daily Basis
(6)	→	1282.59 sq.ft.	x	.25	=	320.65 sq.ft.
(12)	→	2005.17 sq.ft.	x	.25	=	501.29 sq.ft.
(25) and (50)	→	2727.76 sq.ft.	x	.25	=	681.94 sq.ft.

AVERAGE SURFACE AREA FOR DAILY CLEANSING/SANITIZING

												Average Surface for Daily
(6)	→	1282.59 x .75	=	961.94	÷	14	=	68.71	+	320.65	=	389.36 sq.ft.
(12)	→	2005.17 x .75	=	1503.88	÷	14	=	107.42	+	501.29	=	608.71 sq.ft.
(25) and (50)	→	2727.76 x .75	=	2045.82	÷	14	=	146.13	+	681.94	=	828.07 sq.ft.

Assume that cleansing and sanitizing will be accomplished by use of Wash'n Dri® Towelettes or more suitable substitute of equivalent size.



Individual Packet

Note: Wash'n Dri® Towelettes are readily available commercial products, in individually sealed packets, manufactured by Cannan Products, Inc. of Canaan, Connecticut (a subsidiary of the Colgate-Palmolive Company).

Weight = .013 lb.
Volume 2.25 x 3.0 x .125 inches = .844 cu.in. ÷ 1728 = .0004884 cu.ft.

Assume that one (1) Towelette can clean and sanitize 25 sq.ft. of surface before discarding.

Assume that 25 sq.ft. can be cleaned in 6.25 minutes.

QUANTITY OF TOWELETTES (WIPES) NEEDED

	Average Daily Surface Area						Number Towelettes Needed		Add 25% Contingency		Daily Usage
(6)	389.36 sq.ft.	÷	25	=	15.574	→	16	+	4	=	20
(12)	608.71 sq.ft.	÷	25	=	24.348	→	24	+	6	=	30
(25) and (50)	828.07 sq.ft.	÷	25	=	33.122	→	32	+	8	=	40

RESUPPLY WEIGHTS OF TOWELETTES

	Daily Quantity		Weight Per Towelette (lb)		Daily Weight (lb)		Number Days in Resupply Period		Resupply Weight (lb)		Number of Resupplies in 10 Years		10 Year Resupply Weight (lb)
	20	x	.013	=	.260	x	14	=	3.640	x	260	=	946.40
6	20	x	↕	=	.260	x	90	=	23.400	x	40	=	936.00
	20	x		=	.260	x	180	=	46.800	x	20	=	936.00
	30	x		=	.390	x	14	=	5.460	x	260	=	1419.60
12	30	x		=	.390	x	90	=	35.100	x	40	=	1404.00
	30	x		=	.390	x	180	=	70.200	x	20	=	1404.00
25 and 50	40	x		=	.520	x	14	=	7.280	x	260	=	1892.80
	40	x		=	.520	x	90	=	46.800	x	40	=	1872.00
	40	x	.013	=	.520	x	180	=	93.600	x	20	=	1872.00

RESUPPLY VOLUMES OF TOWELETTES

	Daily Quantity		Volume Per Towelette (cu.ft.)		Daily Volume (cu.ft.)		Number Days in Resupply Period		Resupply Volume (cu.ft.)		Number of Resupplies in 10 Years		10 Year Resupply Volume (cu.ft.)
	20	x	.0004884	=	.009768	x	14	=	.13675	x	260	=	35.555
6	20	x	↕	=	.009768	x	90	=	.87912	x	40	=	35.165
	20	x		=	.009768	x	180	=	1.75824	x	20	=	35.165
	30	x		=	.014652	x	14	=	.20513	x	260	=	53.334
12	30	x		=	.014652	x	90	=	1.31868	x	40	=	52.747
	30	x		=	.014652	x	180	=	2.63736	x	20	=	52.747
25 and 50	40	x		=	.019536	x	14	=	.27350	x	260	=	71.110
	40	x		=	.019536	x	90	=	1.75824	x	40	=	70.330
	40	x	.0004884	=	.019536	x	180	=	3.51648	x	20	=	70.330

ESTIMATION OF CREW OPERATING TIME

Assume that 10 square feet of surface can be cleaned in 2.5 minutes with additional average allowance of 0.5 minute to cover changing position and changing wipes (one per 25 sq ft) as usefulness is expended; therefore, cleaning rate is 3 minutes or .05 hour per 10 sq.ft.:

	Average Daily Surface Area						Clean Rate per 10 sq ft		Crew Time
(6)	389.36 sq ft	÷	10	=	38.94	x	.05 hr	=	1.947 hrs/day
(12)	608.71 sq ft	÷	10	=	60.87	x	.05 hr	=	3.044 hrs/day
(25)	828.07 sq ft	÷	10	=	82.81	x	.05 hr	=	4.141 hrs/day

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.1.8 Title: Hand Cleaning With Impregnated Reusable Wipes

Assumptions:

Sector area allocations were based on the North American Rockwell "Phase B" Space Station studies and mock-up for a 12-man crew.

Formulae:

Significant Factors:

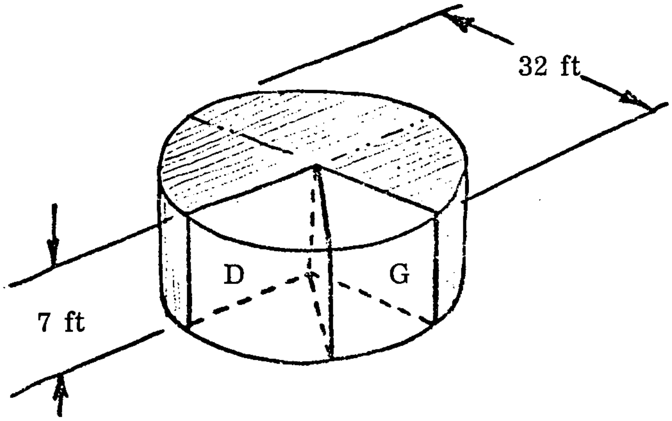
General Information:

Interface with space vehicle environmental control system, and water reclamation system (presuming existence of general laundry facility).

References:

None

ESTIMATION OF SURFACE AREA TO BE CLEANED



Area = 3.1417 x 16^2 = 804.28 sq ft

Circum = 3.1417 x 32 = 100.53 ft

Assume 33 feet diameter vehicle with 6-inch wall thickness; therefore, interior diameter is 32 feet.

Assume 90 degree sector allocation for 6 men Galley/Dining requisites.

Assume 180 degree sector allocation for 12 men.

Assume 270 degree sector allocation for 25 men (50 men same as 25 men; Dining in 2 sessions).

6-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .25 =	175.93 sq.ft.
Sector Surface = 804.28 x .25 = 201.07 sq.ft. x 2 =	402.14 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partition) =	448.00 sq.ft.
Sub Total:	1026.07 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	256.52 sq.ft.
TOTAL:	1282.59 sq.ft.

12-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .50 =	351.86 sq.ft.
Sector Surface = 804.28 x .50 = 402.14 sq.ft. x 2 =	804.28 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partiaion) =	448.00 sq.ft.
Sub Total:	1604.14 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	401.03 sq.ft.
TOTAL:	2005.17 sq.ft.

25-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .75 =	527.79 sq.ft.
Sector Surface = 804.28 x .75 = 603.21 sq.ft. x 2 =	1206.42 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partition)	448.00 sq.ft.
Sub Total:	2182.21 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	545.55 sq.ft.
TOTAL:	2727.76 sq.ft.

FREQUENCY OF CLEANSING/SANITIZING

Assume 25% of total surface to be cleaned on daily basis.

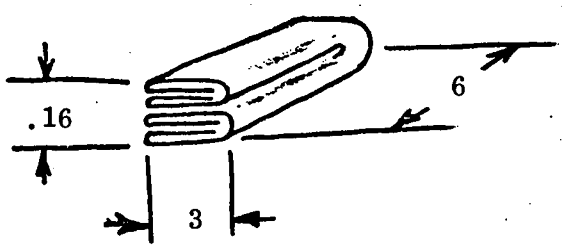
Assume entire surfaces to be cleaned at two-week intervals.

	Surfaces @ 2-Week Intervals				Surfaces Daily Basis
(6) →	1282.59 sq.ft.	x	.25	=	320.65 sq.ft.
(12) →	2005.17 sq.ft.	x	.25	=	501.29 sq.ft.
(25) and (50) →	2727.76 sq.ft.	x	.25	=	681.94 sq.ft.

AVERAGE SURFACE AREA FOR DAILY CLEANSING/SANITIZING

											Average Surface for Daily
(6) →	1282.59 x .75	=	961.94	÷	14	=	68.71	+	320.65	=	389.36 sq.ft.
(12) →	2005.17 x .75	=	1503.88	÷	14	=	107.42	+	501.29	=	608.71 sq.ft.
(25) and (50) →	2727.76 x .75	=	2045.82	÷	14	=	146.13	+	681.94	=	828.07 sq.ft.

Assume use of cotton cloth cleaning wipes approximately 12 x 12 inches unfolded. The wipes would be folded to dimensions of 6 x 3 x .16 inches for storage:



Single wipe weight = .075 lbs
volume 3 x 6 x .16 inches = 2.88 cu.in. ÷ 1728 = .001672 cu.ft.

Assume usage of 1 wipe per approximately 200 sq.ft. of surface area to be cleaned or sanitized, after which it would be laundered prior to return to storage for subsequent reuse.

	Surface to be Cleaned Daily (sq.ft.)	Single Wipe Coverage (sq.ft.)	Number Used on each of 13 Days	Surface to be Cleaned at 2 Week Period (sq.ft.)	Single Wipe Coverage (sq.ft.)	Number Used on the 14th Day
(6)	320.65 ÷	200 =	1.6 → 2	1282.59 ÷	200 =	6.1 → 6
(12)	501.29 ÷	200 =	2.5 → 3	2005.17 ÷	200 =	10.0 → 9
(25) and (50)	681.94 ÷	200 =	3.4 → 4	2727.76 ÷	200 =	13.6 → 12

QUANTITY OF WASHING CLOTHS NEEDED FOR INITIAL SUPPLY.

(6)	14 Cloths	Correlated to Laundering Schedule
(12)	21 Cloths	
(25) and (50)	28 Cloths	

QUANTITY OF CLEANING FLUID NEEDED

Assume premixed evaporative detergent/germicidal solution supplied in a suitable portable dispensing container for periodic wetting of washing cloth.

Assume 1 mil fluid application on surfaces
(.001 in ÷ 12 = .000083 ft)

	Average Daily Surface Area				Fluid Volume Per Day		*		Fluid Weight Per Day
(6)	389.36 sq.ft.	x	.000083	=	.03245 cu.ft.	x	62.4	=	2.025 lbs
(12)	608.71 sq.ft.	x	.000083	=	.05073 cu.ft.	x	62.4	=	3.165 lbs
(25) and (50)	828.07 sq.ft.	x	.000083	=	.06901 cu.ft.	x	62.4	=	4.306 lbs

(*Solution density assumed to be same as water; 62.4 lb/cu ft)

WEIGHTS OF CLEANING FLUID

	Initial Supply (lbs)	Fluid Weight Per Day (lbs)		Number Days in Resupply Period		Resupply Weight (lbs)		Number of Resupplies in 10 Years		10 Year Resupply Weight (lbs)
(6)	0	2.025	x	14	=	28.350	x	260	=	7371.00
	0	2.025	x	90	=	182.250	x	40	=	7290.00
	0	2.025	x	180	=	364.500	x	20	=	7290.00
(12)	0	3.165	x	14	=	44.310	x	260	=	11520.60
	0	3.165	x	90	=	284.850	x	40	=	11394.00
	0	3.165	x	180	=	569.700	x	20	=	11394.00
(25) and (50)	0	4.306	x	14	=	60.284	x	260	=	15673.84
	0	4.306	x	90	=	387.540	x	40	=	15501.60
	0	4.306	x	180	=	775.080	x	20	=	15501.60

VOLUMES OF CLEANING FLUID

	Initial Supply (cu ft)	Fluid Volume Per Day (cu ft)		Number Days in Resupply Period		Resupply Volume (cu ft)		Number of Resupplies in 10 Years		10 Year Resupply Volume (cu ft)
(6)	0	.03245	x	14	=	.45430	x	260	=	118.118
	0	.03245	x	90	=	2.92050	x	40	=	116.820
	0	.03245	x	180	=	5.84100	x	20	=	116.820
(12)	0	.05073	x	14	=	.71022	x	260	=	184.657
	0	.05073	x	90	=	4.56570	x	40	=	182.628
	0	.05073	x	180	=	9.13140	x	20	=	182.628
(25) and (50)	0	.06901	x	14	=	.96614	x	260	=	258.996
	0	.06901	x	90	=	6.21090	x	40	=	248.436
	0	.06901	x	180	=	12.42180	x	20	=	248.436

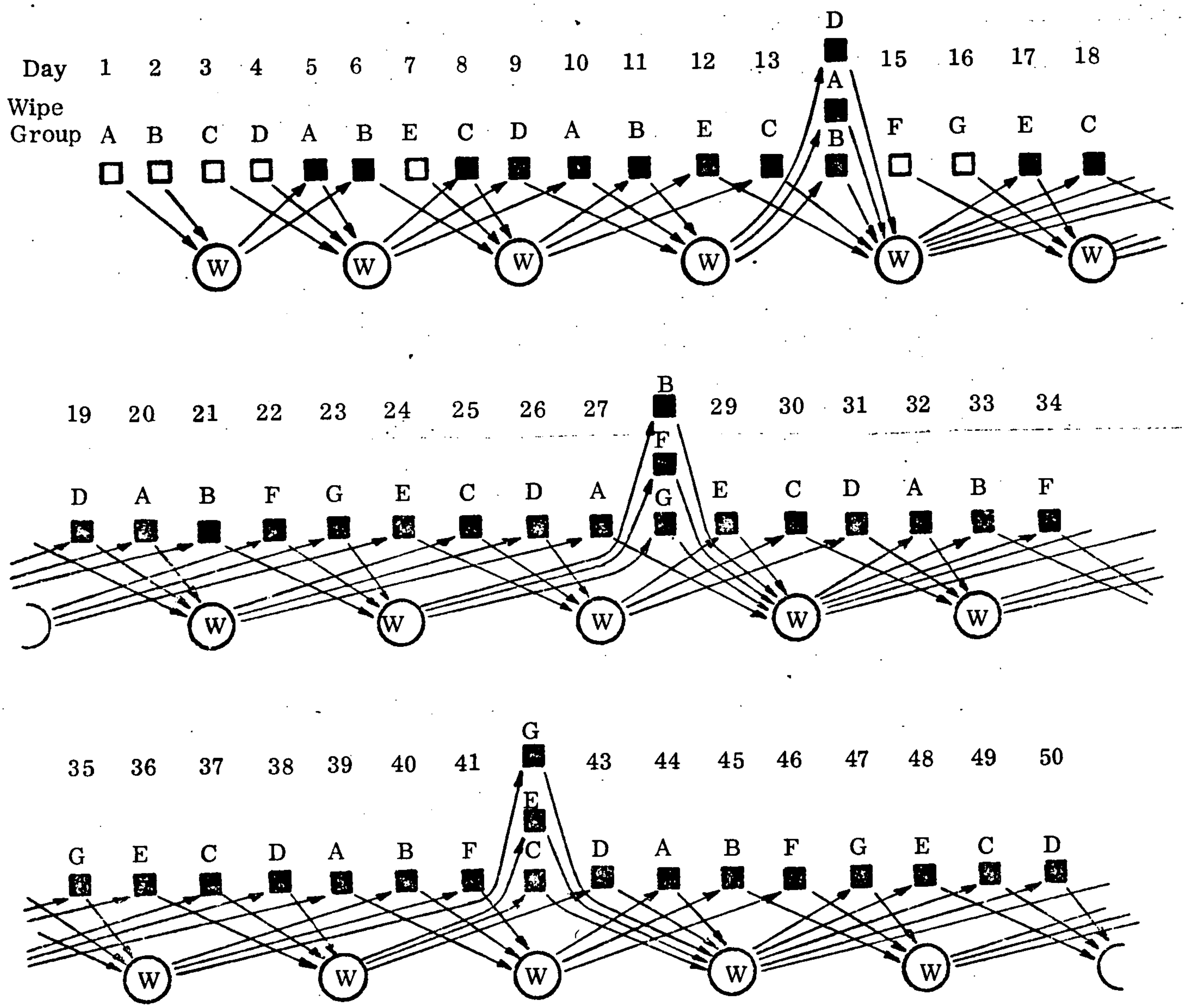
RATIONALE FOR SUPPLIES OF REUSABLE WASHING CLOTHS

Assume existence of laundering facilities on the space vehicle, and that general laundering is accomplished every third day with a two-day lapse for return of articles from laundry.

The following figure exemplifies the assumed schedule of usage and laundering for a group-quantity of wipes, indicating availability of proper quantities for day-to-day clean-up functions. If the group quantity is *2 wipes for A through G inclusive (typical of 6-man crew size), then 4 wipes are taken from initial supply for the first and second days (Group A and B) after which they are sent to laundry. An additional 4 wipes (Group C and D) are taken from initial supply to satisfy the third and fourth days after which they are sent to laundry. In the interim, the 4 wipes of Group A and B have been returned and are used on the fifth and sixth day, then back to laundry. Since all heretofore used wipes are not available, an additional 2 wipes (Group E) are taken from initial supply for the seventh day. The cycle continues with laundered wipe groups, through the fourteenth day when 6 wipes are needed for the more extensive bi-monthly clean-up. Again, all heretofore used wipes are not available and the remaining 4 wipes (Group F and G) are taken from initial supply to satisfy the fifteenth and sixteenth day clean-up requirements. The cycle continues with laundered group quantities until deteriorated and replenished during a subsequent resupply mission.

(*Group quantity of wipes varies with crew size)

RATIONALE FOR SUPPLIES OF REUSABLE WASHING CLOTHS



(□ Initial Supply, ■ Laundered Supply, (W) In Laundry)

Determination of number of times each cloth is washed in 48 days: A/9, B/9, C/8, D/8, E/7, F/6, G/6 → (53 x 7 = 371 ÷ 48 = 7.7); each washing cloth is laundered an average of one time per 7.7 days of mission duration.

Assume that the useful life of these washing cloths, which are subjected to abrasive action, is approximately 45 launderings or approximately 346 days.

Replacement Schedules for Washing Cloths

For 14 day resupply: Replace each 26 missions (364 days), 10 times in 10 years.
For 90 day resupply: Replace each 4 missions (360 days), 10 times in 10 years.
For 180 day resupply: Replace each 2 missions (360 days), 10 times in 10 years.

WEIGHTS OF WASHING CLOTHS

	Number of Days in Resupply Period	Weight Per Wash Cloth (lbs)		Initial Supply Wash Cloths		Initial Supply Weight (lbs)				Average Resupply Weight (lbs)		Number of Re-supplies in 10 Years		10 Year Resupply Weight (lbs)
(6)	14	.075	x	14	=	1.050	÷	26	=	.04038	x	260	=	10.50
	90	.075	x	14	=	1.050	÷	4	=	.26250	x	40	=	10.50
	180	.075	x	14	=	1.050	÷	2	=	.52500	x	20	=	10.50
(12)	14	.075	x	21	=	1.575	÷	26	=	.06058	x	260	=	15.75
	90	.075	x	21	=	1.575	÷	4	=	.39375	x	40	=	15.75
	180	.075	x	21	=	1.575	÷	2	=	.78750	x	20	=	15.75
(25) and (50)	14	.075	x	28	=	2.100	÷	26	=	.08076	x	260	=	21.00
	90	.075	x	28	=	2.100	÷	4	=	.52500	x	40	=	21.00
	180	.075	x	28	=	2.100	÷	2	=	1.05000	x	20	=	21.00

VOLUMES OF WASHING CLOTHS

	Number of Days in Resupply Period	Volume Per Wash Cloth (cu ft)		Initial Supply Wash Cloths		Initial Supply Volume (cu ft)				Average Resupply Volume (cu ft)		Number of Re-supplies in 10 Years		10 Year Resupply Volume (cu ft)
(6)	14	.001672	x	14	=	.02341	÷	26	=	.00094	x	260	=	.2341
	90	.001672	x	14	=	.02341	÷	4	=	.00585	x	40	=	.2341
	180	.001672	x	14	=	.02341	÷	2	=	.01170	x	20	=	.2341
(12)	14	.001672	x	21	=	.03511	÷	26	=	.00135	x	260	=	.3511
	90	.001672	x	21	=	.03511	÷	4	=	.00878	x	40	=	.3511
	180	.001672	x	21	=	.03511	÷	2	=	.01756	x	20	=	.3511
(25) and (50)	14	.001672	x	28	=	.04682	÷	26	=	.00188	x	260	=	.4682
	90	.001672	x	28	=	.04682	÷	4	=	.01170	x	40	=	.4682
	180	.001672	x	28	=	.04682	÷	2	=	.02340	x	20	=	.4682

INSTALLED WEIGHTS AND VOLUMES

Same as Initial Supply shown in Weights and Volumes (preceding page).

RESUPPLY WEIGHTS

	Number of Days in Resupply Period	Average Resupply Cloths (lbs)	Clean Fluid Resupply (lbs)	Total Resupply (lbs)	10 Year Resupply Cloths (lbs)	10 Year Resupply Clean Fluid (lbs)	Total 10 Year Resupply (lbs)
(6)	14	.04038 +	28.350	= 28.39	10.50 +	7371.00	= 7381.50
	90	.26250 +	182.250	= 182.51	10.50 +	7290.00	= 7300.50
	180	.52500 +	364.500	= 365.02	10.50 +	7290.00	= 7300.50
(12)	14	.06058 +	44.310	= 44.37	15.75 +	11520.60	= 11536.35
	90	.39375 +	284.850	= 285.24	15.75 +	11394.00	= 11409.75
	180	.78750 +	569.700	= 570.49	15.75 +	11394.00	= 11409.75
(25) and (50)	14	.08076 +	60.284	= 60.36	21.00 +	15673.84	= 15694.84
	90	.52500 +	387.540	= 388.07	21.00 +	15501.60	= 15522.60
	180	1.05000 +	775.080	= 776.13	21.00 +	15501.60	= 15522.60

RESUPPLY VOLUMES

	Number of Days in Resupply Period	Average Resupply Cloths (cu ft)	Clean Fluid Resupply (cu ft)	Total Resupply (cu ft)	10 Year Resupply Cloths (cu ft)	10 Year Resupply Clean Fluid (cu ft)	Total 10 Year Resupply (cu ft)
(6)	14	.00094 +	.45430	= .455	.2341 +	118.118	= 118.352
	90	.00585 +	2.92050	= 2.927	.2341 +	116.820	= 117.054
	180	.01170 +	5.84100	= 5.853	.2341 +	116.820	= 117.054
(12)	14	.00135 +	.71022	= .712	.3511 +	184.657	= 185.008
	90	.00878 +	4.56570	= 4.575	.3511 +	182.628	= 182.979
	180	.01756 +	9.13140	= 9.149	.3511 +	182.628	= 182.979
(25) and (50)	14	.00188 +	.96614	= .968	.4682 +	258.996	= 259.464
	90	.01170 +	6.21090	= 6.223	.4682 +	248.436	= 248.904
	180	.02340 +	12.42180	= 12.445	.4682 +	248.436	= 248.904

ESTIMATION OF CREW OPERATING TIME

Assume that 10 square feet of surface can be cleaned in 2.5 minutes with additional average allowance of 0.5 minute to cover changing position and reapplication of cleaning fluid to wipes as moisture content is expended; therefore, cleaning rate is 3 minutes or .05 hour per 10 square feet.

	Average Daily Surface Area					Clean Rate per 10 sq ft		Crew Time
6	389.36	sq ft ÷ 10	=	38.94	x	.05 hr	=	1.947 hrs/day
12	608.71	sq ft ÷ 10	=	60.87	x	.05 hr	=	3.044 hrs/day
25	828.07	sq ft ÷ 10	=	82.81	x	.05 hr	=	4.141 hrs/day

ASSOCIATED LAUNDERING REQUIREMENTS

Assume existence of remotely located laundering facility in space vehicle.

Base operating time requirements on estimates of:

(A) 25-30 minutes for wash/rinse/spin-dry of 10-15 pounds of cloth articles → 2 minutes (.033 hrs) per pound.

(B) 15-20 minutes for electric drying of 10-15 pounds of cloth articles → 1.5 minutes (.025 hrs) per pound.

Base power requirements on estimates of:

(A) Automatic Washing Machine rating of 1500 watts.

(B) Automatic Drying Machine rating of 6000 watts, (i.e., 4500 W heat element, 1500 W motor)

Base water requirements on estimates of 5-6 pounds of water per pound for washing plus 15 pounds of water per pound for rinsing.

Therefore, the following assumptions will be used where applicable:

(A)	Laundering:	20 lbs water per 1 pound cloth articles.
		50 watt-hours per 1 pound cloth articles.
(B)	Drying:	150 watt-hours per 1 pound cloth articles.

Determination of associated water and power requirements based on laundering schedule; adjusted for DAILY AVERAGE:

Day Washed	Quantity Washed (6)	Quantity Washed (12)	Quantity Washed (25)	Quantity Washed (50)
3	4	6	8	8
6	6	9	12	12
9	6	9	12	12
12	6	9	12	12
15	10	15	20	20
18	6	9	12	12
21	6	9	12	12
24	6	9	12	12
27	6	9	12	12
30	10	15	20	20
33	6	9	12	12
36	6	9	12	12
39	6	9	12	12
42	6	9	12	12
45	10	15	20	20
48	6	9	12	12
Totals →	106	159	212	212
Totals ÷ 48 →	Average 2.208 Per Day	Average 3.312 Per Day	Average 4.416 Per Day	Average 4.416 Per Day

ASSOCIATED DAILY WATER NEED

	Average Wash Cloths		Weight Per Wash Cloth		Average Cloth Weight		Ratio Water to Cloth		Average Water Weight
(6)	2.208	x	.075 lbs	=	.1656 lbs	x	20	=	3.312 lbs
(12)	3.312	x	.075 lbs	=	.2484 lbs	x	20	=	4.968 lbs
(25) and (50)	4.416	x	.075 lbs	=	.3312 lbs	x	20	=	6.624 lbs

ASSOCIATED DAILY POWER NEED

	Average Wash Cloths		Weight Per Wash Cloth		Average Cloth Weight		Wash and Dry Watt-Hour Ratio to Cloth		Average Energy
(6)	2.208	x	.075 lbs	=	.1656 lbs	x	200	=	33.12 watt-hrs
(12)	3.312	x	.075 lbs	=	.2484 lbs	x	200	=	49.68 watt-hrs
(25) and (50)	4.416	x	.075 lbs	=	.3312 lbs	x	200	=	66.24 watt-

4

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.1.10 Title: Guided Transport "ASTROVAC" Cleaning Unit

Assumptions:

Section area allocations were based on the North American Rockwell "Phase B" Space Station studies and mock-up for a 12-man crew.

Formulae:

Significant Factors:

"Astrovac" sizing criteria were based on design and tests of the F/H "Astrovac" unit fabricated for the Manned Orbiting Laboratory (MOL).

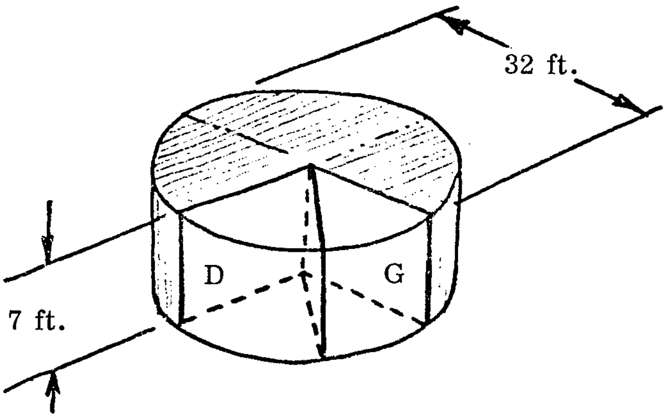
General Information:

Interface with space vehicle electrical power system, environmental control system, water reclamation system, structural design, and general debris processing techniques.

References:

None

ESTIMATION OF SURFACE AREA TO BE CLEANED



Assume 33 feet diameter vehicle with 6-inch wall thickness; therefore, interior diameter is 32 feet.

Assume 90 degree sector allocation for 6 men Galley/Dining requisites.

Assume 180 degree sector allocation for 12 men.

Assume 270 degree sector allocation for 25 men (50 men same as 25 men; Dining in 2 sessions).

6-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .25 =	175.93 sq.ft.
Sector Surface = 804.28 x .25 = 201.07 sq.ft. x 2 =	402.14 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partition) =	448.00 sq.ft.
Sub Total:	1026.07 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	256.52 sq.ft.
TOTAL:	1282.59 sq.ft.

12-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .50 =	351.86 sq.ft.
Sector Surface = 804.28 x .50 = 402.14 sq.ft. x 2 =	804.28 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partiaion) =	448.00 sq.ft.
Sub Total:	1604.14 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	401.03 sq.ft.
TOTAL:	2005.17 sq.ft.

25-Men Galley/Dining Room

Peripheral Surface = 7 x 100.53 = 703.71 sq.ft. x .75 =	527.79 sq.ft.
Sector Surface = 804.28 x .75 = 603.21 sq.ft. x 2 =	1206.42 sq.ft.
Radial Surface = 7 x 16 = 112 sq.ft. x 4 (including G/D partition)	448.00 sq.ft.
Sub Total:	2182.21 sq.ft.
Est. additional 25% of sub total for Equipment and Furnishings	545.55 sq.ft.
TOTAL:	2727.76 sq.ft.

FREQUENCY OF CLEANSING/SANITIZING

Assume 25% of total surface to be cleaned on daily basis.

Assume entire surfaces to be cleaned at two-week intervals.

		Surfaces @ 2-Week Intervals				Surfaces Daily Basis
(6)	→	1282.59 sq.ft.	x	.25	=	320.65 sq.ft.
(12)	→	2005.17 sq.ft.	x	.25	=	501.29 sq.ft.
(25) and (50)	→	2727.76 sq.ft.	x	.25	=	681.94 sq.ft.

AVERAGE SURFACE AREA FOR DAILY CLEANSING/SANITIZING

												Average Surface for Daily
(6)	→	1282.59 x .75	=	961.94	÷	14	=	68.71	+	320.65	=	389.36 sq.ft.
(12)	→	2005.17 x .75	=	1503.88	÷	14	=	107.42	+	501.29	=	608.71 sq.ft.
(25) and (50)	→	2727.76 x .75	=	2045.82	÷	14	=	146.13	+	681.94	=	828.07 sq.ft.

QUANTITY OF CLEANING FLUID NEEDED

Assume premixed detergent/bactericide solution is used in ratio of 1 part solution to 12 parts of water dispensed to Astrovac scrubber-sponge head.

Assume 3 mil fluid application on surfaces (.003 in. ÷ 12 = .000249 ft.).

	Average Daily Surface Area				Fluid Volume Per Day		*		Fluid Weight Per Day
(6)	389.36 sq. ft.	x	.000249	=	.09735 cu.ft.	x	62.4	=	6.075 lbs.
(12)	608.71 sq. ft.	x	.000249	=	.15219 cu.ft.	x	62.4	=	9.497 lbs.
(25) and (50)	828.07 sq. ft.	x	.000249	=	.20703 cu.ft.	x	62.4	=	12.919 lbs.

(*Solution density assumed to be same as water; 62.4 lb/cu ft)

PROPORTIONS OF FLUIDS

	Fluid Per Day				Bactericide Solution Per Day				Water Per Day
(6)	6.075 lbs	÷	13	=	.4673 lbs	x	12	=	5.6077 lbs
	.09735 cu ft	÷	13	=	.00749 cu ft	x	12	=	.08988 cu ft
(12)	9.497 lbs	÷	13	=	.7305 lbs	x	12	=	8.7660 lbs
	.15219 cu ft	÷	13	=	.01171 cu ft	x	12	=	.14052 cu ft
(25) and (50)	12.919 lbs	÷	13	=	.9938 lbs	x	12	=	11.9256 lbs
	.20703 cu ft	÷	13	=	.01593 cu ft	x	12	=	.01593 cu ft

WEIGHTS OF BACTERICIDE SOLUTION

	Initial Supply (lbs)	Weight of Solution Per Day (lbs)		Number Days In Resupply Period		Resupply Weight (lbs)		Number of Resupplies In 10 Years		10 Year Resupply Weight (lbs)
(6)	0	.4673	x	14	=	6.5422	x	260	=	1700.972
	0	.4673	x	90	=	42.0570	x	40	=	1682.280
	0	.4673	x	180	=	84.1140	x	20	=	1682.280
(12)	0	.7305	x	14	=	10.2270	x	260	=	2659.020
	0	.7305	x	90	=	65.7450	x	40	=	2629.800
	0	.7305	x	180	=	131.4900	x	20	=	2629.800
(25) and (50)	0	.9938	x	14	=	13.9132	x	260	=	3617.432
	0	.9938	x	90	=	89.4420	x	40	=	3577.680
	0	.9938	x	180	=	178.8840	x	20	=	3577.680

VOLUMES OF BACTERICIDE SOLUTION

	Initial Supply (lbs)	Volume of Solution Per Day (cu ft)		Number Days In Resupply Period		Resupply Volume (cu ft)		Number of Resupplies In 10 Years		10 Year Resupply Volume (cu ft)
(6)	0	.00749	x	14	=	.10486	x	260	=	27.2636
	0	.00749	x	90	=	.67410	x	40	=	26.9640
	0	.00749	x	180	=	1.34820	x	20	=	26.9640
(12)	0	.01171	x	14	=	.16394	x	260	=	42.6244
	0	.01171	x	90	=	1.05390	x	40	=	42.1560
	0	.01171	x	180	=	2.10780	x	20	=	42.1560
(25) and (50)	0	.01593	x	14	=	.22302	x	260	=	57.9852
	0	.01593	x	90	=	1.43370	x	40	=	57.3480
	0	.01593	x	180	=	2.86740	x	20	=	57.3480

DETERMINATION OF ASTROVAC SPONGE (SCRUBBER) QUANTITIES

Sponge dimensions are 2.25 inch dia. x .50 inch thick

Weight = .02 lbs
Volume = $3.1417 \times 1.125^2 \times .5 = .633$ cu.in. ÷ 1728 = .000309 cu.ft.

Assume replacement requirements as:

(6)	1 sponge replacement for 3 days of use
(12)	1 sponge replacement for 2 days of use
(25) and (50)	1 sponge replacement for 1 day of use

WEIGHTS OF SPONGES

	Number Days In Resupply Period				Number of Sponges Per Resupply		Weight Per Sponge (lbs)		Resupply Weight (lbs)		Number of Resupplies In 10 Years		10 Year Resupply Weight (lbs)
(6)	14	÷	3	=	5	x	.02	=	.10	x	260	=	26.0
	90	÷	3	=	30	x	.02	=	.60	x	40	=	24.0
	180	÷	3	=	60	x	.02	=	1.20	x	20	=	24.0
(12)	14	÷	2	=	7	x	.02	=	.14	x	260	=	36.4
	90	÷	2	=	45	x	.02	=	.90	x	40	=	36.0
	180	÷	2	=	90	x	.02	=	1.80	x	20	=	36.0
(25) and (50)	14	÷	1	=	14	x	.02	=	.28	x	260	=	72.8
	90	÷	1	=	90	x	.02	=	1.80	x	40	=	72.0
	180	÷	1	=	180	x	.02	=	3.60	x	20	=	72.0

VOLUME OF SPONGES

	Number Days in Resupply Period				Number of Sponges Per Resupply		Volume Per Sponge (cu ft)		Resupply Volume (cu ft)		Number of Resupplies In 10 Years		10 Year Resupply Volume (cu ft)
(6)	14	÷	3	=	5	x	.000309	=	.001545	x	260	=	.40170
	90	÷	3	=	30	x	.000309	=	.009270	x	40	=	.37080
	180	÷	3	=	60	x	.000309	=	.018540	x	20	=	.37080
(12)	14	÷	2	=	7	x	.000309	=	.002163	x	260	=	.56238
	90	÷	2	=	45	x	.000309	=	.013905	x	40	=	.55620
	180	÷	2	=	90	x	.000309	=	.027810	x	20	=	.55620
(25) and (50)	14	÷	1	=	14	x	.000309	=	.004326	x	260	=	1.12476
	90	÷	1	=	90	x	.000309	=	.027810	x	40	=	1.11240
	180	÷	1	=	180	x	.000309	=	.055620	x	20	=	1.11240

RESUPPLY WEIGHTS

	Number Days In Resupply Period	Resupply Sponges (lbs)		Resupply Bactericide Solution (lbs)		Total Resupply (lbs)	10 Year Resupply Sponges (lbs)		10 Year Resupply Bactericide Solution (lbs)		Total 10 Year Resupply (lbs)
	14	.10	+	6.542	=	6.642	26.0	+	1700.97	=	1726.97
(6)	90	.60	+	42.057	=	42.657	24.0	+	1682.28	=	1706.28
	180	1.20	+	84.114	=	85.314	24.0	+	1682.28	=	1706.28
	14	.14	+	10.277	=	10.367	36.4	+	2659.02	=	2695.42
(12)	90	.90	+	65.745	=	66.645	36.0	+	2629.80	=	2665.80
	180	1.80	+	131.490	=	133.290	36.0	+	2629.80	=	2665.80
	14	.28	+	13.913	=	14.193	72.8	+	3617.43	=	3690.23
(25) and (50)	90	1.80	+	89.442	=	91.242	72.0	+	3577.68	=	3649.68
	180	3.60	+	178.884	=	182.484	72.0	+	3577.68	=	3649.68

RESUPPLY VOLUMES

	Number Days In Resupply Period	Resupply Sponges (cu ft)		Resupply Bactericide Solution (cu ft)		Total Resupply (cu ft)	10 Year Resupply Sponges (cu ft)		10 Year Resupply Bactericide Solution (cu ft)		Total 10 Year Resupply (cu ft)
	14	.00155	+	.10486	=	.10641	.40170	+	27.2636	=	27.66530
(6)	90	.00927	+	.67410	=	.68337	.37080	+	26.9640	=	27.33480
	180	.01854	+	1.34820	=	1.36674	.27080	+	26.9640	=	27.33480
	14	.00216	+	.16394	=	.16610	.56238	+	42.6244	=	43.18678
(12)	90	.01391	+	1.05390	=	1.06781	.55620	+	42.1560	=	42.71220
	180	.02781	+	2.10780	=	2.13561	.55620	+	42.1560	=	42.71220
	14	.00433	+	.22302	=	.22735	1.12476	+	57.9852	=	59.10996
(25) and (50)	90	.02781	+	1.43370	=	1.46151	1.11240	+	57.3480	=	58.46040
	180	.05562	+	2.86740	=	2.92302	1.11240	+	57.3480	=	58.46040

DETERMINATION OF ELECTRICAL POWER USAGE

Assume motor operates at 1500 watts continuously during the cleaning process.

Assume that 10 square feet of surface can be cleaned in 2.5 minutes or .042 hours.

	Average Daily Surface Area (sq ft)					Clean Rate Per 10 Sq Ft		Operating Time Per Day (hours)		Operating Power (watts)		Energy Watt-Hours Per Day
(6)	389.36	÷	10	=	38.94 x	.042	=	1.635	x	1500	=	2452.50
(12)	608.71	÷	10	=	60.87 x	.042	=	2.557	x	1500	=	3835.50
(25)	828.07	÷	10	=	82.81 x	.042	=	3.478	x	1500	=	5217.00

DETERMINATION OF CREW OPERATING TIME

Assume that approximately 10 to 12 minutes (.2 hour) are expended by a crewmember in preparatory and post-operative functions associated with this cleaning equipment.

	Equipment Operate Time		Time For Associated Functions		Crew Time
(6)	1.635 hrs/day	+	.2 hr/day	=	1.835 hrs/day
(12)	2.557 hrs/day	+	.2 hr/day	=	2.757 hrs/day
(25)	3.478 hrs/day	+	.2 hr/day	=	3.678 hrs/day

10-YEAR OPERATIMG TIME OF EQUIPMENT

Daily operating time is multiplied by 3650 to obtain equipment operating time over a 10-year period.

(6)	1.635 hrs/day	x	3650	=	5967.75 hrs in 10 years
(12)	2.557 hrs/day	x	3650	=	9333.05 hrs in 10 years
(25)	3.478 hrs/day	x	3650	=	12694.70 hrs in 10 years

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 500,000	$ 500,000	$ 500,000
B.	Tooling	350,000	350,000	350,000
C.	Fabrication	350,000	350,000	350,000
D.	Qualification	800,000	800,000	800,000
E.	Documentation	30,000	30,000	30,000
	TOTALS →	$ 2,030,000	$ 2,030,000	$ 2,030,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.2.1 Title: Dispenser for Disposable Personal Wipes

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle general debris processing techniques.

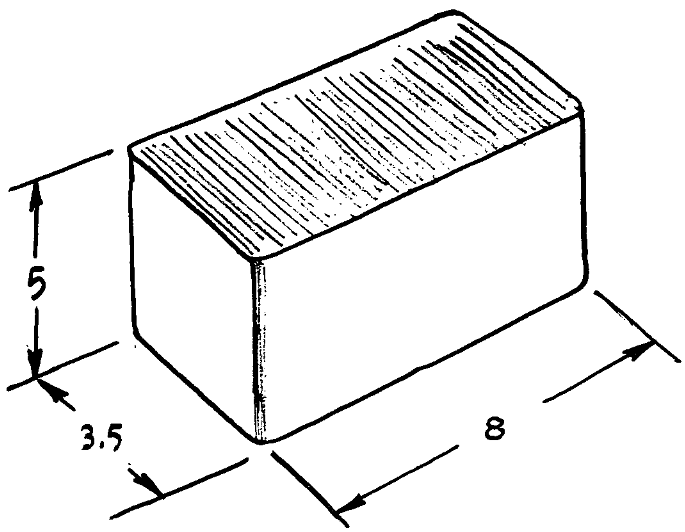
References:

None

Dispenser Weight = 1.48 lbs;

Volume 6 x 4.75 x 4.25 inches = 121.1 cu.in. ÷ 1728 = .07 cu.ft.

Commercial Package of 300 paper napkins, 12 x 10 inch sheet size (unfolded), 5 x 3.5 inch folded, similar to MARATHON COMPACT NAPKINS #170 JUNIOR manufactured by MARATHON DIVISION of AMERICAN CAN COMPANY, Menasha, Wisconsin.



Weight per sheet = .0036 lbs
Weight per package = .8375 lbs

Volume per package 8 x 5 x 3.5 inches
= 140 cu.in. ÷ 1728
= .08102 cu.ft.

DETERMINATION OF DISPENSER REQUIREMENTS

Assume 1 dispenser for each group of three dining positions; therefore, suggested quantities are:

2 dispensers for 6-man crew size
4 dispensers for 12-man crew size
9 dispensers for 25- and 50-man crew size

INSTALLED WEIGHTS AND VOLUMES

	Dispenser Weight and Volume		Suggested Quantity		Installed Weight and Volume
(6)	1.48 lbs.	x	2	=	2.96 lbs.
	.07 cu.ft.	x	2	=	.14 cu.ft.
(12)	1.48 lbs.	x	4	=	5.92 lbs.
	.07 cu.ft.	x	4	=	.28 cu.ft.
(25) and (50)	1.48 lbs.	x	9	=	13.32 lbs.
	.07 cu.ft.	x	9	=	.63 cu.ft.

DETERMINATION OF WIPE REQUIREMENTS

Assume use of 2 paper napkins per man per meal.

Assume additional 33% of total for contingency factor.

	Napkins Per Man		Crew Size		Napkins Per Meal		Meals Per Day		Accountable Usage Per Day		33% Contingency		Total Napkins Per Day
(6)	2	x	6	=	12	x	3	=	36	+	12	=	48
(12)	2	x	12	=	24	x	3	=	72	+	24	=	96
(25)	2	x	25	=	50	x	3	=	150	+	50	=	200
(50)	2	x	50	=	100	x	3	=	300	+	100	=	400

QUANTITY OF WIPES FOR MISSIONS

	Total Sheets Per Day		Number Days in Resupply Period		Resupply Quantity Sheets		Number of Resupplies in 10 Years		10 Year Resupply Quantity
	48	x	14	=	672	x	260	=	174720
(6)	48	x	90	=	4320	x	40	=	172800
	48	x	180	=	8640	x	20	=	172800
	96	x	14	=	1344	x	260	=	349440
(12)	96	x	90	=	8640	x	40	=	345600
	96	x	180	=	17280	x	20	=	345600
	200	x	14	=	2800	x	260	=	728000
(25)	200	x	90	=	18000	x	40	=	720000
	200	x	180	=	36000	x	20	=	720000
	400	x	14	=	5600	x	260	=	1456000
(50)	400	x	90	=	36000	x	40	=	1440000
	400	x	180	=	72000	x	20	=	1440000

NOTE: It appears logical to provide complete commercial packages for resupply missions in lieu of sheet quantities.

CONVERSION OF WIPE QUANTITIES TO COMMERCIAL PACKAGES FOR RESUPPLY

	Number Days in Resupply Period	Resupply Quantity Sheets		Number of Sheets Per Package		Number of Packages Required		*Resupply Nearest Full Package		Number of Resupplies in 10 Years		10 Year Resupply Full Packages
(6)	14	672	÷	300	=	2.24	→	2	x	260	=	520
	90	4320	÷	300	=	14.40	→	14	x	40	=	560
	180	8640	÷	300	=	28.80	→	28	x	20	=	560
(12)	14	1344	÷	300	=	4.48	→	4	x	260	=	1040
	90	8640	÷	300	=	28.80	→	29	x	40	=	1160
	180	17280	÷	300	=	57.60	→	58	x	20	=	1160
(25)	14	2800	÷	300	=	9.33	→	9	x	260	=	2340
	90	18000	÷	300	=	60.00	→	60	x	40	=	2400
	180	36000	÷	300	=	120.00	→	120	x	20	=	2400
(50)	14	5600	÷	300	=	18.67	→	18	x	260	=	4680
	90	36000	÷	300	=	120.00	→	120	x	40	=	4800
	180	72000	÷	300	=	240.00	→	240	x	20	=	4800

*NOTE: Adjusting resupply requirements to nearest full single package has slight effect in increasing or decreasing the contingency quantity.

RESUPPLY WEIGHTS (FOR COMMERCIAL PACKAGES)

	Number Days in Resupply Period	Resupply Nearest Full Package		Weight Per Package (lbs)		Resupply Weight (lbs)		Number of Resupplies in 10 Years		10 Year Resupply Weight (lbs)
(6)	14	2	x	.84	=	1.68	x	260	=	436.80
	90	14	x	.84	=	11.76	x	40	=	470.40
	180	28	x	.84	=	23.52	x	20	=	470.40
(12)	14	4	x	.84	=	3.36	x	260	=	873.60
	90	29	x	.84	=	24.36	x	40	=	974.40
	180	58	x	.84	=	42.72	x	20	=	974.40
(25)	14	9	x	.84	=	7.56	x	260	=	1965.60
	90	60	x	.84	=	50.40	x	40	=	2016.00
	180	120	x	.84	=	100.80	x	20	=	2016.00
(50)	14	18	x	.84	=	15.12	x	260	=	3931.20
	90	120	x	.84	=	100.80	x	40	=	4032.00
	180	240	x	.84	=	201.60	x	20	=	4032.00

RESUPPLY VOLUMES (FOR COMMERCIAL PACKAGES

	Number Days in Resupply Period	Resupply Nearest Full Package		Volume Per Package (cu ft)		Resupply Volume (cu ft)		Number of Resupplies in 10 Years		10 Year Resupply Volume (cu ft)
(6)	14	2	x	.081	=	.162	x	260	=	42.120
	90	14	x	.081	=	1.134	x	40	=	45.360
	180	28	x	.081	=	2.268	x	20	=	45.360
(12)	14	4	x	.081	=	.324	x	260	=	84.240
	90	29	x	.081	=	2.349	x	40	=	93.960
	180	58	x	.081	=	4.698	x	20	=	93.960
(25)	14	9	x	.081	=	.729	x	260	=	189.540
	90	60	x	.081	=	4.860	x	40	=	194.400
	180	120	x	.081	=	9.720	x	20	=	194.400
(50)	14	18	x	.081	=	1.458	x	260	=	379.080
	90	120	x	.081	=	9.720	x	40	=	388.800
	180	240	x	.081	=	19.440	x	20	=	388.800

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		6		12		25
A. Engineering		$ 6,000		$ 6,000		$ 6,000
B. Tooling		3,500		3,500		3,500
C. Fabrication	(2)	1,000	(4)	2,000	(9)	4,500
D. Qualification		10,000		10,000		10,000
E. Documentation		1,000		1,000		1,000
TOTALS →		$21,500		$22,500		$25,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept #- 6.2.2 Title: Dispenser For Reusable Personal Wipes

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle water reclamation system (presuming existence of general laundry facility).

References:

None

DETERMINATION OF DISPENSER REQUIREMENTS

Assume use of drawer-type container for storage of folded cloth napkins. Drawer dimensions would be approximately 8 inches long x 8 inches wide x 2 inches deep.

Weight = 2.5 lbs
Volume 8 x 8 x 2 inches - 128 cu.in. ÷ 1728 = .074 cu.ft.

Assume 1 drawer (dispenser) unit between each two dining positions; therefore, suggested quantities are:

4 drawers for 6-man crew size
8 drawers for 12-man crew size
16 drawers for 25- and 50-man crew size

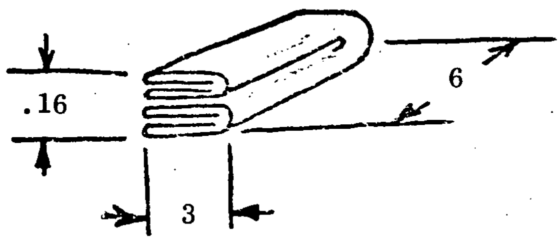
Each drawer unit divided into two sections which would hold daily supply of napkins; i.e., one section per man. The supply in drawer would be doubled for 50-man crew (2 sittings per meal period).

DISPENSER WEIGHTS AND VOLUMES

	Unit Weight and Volume		Suggested Quantity		Total Weight and Volume
(6)	2.5 lbs	x	4	=	10.0 lbs
	.074 cu ft	x	4	=	.296 cu ft
(12)	2.5 lbs	x	8	=	20.0 lbs
	.074 cu ft	x	8	=	.592 cu ft
(25) and (50)	2.5 lbs	x	16	=	40.0
	.074 cu ft	x	16	=	1.184 cu ft

DETERMINATION OF WIPE REQUIREMENTS

Assume use of cloth napkins, approximately 12 x 12 inches unfolded. The napkins would be folded to dimensions of 6 x 3 x .16 inches for storage:



Single napkin weight = .075 lbs
volume 3 x 6 x .16 inches = 2.88 cu.in. ÷ 1728 = .001672 cu.ft.

Assume use of 1 napkin per man per meal.

Assume additional 33% of total for contingency factor.

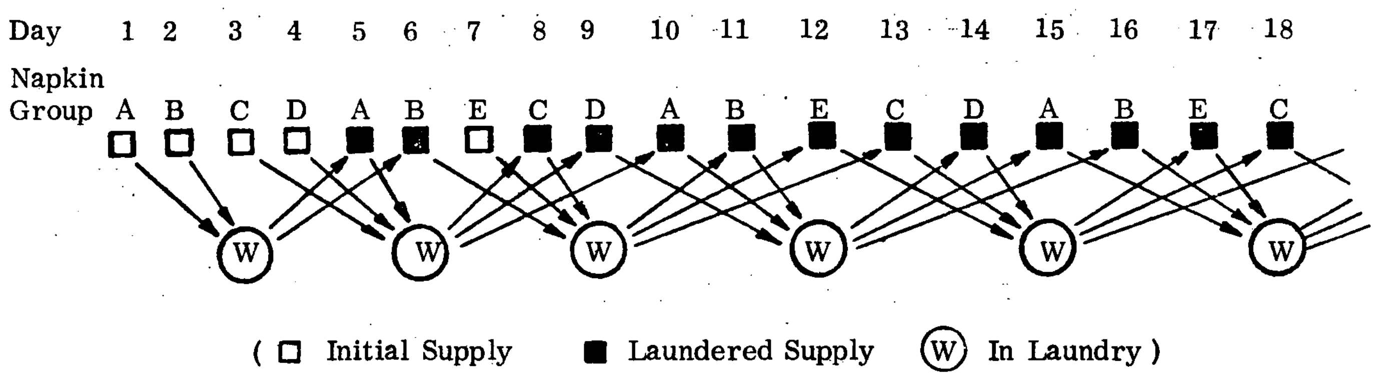
	Napkins Per Man		Crew Size		Napkins Per Meal		Meals Per Day		Accountable Usage Per Day		33% Contingency		Total Napkins Per Day
6	1	x	6	=	6	x	3	=	18	+	6	=	24
12	1	x	12	=	12	x	3	=	36	+	12	=	48
25	1	x	25	=	25	x	3	=	75	+	75	=	100
50	1	x	50	=	50	x	3	=	150	+	50	=	200

RATIONALE FOR SUPPLIES OF REUSABLE NAPKINS

Assume existence of laundering facilities on the space vehicle, and that general laundering is accomplished every third day with a two-day lapse for return of articles from laundry.

The following figure exemplifies the assumed schedule of usage and laundering for a group-quantity of napkins, indicating availability of proper quantities for day-to-day clean-up functions. If the group quantity is *24 napkins for A through E inclusive (typical of 6-man crew size), then 48 napkins are taken from initial supply for the first and second days (Group A and B) after which they are sent to laundry. An additional 48 napkins (Group C and D) are taken from initial supply to satisfy the third and fourth days after which they are sent to laundry. In the interim, the 48 napkins of Group A and B have been returned and are used on the fifth and sixth day, then back to laundry. Since all heretofore used napkins are not available, the remaining 24 napkins (Group E) are taken from initial supply for the seventh day clean-up requirements. The cycle continues with laundered group quantities until deteriorated and replenished during a subsequent resupply mission.

(*Group quantity of napkins varies with crew size)



Each napkin is laundered 1 time per 5 days of mission duration.

Assume existence of laundering facilities on the space vehicle and that general laundering is accomplished every third day with a 2-day lapse for return of articles from laundry.

Assume that the useful life of these napkins, which are not subjected to any abrasive action, is approximately 90 launderings or approximately 450 days.

REPLACEMENT SCHEDULE FOR NAPKINS

For 14-day Resupply:	Replace each 32 missions (448 days), 8 times in 10 years.
For 90-day Resupply:	Replace each 5 missions (450 days), 8 times in 10 years.
For 180-day Resupply:	Replace each 2.5 missions (450 days), 8 times in 10 years.

QUANTITY OF NAPKINS FOR INITIAL SUPPLY

	Number Days in Resupply Period	Initial Supply		Average Resupply		Number of Resupplies in 10 Years		10 Year Resupply
	14	120 ÷ 32	=	3.75	x	260	=	975
(6)	90	120 ÷ 5	=	24.0	x	40	=	960
	180	120 ÷ 2.5	=	48.0	x	20	=	960
	14	240 ÷ 32	=	7.5	x	260	=	1950
(12)	90	240 ÷ 5	=	48.0	x	40	=	1920
	180	240 ÷ 2.5	=	96.0	x	20	=	1920
	14	500 ÷ 32	=	15.625	x	260	=	4063
(25)	90	500 ÷ 5	=	100.0	x	40	=	4000
	180	500 ÷ 2.5	=	200.0	x	20	=	4000
	14	1000 ÷ 32	=	31.25	x	260	=	8125
(50)	90	1000 ÷ 5	=	200.0	x	40	=	8000
	180	1000 ÷ 2.5	=	400.0	x	20	=	8000

WEIGHTS OF NAPKINS NEEDED

	Number Days in Resupply Period	Initial Supply Napkins		Weight Per Napkin (lbs)		Initial Supply Weight (lbs)		Average Resupply Weight (lbs)		Number of Resupplies In 10 Years		10 Year Resupply Weight (lbs)
	14	120	x	.075	=	9.0 ÷ 32	=	.28125	x	260	=	73.125
(6)	90	120	x	.075	=	9.0 ÷ 5	=	1.800	x	40	=	72.000
	180	120	x	.075	=	9.0 ÷ 2.5	=	3.600	x	20	=	72.000
	14	240	x	.075	=	18.0 ÷ 32	=	.56250	x	260	=	146.250
(12)	90	240	x	.075	=	18.0 ÷ 5	=	3.600	x	40	=	144.000
	180	240	x	.075	=	18.0 ÷ 2.5	=	7.200	x	20	=	144.000
	14	500	x	.075	=	37.5 ÷ 32	=	1.17187	x	260	=	304.686
(25)	90	500	x	.075	=	37.5 ÷ 5	=	7.500	x	40	=	300.000
	180	500	x	.075	=	37.5 ÷ 2.5	=	15.000	x	20	=	300.000
	14	1000	x	.075	=	75.0 ÷ 32	=	2.34375	x	260	=	609.375
(50)	90	1000	x	.075	=	75.0 ÷ 5	=	15.000	x	40	=	600.000
	180	1000	x	.075	=	75.0 ÷ 2.5	=	30.000	x	20	=	600.000

VOLUMES OF NAPKINS NEEDED

	Number Days in Resupply Period	Initial Supply Napkins		Volume Per Napkin (cu ft)		Initial Supply Volume (cu ft)				Average Resupply Volume (cu ft)		Number of Resupplies In 10 Years		10 Year Resupply Volume (cu ft)
(6)	14	120	x	.001672	=	.2006	÷	32	=	.00626	x	260	=	1.628
	90	120	x	.001672	=	.2006	÷	5	=	.04012	x	40	=	1.605
	180	120	x	.001672	=	.2006	÷	2.5	=	.08024	x	20	=	1.605
(12)	14	240	x	.001672	=	.4012	÷	32	=	.01253	x	260	=	3.258
	90	240	x	.001672	=	.4012	÷	5	=	.08024	x	40	=	3.210
	180	240	x	.001672	=	.4012	÷	2.5	=	.16048	x	20	=	3.210
(25)	14	500	x	.001672	=	.836	÷	32	=	.02612	x	260	=	6.791
	90	500	x	.001672	=	.836	÷	5	=	.16720	x	40	=	6.688
	180	500	x	.001672	=	.836	÷	2.5	=	.33440	x	20	=	6.688
(50)	14	1000	x	.001672	=	1.672	÷	32	=	.05225	x	260	=	13.585
	90	1000	x	.001672	=	1.672	÷	5	=	.33440	x	40	=	13.376
	180	1000	x	.001672	=	1.672	÷	2.5	=	.66880	x	20	=	13.376

INSTALLED WEIGHTS AND VOLUMES

	Dispenser Units		Initial Supply Napkins		Installed Weight
(6)	10.0 lbs	+	9.0 lbs	=	19.0 lbs
	.296 cu ft	+	.2006 cu ft	=	.4966 cu ft
(12)	20.0 lbs	+	18.0 lbs	=	38.0 lbs
	.592 cu ft	+	.4012 cu ft	=	.9932 cu ft
(25)	40.0 lbs	+	37.5 lbs	=	77.5 lbs
	1.184 cu ft	+	.836 cu ft	=	2.020 cu ft
(50)	40.0 lbs	+	75.0 lbs	=	115.0 lbs
	1.184 cu ft	+	1.672 cu ft	=	2.856 cu ft

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 6,000	$ 6,000	$ 6,000
B.	Tooling	3,500	3,500	3,500
C.	Fabrication	(4) 2,000	(8) 4,000	(16) 8,000
D.	Qualification	10,000	10,000	10,000
E.	Documentation	1,000	1,000	1,000
	SUB - TOTALS →	22,500	24,500	28,500
F.	Procure Cloth Wipes (1.00 each)	(120) 120	(240) 240	(500) 500
	TOTALS	$ 22,620	$ 24,740	$ 29,000

ASSOCIATED LAUNDERING REQUIREMENTS

Assume existence of remotely located laundering facility in space vehicle.

Base operating time requirements on estimates of:

(A) 25-30 minutes for wash/rinse/spin-dry of 10-15 pounds of cloth articles → 2 minutes (.033 hours) per pound.

(B) 15-20 minutes for electric drying of 10-15 pounds of cloth articles → 1.5 minutes (.025 hours) per pound.

Base power requirements on estimates of:

(A) Automatic Washing Machine rating of 1500 watts.

(B) Automatic Drying Machine rating of 6000 watts, (i.e., 4500W heat element, 1500W motor).

Base water requirements on estimates of 5-6 pounds of water per pound for washing plus 15 pounds of water per pound for rinsing.

Therefore, the following assumptions will be used where applicable:

(A) Laundering: 20 lbs water per 1 lb cloth articles
50 watt-hours per 1 lb cloth articles

(B) Drying: 150 watt-hours per 1 lb cloth articles

Determination of associated water and power requirements with laundering schedule adjusted for DAILY AVERAGE; (i.e., if laundering occurs every third day and a 3-day soiled quantity is washed and dried at such time, then the adjusted daily average for laundering estimates is equal to the daily usage rate).

(6)	(12)	(25)	(50)
24 per day	48 per day	100 per day	200 per day

ASSOCIATED DAILY WATER NEED

	Average Napkins		Weight Per Per Napkin		Average Cloth Weight		Ratio Water To Cloth		Average Water Weight
(6)	24	x	.075 lbs	=	1.80 lbs	x	20	=	36.00 lbs
(12)	48	x	.075 lbs	=	3.60 lbs	x	20	=	72.00 lbs
(25)	100	x	.075 lbs	=	7.50 lbs	x	20	=	150.00 lbs
(50)	200	x	.075 lbs	=	15.00 lbs	x	20	=	300.00 lbs

ASSOCIATED DAILY POWER NEED

	Average Napkins		Weight Per Per Napkin		Average Cloth Weight		Wash and Dry Watt-Hour Ratio To Cloth		Average Energy
(6)	24	x	.075 lbs	=	1.80 lbs	x	200	=	360.0 watt-hours
(12)	48	x	.075 lbs	=	3.60 lbs	x	200	=	720.0 watt-hours
(25)	100	x	.075 lbs	=	7.50 lbs	x	200	=	1500.0 watt-hours
(50)	200	x	.075 lbs	=	15.00 lbs	x	200	=	3000.0 watt-hours

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept #- 6.2.3 Title: Dispenser For Impregnated Personal Cleansing Wipes

Assumptions:

Formulae:

Significant Factors:

General Information:

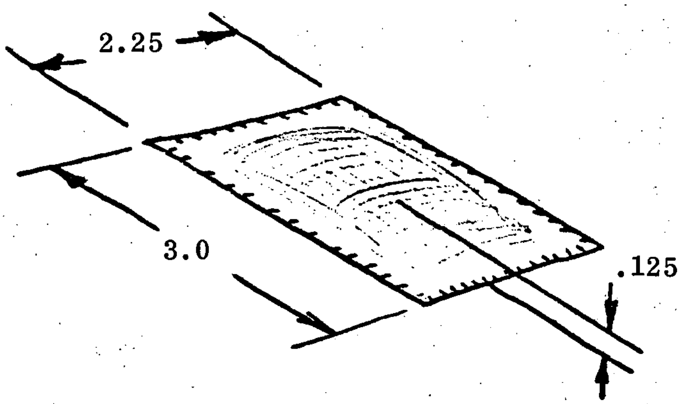
Interface with space vehicle general debris processing techniques.

References:

Information predicated upon use of Wash'n Dri® Towelette manufactured by CANAAN PRODUCTS, INC. of Canaan, Connecticut (a Subsidiary of the Colgate-Palmolive Company).

Dispenser Weight = .80 lbs
Volume 4.25 x 4.25 x 3.25 inches = 58.70 cu.in. ÷ 1727 = .034 cu.ft.

Cleansing wipes, impregnated and sealed in individual packets, equivalent to Wash'n Dri® Towelettes.



Note: Wash'n Dri® Towelettes are readily available commercial products, in individually sealed packets, manufactured by Canaan Products, Inc., of Canaan, Connecticut (a Subsidiary of the Colgate-Palmolive Company).

Individual Packet

Weight = .013 lbs
Volume 2.25 x 3.0 x .125 inches = .844 cu.in. ÷ 1728 = .0004884 cu.ft.

DETERMINATION OF DISPENSER REQUIREMENTS

Assume 1 dispenser for each group of three dining positions; therefore, suggested quantities are:

2 dispensers for 6-man crew size
4 dispensers for 12-man crew size
9 dispensers for 25- and 50-man crew size

INSTALLED WEIGHTS AND VOLUMES

	Dispenser Weight and Volume		Suggested Quantity		Installed Weight and Volume
(6)	.80 lbs	x	2	=	1.60 lbs
	.034 cu ft	x	2	=	.068 cu ft
(12)	.80 lbs	x	4	=	3.20 lbs
	.034 cu ft	x	4	=	.136 cu ft
(25) and (50)	.80 lbs	x	9	=	7.20 lbs
	.034 cu ft	x	9	=	.306 cu ft

DETERMINATION OF WIPE REQUIREMENTS

Assume use of 1 "towelette" per man per meal.

	Towelettes Per Man		Crew Size		Towelettes Per Meal		Meals Per Day		Towelettes Per Day
6	1	x	6	=	6	x	3	=	18
12	1	x	12	=	12	x	3	=	36
25	1	x	25	=	25	x	3	=	75
50	1	x	50	=	50	x	3	=	150

QUANTITY OF WIPES FOR MISSIONS

	Total Towelettes Per Day		Number Days in Resupply Period		Resupply Quantity Towelettes		Number of Resupplies in 10 Years		10 Year Resupply Quantity
	18	x	14	=	252	x	260	=	65,520
(6)	18	x	90	=	1620	x	40	=	64,800
	18	x	180	=	3240	x	20	=	64,800
	36	x	14	=	504	x	260	=	131,040
(12)	36	x	90	=	3240	x	40	=	129,600
	36	x	180	=	6480	x	20	=	129,600
	75	x	14	=	1050	x	260	=	273,000
(25)	75	x	90	=	6750	x	40	=	270,000
	75	x	180	=	13500	x	20	=	270,000
	150	x	14	=	2100	x	260	=	546,000
(50)	150	x	90	=	13500	x	40	=	540,000
	150	x	180	=	27000	x	20	=	540,000

RESUPPLY WEIGHTS OF TOWELETTES

	Daily Quantity		Weight Per Towelette (lbs)		Daily Weight (lbs)		Number Days in Resupply Period		Resupply Weight (lbs)		Number of Resupplies in 10 Years		10 Year Resupply Weight (lbs)
(6)	18	x	.013	=	.234	x	14	=	3.276	x	260	=	851.76
	18	x	.013	=	.234	x	90	=	21.060	x	40	=	842.40
	18	x	.013	=	.234	x	180	=	42.120	x	20	=	842.40
(12)	36	x	.013	=	.468	x	14	=	6.552	x	260	=	1703.52
	36	x	.013	=	.468	x	90	=	42.120	x	40	=	1684.80
	36	x	.013	=	.468	x	180	=	84.240	x	20	=	1684.80
(25)	75	x	.013	=	.975	x	14	=	13.650	x	260	=	3549.00
	75	x	.013	=	.975	x	90	=	87.750	x	40	=	3510.00
	75	x	.013	=	.975	x	180	=	175.500	x	20	=	3510.00
(50)	150	x	.013	=	1.950	x	14	=	27.300	x	260	=	7098.00
	150	x	.013	=	1.950	x	90	=	175.500	x	40	=	7020.00
	150	x	.013	=	1.950	x	180	=	351.000	x	20	=	7020.00

RESUPPLY VOLUMES OF TOWELETTES

	Daily Quantity		Volume Per Towelette (cu ft)		Daily Volume (cu ft)		Number Days in Resupply Period		Resupply Volume (cu ft)		Number of Resupplies in 10 Years		10 Year Resupply Volume (cu ft)
(6)	18	x	.0004884	=	.00879	x	14	=	.123	x	260	=	31.980
	18	x	.0004884	=	.00879	x	90	=	.791	x	40	=	31.640
	18	x	.0004884	=	.00879	x	180	=	1.582	x	20	=	31.640
(12)	36	x	.0004884	=	.01758	x	14	=	.246	x	260	=	63.960
	36	x	.0004884	=	.01758	x	90	=	1.582	x	40	=	63.280
	36	x	.0004884	=	.01758	x	180	=	3.164	x	20	=	63.280
(25)	75	x	.0004884	=	.03663	x	14	=	.513	x	260	=	133.380
	75	x	.0004884	=	.03663	x	90	=	3.297	x	40	=	131.880
	75	x	.0004884	=	.03663	x	180	=	6.594	x	20	=	131.880
(50)	150	x	.0004884	=	.07326	x	14	=	1.026	x	260	=	266.760
	150	x	.0004884	=	.07326	x	90	=	6.594	x	40	=	263.760
	150	x	.0004884	=	.07326	x	180	=	13.188	x	20	=	263.760

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 5,000	$ 5,000	$ 5,000
B.	Tooling	2,000	2,000	2,000
C.	Fabrication	(2) 1,000	(4) 2,000	(9) 4,500
D.	Qualification	10,000	10,000	10,000
E.	Documentation	1,000	1,000	1,000
	TOTALS →	$ 19,000	$ 20,000	$ 22,500

CONCEPT BACK-UP INFORMATION SHEET

FOOD SYSTEM STUDY

Concept # 6.2.4 Title: Receptacle for Temporary Retention of Soiled Wipes

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle general debris processing techniques.

References:

None

Receptacle Weight = .50 lbs
Volume 6 x 6 x 8 inches = 288 cu.in. ÷ 1728 = .167 cu.ft.

Disposable Bag Weight = .001 lbs
Volume (folded) 3 x 3 x .03 inches = .27 cu.in. ÷ 1728 = .000156 cu.ft.

DETERMINATION OF RECEPTACLE REQUIREMENTS

Assume 1 receptacle between each 2 dining positions, therefore suggested quantities are:

3 receptacles for 6-man crew size

6 receptacles for 12-man crew size

13 receptacles for 25- and 50-man crew size

INSTALLED WEIGHTS AND VOLUMES

	Receptacle Weight and Volume		Suggested Quantity		Installed Weight and Volume
(6)	.50 lbs.	x	3	=	1.50 lbs.
	.167 cu.ft.	x	3	=	.501 cu.ft.
(12)	.50 lbs.	x	6	=	3.00 lbs.
	.167 cu.ft.	x	6	=	1.002 cu.ft.
(25) and (50)	.50 lbs.	x	13	=	6.50 lbs.
	.167 cu.ft.	x	13	=	2.171 cu.ft.

DETERMINATION OF BAG REQUIREMENTS

Assume use of 1 bag per receptacle per meal period. (NOTE: No replacement in between the two 25-man sittings of 50-man crew.)

	Number of Receptacles		Meals Per Day		Bag Usage Per Day
(6)	3	x	3	=	9
(12)	6	x	3	=	18
(25) and (50)	13	x	3	=	39

RESUPPLY WEIGHTS

	Number Bags Per Day		Weight Per Bag (lbs)		Weight Per Day (lbs)		Number Days in Resupply Period		Resupply Weight (lbs)		Number of Resupplies in 10 Years		10 Year Resupply Weight (lbs)
	9	x	.001	=	.009	x	14	=	.546	x	260	=	32.76
(6)	9	x	.001	=	.009	x	90	=	.81	x	40	=	32.40
	9	x	.001	=	.009	x	180	=	1.62	x	20	=	32.40
	18	x	.001	=	.018	x	14	=	.252	x	260	=	65.52
(12)	18	x	.001	=	.018	x	90	=	1.62	x	40	=	64.80
	18	x	.001	=	.018	x	180	=	3.24	x	20	=	64.80
	39	x	.001	=	.039	x	14	=	.546	x	260	=	141.96
	39	x	.001	=	.039	x	90	=	3.51	x	40	=	140.40
(25) and (50)	39	x	.001	=	.039	x	180	=	7.02	x	20	=	140.40

RESUPPLY VOLUMES

	Number Bags Per Day		Volume Per Bag (cu ft)		Volume Per Day (cu ft)		Number Days in Resupply Period		Resupply Volume (cu ft)		Number of Resupplies in 10 Years		10 Year Resupply Volume (cu ft)
	9	x	.000156	=	.001404	x	14	=	.019656	x	260	=	5.111
(6)	9	x	.000156	=	.001404	x	90	=	.126360	x	40	=	5.054
	9	x	.000156	=	.001404	x	180	=	.252720	x	20	=	5.054
	18	x	.000156	=	.002808	x	14	=	.039312	x	260	=	10.221
(12)	18	x	.000156	=	.002808	x	90	=	.252720	x	40	=	10.109
	18	x	.000156	=	.002808	x	180	=	.505440	x	20	=	10.109
	39	x	.000156	=	.006084	x	14	=	.085176	x	260	=	22.146
	39	x	.000156	=	.006084	x	90	=	.547560	x	40	=	21.902
(25) and (50)	39	x	.000156	=	.006084	x	180	=	1.095120	x	20	=	21.902

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 5,000	$ 5,000	$ 5,000
B.	Tooling	2,000	2,000	2,000
C.	Fabrication	(3) 1,500	(6) 3,000	(13) 6,500
D.	Qualification	10,000	10,000	10,000
E.	Documentation	1,000	1,000	1,000
	TOTALS →	$19,500	$21,000	$24,500

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.2.8 Title: Hand Carriage for Return of Meal Trays

Assumptions:

Formulae:

REFER TO BACK-UP INFORMATION SHEET

FOR CONCEPT 4.2.1

REFER TO BACK-UP INFORMATION SHEET FOR CONCEPT 4.2.1

Significant Factors:

General Information:

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.2.9 Title: Meal Tray Guided Return Rail System

Assumptions:

Formulae:

REFER TO BACK-UP INFORMATION SHEET

FOR CONCEPT 4.1.3

Significant Factors:

General Information:

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.2.10 **Title:** Meal Tray Guided Return Carrier Unit

Assumptions:

Formulae:

REFER TO BACK-UP INFORMATION SHEET

FOR CONCEPT 4.1.7

Significant Factors:

General Information:

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.3.1 Title: Temporary Reusable Soiled Wipes Storage Unit

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle water reclamation system (presuming existence of general laundry facility).

References:

None

Container Weight = 2.0 lbs.
Volume 10 x 10 x 30 = 3000 cu.in. ÷ 1728 = 1.736 cu.ft.

Reusable Bag Weight = .20 lbs.
Volume (folded) 5 x 10 x .5 = 25 cu.in. ÷ 1728 = .01446 cu.ft.

DETERMINATION OF CONTAINER REQUIREMENTS

Assume containers installed in following quantities:

1 container for 6- and 12-man crew size

2 containers for 25-man crew size

4 containers for 50-man crew size

CONTAINER WEIGHTS AND VOLUMES

	Unit Weight and Volume		Suggested Quantity		Containers Weight and Volume
(6) and (12)	2.0 lbs.	x	1	=	2.0 lbs.
	1.736 cu.ft.	x	1	=	1.736 cu.ft.
(25)	2.0 lbs.	x	2	=	4.0 lbs.
	1.736 cu.ft.	x	2	=	3.472 cu.ft.
(50)	2.0 lbs.	x	4	=	8.0 lbs.
	1.736 cu.ft.	x	4	=	6.944 cu.ft.

DETERMINATION OF BAG REQUIREMENTS

Assume use of 1 bag per container per day:

1 bag per day for 6- and 12-man crew size

2 bags per day for 25-man crew size

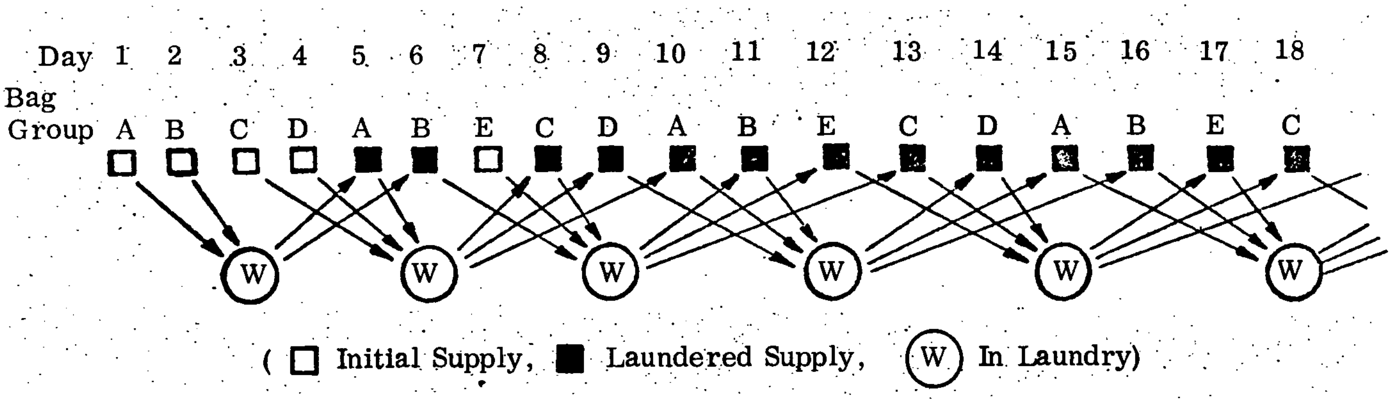
4 bags per day for 50-man crew size

RATIONALE FOR SUPPLIES OF REUSABLE BAGS

Assume existence of laundering facilities on the space vehicle, and that general laundering is accomplished every third day with a two-day lapse for return of articles from laundry.

The following figure exemplifies the assumed schedule of usage and laundering for a group-quantity of laundry bags, indicating availability of proper quantities for day-to-day clean-up functions. If the group quantity is *1 bag for A through E inclusive (typical of 6-man crew size), then 2 bags are taken from initial supply for the first and second days (Group A and B) after which they are sent to laundry. An additional 2 bags (Group C and D) are taken from initial supply to satisfy the third and fourth days after which they are sent to laundry. In the interim, the 2 bags of Group A and B have been returned and are used on the fifth and sixth day, then back to laundry. Since all heretofore used bags are not available, the remaining bag (Group E) is taken from initial supply for the seventh day clean-up requirements. The cycle continues with laundered group quantities until deteriorated and replenished during a subsequent resupply mission.

(*Group quantity of bags varies with crew size)



Each bag is laundered one time per five days of mission duration.

Assume that the useful life of these bags, which are not subjected to any abrasive action, is approximately 90 launderings or approximately 450 days.

REPLACEMENT SCHEDULES FOR BAGS

For 14-day resupply:	Replace each 32 missions (448 days), 8 times in 10 years.
For 90-day resupply:	Replace each 5 missions (450 days), 8 times in 10 years.
For 180-day resupply:	Replace each 2.5 missions (450 days), 8 times in 10 years.

QUANTITY OF BAGS FOR INITIAL SUPPLY

	Bags Per Day		Days Before Wash		Bags in Laundry		2-Day Quantity On Hand		Initial Supply Bags
(6) and (12)	1	x	3	=	3	+	2	=	5
(25)	2	x	3	=	6	+	4	=	10
(50)	4	x	3	=	12	+	8	=	20

QUANTITY OF BAGS FOR RESUPPLY

	Number Days in Resupply Period	Initial Supply				Average Resupply		Number of Resupplies in 10 Years		10-Year Resupply
(6) and (12)	14	5	÷	32	=	.15625	x	260	=	40.63
	90	5	÷	5	=	1.00	x	40	=	40.00
	180	5	÷	2.5	=	2.00	x	20	=	40.00
(25)	14	10	÷	32	=	.3125	x	260	=	81.25
	90	10	÷	5	=	2.00	x	40	=	80.00
	180	10	÷	2.5	=	4.00	x	20	=	80.00
(50)	14	20	÷	32	=	.625	x	260	=	162.50
	90	20	÷	5	=	4.00	x	40	=	160.00
	180	20	÷	2.5	=	8.00	x	20	=	160.00

WEIGHTS OF BAGS NEEDED

	Number Days in Resupply Period	Initial Supply Bags		Weight Per Bag (lbs)		Initial Supply Weight (lbs)				Average Resupply Weight (lbs)		Number of Resupplies in 10 Years		10-Year Resupply Weight (lbs)
(6) and (12)	14	5	x	.20	=	1.00	÷	32	=	.03125	x	260	=	8.125
	90	5	x	.20	=	1.00	÷	5	=	.20	x	40	=	8.000
	180	5	x	.20	=	1.00	÷	2.5	=	.40	x	20	=	8.000
(25)	14	10	x	.20	=	2.00	÷	32	=	.06250	x	260	=	16.250
	90	10	x	.20	=	2.00	÷	5	=	.40	x	40	=	16.000
	180	10	x	.20	=	2.00	÷	2.5	=	.80	x	20	=	16.000
(50)	14	20	x	.20	=	4.00	÷	32	=	.12500	x	260	=	32.500
	90	20	x	.20	=	4.00	÷	5	=	.80	x	40	=	32.000
	180	20	x	.20	=	4.00	÷	2.5	=	1.60	x	20	=	32.000

VOLUMES OF BAGS NEEDED

	Number Days in Resupply Period	Initial Supply Bags		Volume Per Bag (cu ft)		Initial Supply Volume (cu ft)				Average Resupply Volume (cu ft)		Number of Resupplies in 10 Years		10 Year Resupply Volume (cu ft)
(6) and (12)	14	5	x	.01446	=	.07230	÷	32	=	.00225	x	260	=	.5850
	90	5	x	.01446	=	.07230	÷	5	=	.01446	x	40	=	.5784
	180	5	x	.01446	=	.07230	÷	2.5	=	.02892	x	20	=	.5784
(25)	14	10	x	.01446	=	.14460	÷	32	=	.06250	x	260	=	1.1726
	90	10	x	.01446	=	.14460	÷	5	=	.02892	x	40	=	1.1568
	180	10	x	.01446	=	.14460	÷	2.5	=	.05784	x	20	=	1.1568
(50)	14	20	x	.01446	=	.28920	÷	32	=	.00903	x	260	=	2.3478
	90	20	x	.01446	=	.28920	÷	5	=	.05784	x	40	=	2.3136
	180	20	x	.01446	=	.28920	÷	2.5	=	.11568	x	20	=	2.3136

INSTALLED WEIGHTS AND VOLUMES

	Container Units		Initial Supply Bags		Installed Total
(6) and (12)	2.00 lbs	+	1.00 lbs	=	3.00 lbs
	1.736 cu ft	+	.072 cu ft	=	1.808 cu ft
(25)	4.00 lbs	+	2.00 lbs	=	6.00 lbs
	3.472 cu ft	+	.145 cu ft	=	3.617 cu ft
(50)	8.00 lbs	+	4.00 lbs	=	12.00 lbs
	6.944 cu ft	+	.289 cu ft	=	7.233 cu ft

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	(6)	(12)	(25)
A. Engineering	$ 5,000	$ 5,000	$ 5,000
B. Tooling	3,000	3,000	3,000
C. Fabrication	(1) 1,000	(1) 1,000	(2) 2,000
D. Qualification	10,000	10,000	10,000
E. Documentation	1,000	1,000	1,000
SUB TOTALS →	20,000	20,000	21,000
F. Procure Laundry Bags ($5.00 each)	(5) 25	(5) 25	(10) 25
TOTALS →	$20,025	$20,025	$21,050

ASSOCIATED LAUNDERING REQUIREMENTS

Assume existence of remotely located laundering facility in space vehicle.

Base operating time requirements on estimates of:

A. 25-30 minutes for wash/rinse/spin-dry of 10-15 pounds of cloth articles → 2 minutes (.033 hours) per pound.

B. 15-20 minutes for electric drying of 10-15 pounds of cloth articles → 1.5 minutes (.025 hours) per pound.

Base power requirements on estimates of:

A. Automatic Washing Machine rating of 1500 watts.

B. Automatic Drying Machine rating of 6000 watts; (i.e., 4500 W heat element, 1500 W motor).

Base water requirements on estimates of 5-6 pounds of water per pound for washing plus 15 pounds of water per pound for rinsing.

Therefore, the following assumptions will be used where applicable:

A. Laundering: 20 pounds water per 1 pound cloth articles
50 watt-hours per 1 pound cloth articles

B. Drying: 150 watt-hours per 1 pound cloth articles

Determination of associated water and power requirements with laundering schedule adjusted for DAILY AVERAGE; (i.e., if laundering occurs every third day and a 3-day soiled quantity is washed and dried at such time, then the adjusted daily average for laundering estimates is equal to the daily usage rate).

(6) and (12)	(25)	(50)
1 per day	2 per day	4 per day

ASSOCIATED DAILY WATER NEED

	Average Bags		Weight Per Bag		Average Cloth Weight		Ratio Water to Cloth		Average Water Weight
(6) and (12)	1	x	.20 lbs	=	.20 lbs	x	20	=	4.00 lbs
(25)	2	x	.20 lbs	=	.40 lbs	x	20	=	8.00 lbs
(50)	4	x	.20 lbs	=	.80 lbs	x	20	=	16.00 lbs

ASSOCIATED DAILY POWER NEED

	Average Bags		Weight Per Bag		Average Cloth Weight		Wash and Dry Watt-Hour Ratio to Cloth		Average Energy
(6) and (12)	1	x	.20 lbs	=	.20 lbs	x	200	=	40.0 watt-hours
(25)	2	x	.20 lbs	=	.40 lbs	x	200	=	80.0 watt-hours
(50)	4	x	.20 lbs	=	.80 lbs	x	200	=	160.0 watt-hours

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.3.2 Title: Temporary Debris Collection/Storage Unit

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle general debris processing techniques.

References:

None

Receptacle Weight = 2.0 lbs.
Volume 10 x 10 x 30 = 3000 cu. in. ÷ 1728 = 1.736 cu. ft.

Disposable Bag Weight = .02 lbs.
Volume (folded) 5 x 10 x .1 = 5 cu. in. ÷ 1728 = .00289 cu. ft.

DETERMINATION OF RECEPTACLE REQUIREMENTS

Assume receptacles installed in following quantities:

1 receptacle for 6- and 12-man crew size
2 receptacles for 25-man crew size
4 receptacles for 50-man crew size

INSTALLED WEIGHTS AND VOLUMES

	Receptacle Weight and Volume		Suggested Quantity		Installed Weight and Volume
(6) and (12)	2.0 lbs	x	1	=	2.0 lbs
	1.736 cu ft	x	1	=	1.736 cu ft
(25)	2.0 lbs	x	2	=	4.0 lbs
	1.736 cu ft	x	2	=	3.472 cu ft
(50)	2.0 lbs	x	4	=	8.0 lbs
	1.736 cu ft	x	4	=	6.944 cu ft

DETERMINATION OF BAG REQUIREMENTS

Assume use of 1 bag per receptacle, replaced after each meal preparation/serving period.

	Number of Receptacles		Meals Per Day		Bag Usage Per Day
(6) and (12)	1	x	3	=	3
(25)	2	x	3	=	6
(50)	4	x	3	=	12

RESUPPLY WEIGHTS

	Number Bags Per Day		Bag Weight (lbs)		Weight Per Day (lbs)		Number Days in Resupply Period		Resupply Weight (lbs)		Number of Resupplies in 10 Years		10 Year Resupply Weight (lbs)
	3	x	.02	=	.06	x	14	=	.84	x	260	=	218.4
(6) and (12)	3	x	.02	=	.06	x	90	=	5.4	x	40	=	216.0
	3	x	.02	=	.06	x	180	=	10.8	x	20	=	216.0
	6	x	.02	=	.12	x	14	=	1.68	x	260	=	436.8
(25)	6	x	.02	=	.12	x	90	=	10.8	x	40	=	432.0
	6	x	.02	=	.12	x	180	=	21.6	x	20	=	432.0
	12	x	.02	=	.24	x	14	=	3.36	x	260	=	873.6
(50)	12	x	.02	=	.24	x	90	=	21.6	x	40	=	864.0
	12	x	.02	=	.24	x	180	=	43.2	x	20	=	864.0

RESUPPLY VOLUMES

	Number Bags Per Day		Bag Volume (cu ft)		Volume Per Day (cu ft)		Number Days in Resupply Period		Resupply Volume (cu ft)		Number of Resupplies in 10 Years		10 Year Resupply Volume (cu ft)
	3	x	.00289	=	.00867	x	14	=	.12138	x	260	=	31.559
(6) and (12)	3	x	.00289	=	.00867	x	90	=	.78030	x	40	=	31.212
	3	x	.00289	=	.00867	x	180	=	1.56060	x	20	=	31.212
	6	x	.00289	=	.01734	x	14	=	.24276	x	260	=	63.118
(25)	6	x	.00289	=	.01734	x	90	=	1.56060	x	40	=	62.424
	6	x	.00289	=	.01734	x	180	=	3.12120	x	20	=	62.424
	12	x	.00289	=	.03468	x	14	=	.48552	x	260	=	126.235
(50)	12	x	.00289	=	.03468	x	90	=	3.12120	x	40	=	124.848
	12	x	.00289	=	.03468	x	180	=	6.24240	x	20	=	124.848

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 5,000	$ 5,000	$ 5,000
B.	Tooling	3,000	3,000	3,000
C.	Fabrication	(1) 1,000	(1) 1,000	(2) 2,000
D.	Qualification	10,000	10,000	10,000
E.	Documentation	1,000	1,000	1,000
	TOTALS →	$20,000	$20,000	$21,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.3.6 Title: Hand Carriage for Transport of Debris

Assumptions:

Formulae:

NO BACK-UP INFORMATION

REFER TO CONCEPT DATA SHEET

Significant Factors:

General Information:

References:

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.3.7 Title: Manual Movement of Debris Transporter

Assumptions:

Cost data are based on providing structural interface modifications to vehicle to be compatible with debris transporter.

Formulae:

Significant Factors:

General Information:

Interface with space vehicle structural design.

References:

None

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$10,000	$10,000	$10,000
B.	Tooling	5,000	5,000	5,000
C.	Fabrication	2,000	2,500	3,000
D.	Qualification	10,000	10,000	10,000
E.	Documentation	5,000	5,000	5,000
	TOTALS →	$32,000	$32,500	$33,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept #- 6.3.11 Title: Combination Galley Sink for Hand and Utensil Washing

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle electrical power system, structural design, and water reclamation system.

References:

None

Unit Weight = 60.0 lbs
Volume = 24 x 24 x 40 inches = 23,040 cu.in. ÷ 1728 = 13.333 cu.ft.

DETERMINATION OF GALLEY SINK USAGE

Assume usage of galley sink for washing of hands and/or other purposes as follows:

	Prior to Meal Prep		During Meal Prep		After Meal Prep		After Clean-Up		Number of Times Per Meal Period		Number of Meal Periods		Normal Washes Per Day		33% Contingency Use		Total Washings Per Day
(6)	1	+	0	+	1	+	1	=	3	x	3	=	9	+	3	=	12
(12)	1	+	1	+	1	+	1	=	4	x	3	=	12	+	4	=	16
(25)	1	+	2	+	1	+	1	=	5	x	3	=	15	+	5	=	20
(50)	1	+	4	+	1	+	1	=	7	x	3	=	21	+	7	=	28

DETERMINATION OF WATER REQUIREMENTS

Assume that water is used at rate of .2 quart (6 fluid ounces) per hand washing:

	Total Washings Per Day		Quantity Per Wash (quarts)		Total Quantity (quarts)		Weight of Water (lbs/quart)		Weight of Water Per Day (lbs)
(6)	12	x	.2	=	2.4	x	2.05	=	4.92
(12)	16	x	.2	=	3.2	x	2.05	=	6.56
(25)	20	x	.2	=	4.0	x	2.05	=	8.20
(50)	28	x	.2	=	5.6	x	2.05	=	11.48

DETERMINATION OF BACTERICIDE-DETERGENT REQUIREMENTS

Assume usage of bactericide-detergent pre-mixed supply at a ratio of 1 part for 12 parts of wash water:

1 quart water equivalent to 2.05 lbs ÷ 12 = .17 lbs bac-det/qt of water

1 quart water equivalent to .033 cu ft ÷ 12 = .0022 cu ft bac-det/qt of water

RESUPPLY WEIGHTS OF BACTERICIDE-DETERGENT SOLUTION

	Water Usage Per Day (quarts)		Ratio Bac-Det To Water (lbs/qt)		Daily Weight Bac-Det (lbs)		Number Days In Resupply Period		Resupply Weight (lbs)		Number of Resupplies In 10 Years		10 Year Resupply (wt-lbs)
	2.4	x	.17	=	.41	x	14	=	5.74	x	260	=	1492.4
(6)	2.4	x	.17	=	.41	x	90	=	36.9	x	40	=	1476.0
	2.4	x	.17	=	.41	x	180	=	73.8	x	20	=	1476.0
	3.2	x	.17	=	.54	x	14	=	7.56	x	260	=	1965.6
(12)	3.2	x	.17	=	.54	x	90	=	48.6	x	40	=	1944.0
	3.2	x	.17	=	.54	x	180	=	97.2	x	20	=	1944.0
	4.0	x	.17	=	.68	x	14	=	9.52	x	260	=	2475.2
(25)	4.0	x	.17	=	.68	x	90	=	61.2	x	40	=	2448.0
	4.0	x	.17	=	.68	x	180	=	122.4	x	20	=	2448.0
	5.6	x	.17	=	.95	x	14	=	13.3	x	260	=	3458.0
(50)	5.6	x	.17	=	.95	x	90	=	85.5	x	40	=	3420.0
	5.6	x	.17	=	.95	x	180	=	171.0	x	20	=	3420.0

RESUPPLY VOLUMES OF BACTERICIDE-DETERGENT SOLUTION

	Water Usage Per Day (quarts)		Ratio Bac-Det To Water (cu ft/qt)		Daily Volume Bac-Det (cu ft)		Number Days In Resupply Period		Resupply Volume (cu ft)		Number of Resupplies In 10 Years		10 Year Resupply (vol-cu ft)
	2.4	x	.0022	=	.00528	x	14	=	.07392	x	260	=	19.219
(6)	2.4	x	.0022	=	.00528	x	90	=	.47520	x	40	=	19.008
	2.4	x	.0022	=	.00528	x	180	=	.95040	x	20	=	19.008
	3.2	x	.0022	=	.00704	x	14	=	.09856	x	260	=	25.626
(12)	3.2	x	.0022	=	.00704	x	90	=	.63360	x	40	=	25.344
	3.2	x	.0022	=	.00704	x	180	=	1.26720	x	20	=	25.344
	4.0	x	.0022	=	.00880	x	14	=	.12320	x	260	=	32.032
(25)	4.0	x	.0022	=	.00880	x	90	=	.79200	x	40	=	31.680
	4.0	x	.0022	=	.00880	x	180	=	1.58400	x	20	=	31.680
	5.6	x	.0022	=	.01232	x	14	=	.17248	x	260	=	44.845
(50)	5.6	x	.0022	=	.01232	x	90	=	1.10880	x	40	=	44.352
	5.6	x	.0022	=	.01232	x	180	=	2.21760	x	20	=	44.352

DETERMINATION OF ELECTRICAL POWER USAGE

The galley sink operating power is estimated as 1.5 kilowatts.

Assume that the sink is operating for .05 hour (3 minutes) per hand washing:

	Total Washings Per Day		Time Per Wash (hours)		Wash Time Per Day (hours)		Operating Power (watts)		Energy Watt-Hours Per Day
(6)	12	x	.05	=	.6	x	1500	=	900
(12)	16	x	.05	=	.8	x	1500	=	1200
(25)	20	x	.05	=	1.0	x	1500	=	1500
(50)	28	x	.05	=	1.4	x	1500	=	2100

DETERMINATION OF CREW OPERATING TIME

Assume that approximately 10 to 12 minutes (.2 hour) are expended by a crewmember in preparatory and post-operative functions associated with this cleaning equipment:

	Equipment Operating Time		Time For Associated Functions		Crew Time
(6)	.6 hrs/day	+	.2 hr/day	=	.8 hrs/day
(12)	.8 hrs/day	+	.2 hr/day	=	1.0 hrs/day
(25)	1.0 hrs/day	+	.2 hr/day	=	1.2 hrs/day
(50)	1.4 hrs/day	+	.2 hr/day	=	1.6 hrs/day

10 YEAR OPERATING TIME OF EQUIPMENT

Daily operating time is multiplied by 3650 to obtain equipment operating time over a 10-year period:

(6)	.6 hrs/day	x	3650	=	2190.0 hrs in 10 years
(12)	.8 hrs/day	x	3650	=	2920.0 hrs in 10 years
(25)	1.0 hrs/day	x	3650	=	3650.0 hrs in 10 years
(50)	1.4 hrs/day	x	3650	=	5110.0 hrs in 10 years

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 575,000	$ 575,000	$ 575,000
B.	Tooling	350,000	350,000	350,000
C.	Fabrication	350,000	350,000	350,000
D.	Qualification	750,000	750,000	750,000
E.	Documentation	30,000	30,000	30,000
	TOTALS →	$ 2,055,000	$ 2,055,000	$ 2,055,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.3.13 Title: Combination Automatic Dishwasher/Dryer

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle electrical power system, structural design, and water reclamation system.

References:

None

DETERMINATION OF DISHWASHER SIZE, FOR 6-MAN CREW

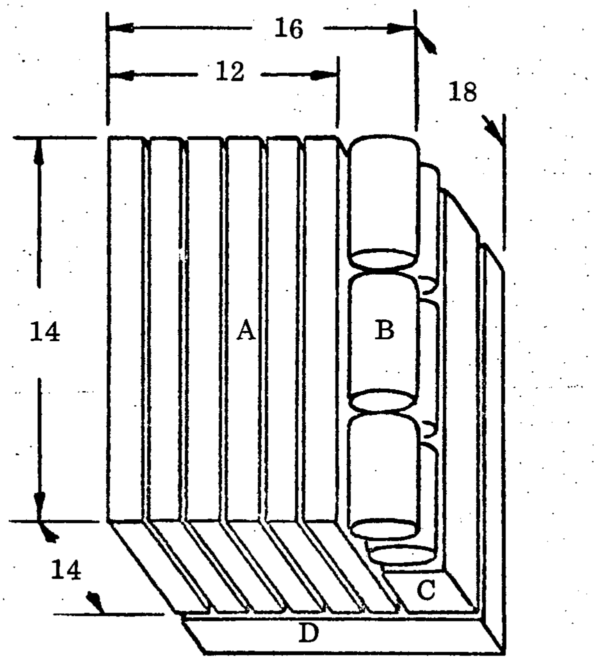
Assume usage of the following equipment, stacked as shown:

A. 6 trays, each of which is 14.0 x 14.0 x 1.5 inches.

B. 6 drinking cups, each of which is 3.0 inch dia x 4.5 inches.

C. 18 utensils, equivalent of knife, fork and spoon, one each of which together would be approximately 7.0 x 1.5 x 1.0 inches.

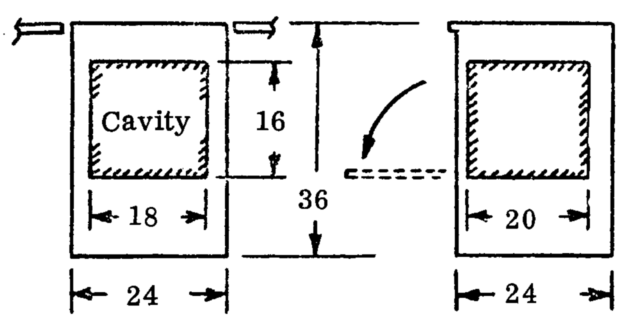
D. Indeterminate food preparation devices for which an approximate 25% volume allowance is allocated.



Assume addition of 2 inches to each of the over-all dimensions of the stacked equipment for a representative cavity:

CAVITY: 16 x 20 x 18 inches; Volume = 5760 cu in ÷ 1728 = 3.333 cu.ft.

Assume dishwasher configuration and dimensions to be as shown:



Unit Weight = 120 lbs
Volume 36 x 24 x 24 in.
= 20736 cu.in. ÷ 1728
= 12.0 cu.ft.

DETERMINATION OF DISHWASHER SIZE, FOR 12-MAN CREW

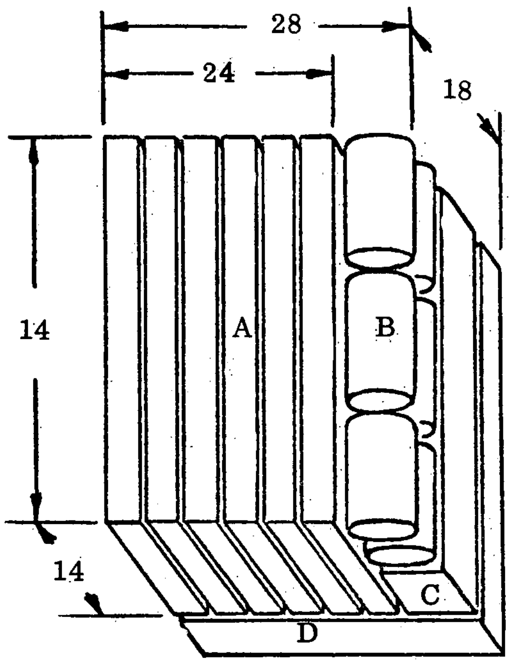
Assume usage of the following equipment, stacked as shown:

A. 12 trays, each of which is 14.0 x 14.0 x 1.5 inches.

B. 12 drinking cups, each of which is 3.0 inch dia x 4.5 inches.

C. 36 utensils, equivalent of knife, fork and spoon, one each of which together would be approximately 7.0 x 1.5 x 1.0 inches.

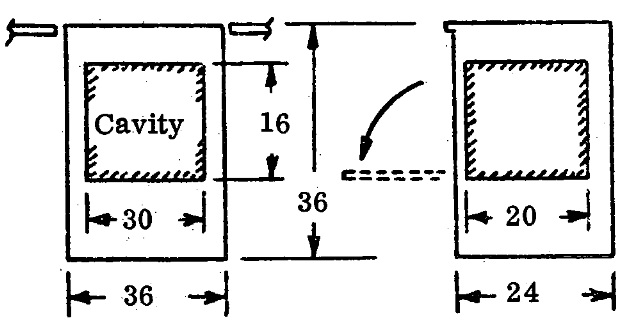
D. Indeterminate food preparation devices for which an approximate 25% volume allowance is allocated.



Assume addition of 2 inches to each of the over-all dimensions of the stacked equipment for a representative cavity:

CAVITY: 16 x 20 x 30 inches; Volume = 9600 cu in ÷ 1728 = 5.555 cu.ft.

Assume dishwasher configuration and dimensions to be as shown:



Unit Weight = 180 lbs
Volume 36 x 24 x 36 in.
= 31104 cu.in. ÷ 1728
= 18.0 cu.ft.

DETERMINATION OF DISHWASHER SIZE, FOR 25 AND 50-MAN CREW

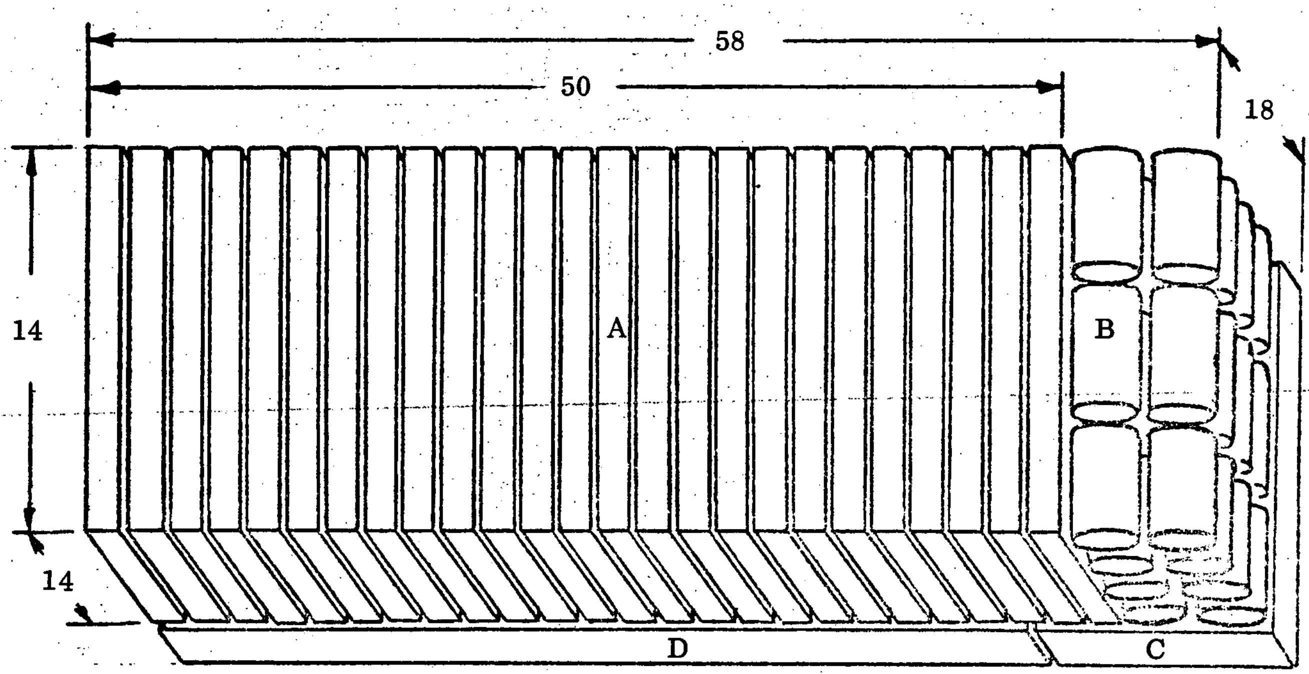
Assume usage of the following equipment, stacked as shown:

A. 25 trays, each of which is 14.0 x 14.0 x 1.5 inches.

B. 25 drinking cups, each of which is 3.0 inch dia x 4.5 inches.

C. 75 utensils, equivalent of knife, fork and spoon, one each of which together would be approximately 7.0 x 1.5 x 1.0 inches.

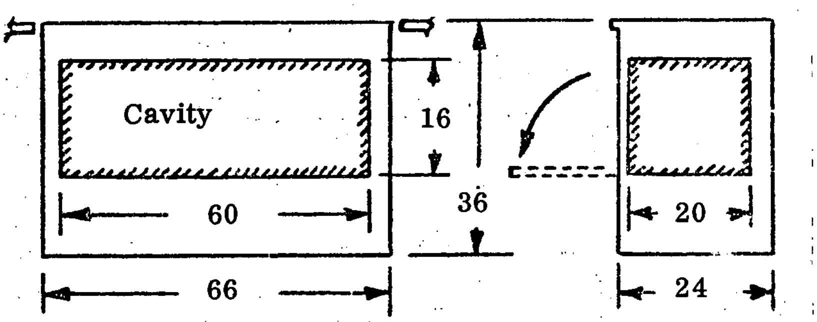
D. Indeterminate food preparation devices for which an approximate 25% volume allowance is allocated.



Assume addition of 2 inches to each of the over-all dimensions of the stacked equipment for a representative cavity:

CAVITY: 16 x 20 x 60 inches; Volume = 19200 cu in ÷ 1728 = 11.111 cu.ft.

Assume dishwasher configuration and dimensions to be as shown:



Unit Weight = 330 lbs
Volume 36 x 24 x 66 in.
= 57024 cu.in. ÷ 1728
= 33.0 cu.ft.

DETERMINATION OF WATER REQUIREMENT

Assume 10% of cavity is occupied by articles to be cleaned.

Assume 5% of cavity is occupied by racks or retention devices.

Assume balance of 85% of cavity will be filled with water.

	Cavity Size (cu.ft.)		Water Volume Ratio		Water in Cavity (cu.ft.)		*Water in Circulating System (cu.ft.)		Wash Water Requirement (cu.ft.)
(6)	3.333	x	.85	=	2.833	+	.03272	=	2.86572
(12)	5.555	x	.85	=	4.722	+	.03272	=	4.75472
(25) and (50)	11.111	x	.85	=	9.444	+	.03272	=	9.47672

*For circulating system, assume volume of a conduit having an inside diameter of 1-inch, and length of 6 feet:

Cross-sectional Area = .7854 sq.in. ÷ 144 = .005454 sq.ft. x 6 = .03272 cu.ft.

Assume additional 30% of wash water volume for rinsing.

	Wash Water (cu.ft.)		Rinse Water Ratio		Rinse Water Requirement (cu.ft.)		Wash Water Requirement (cu.ft.)		Wash and Rinse Water Per Use (cu.ft.)
(6)	2.86572	x	.30	=	.85972	+	2.86572	=	3.72544
(12)	4.75472	x	.30	=	1.42642	+	4.75472	=	6.18114
(25) and (50)	9.47672	x	.30	=	1.94302	+	9.47672	=	11.41974

Assume dishwasher/dryer is used after each meal period, which would be:

3 times per day for 6-, 12-, and 25-man crew size

6 times per day for 50-man crew size

VOLUME OF WATER NEEDED

	Wash and Rinse Water Per Use (cu. ft.)		Number Times Used Per Day		Volume of Water Per Day (cu. ft.)
(6)	3.72544	x	3	=	11.176
(12)	6.18114	x	3	=	18.383
(25)	11.41974	x	3	=	34.258
(50)	11.41974	x	3	=	68.519

WEIGHT OF WATER NEEDED

	Wash and Rinse Water Per Use (cu. ft.)		Weight Ratio (lbs/cu ft)		Weight of Water Per Use (lbs)		Number Times Used Per Day		Weight of Water Per Day (lbs)
(6)	3.72544	x	62.4	=	232.467	x	3	=	697.40
(12)	6.18114	x	62.4	=	385.703	x	3	=	1157.11
(25)	11.41974	x	62.4	=	712.592	x	3	=	2137.78
(50)	11.41974	x	62.4	=	712.592	x	6	=	4275.56

DETERMINATION OF ELECTRICAL POWER USAGE

Assume operating time of 20 minutes per use; the sum of 10 minutes for washing, 4 minutes for rinsing, and 6 minutes for drying.

Assume operating power for major electrical components as follows:

	Pump/Fan/Motor		Heater Element		Ultrasonic Generator		Total Power
6-man unit	1500 W	+	9000 W	+	1500 W	=	12000 W
12-man unit	2250 W	+	15000 W	+	2250 W	=	19500 W
25-man unit	4500 W	+	27000 W	+	4500 W	=	36000 W

Electrical energy would therefore be as follows:

	Time Per Use (min)		Number Times Used Per Day		Total Time Per Day Min → Hrs		Peak Power (watts)		Energy Watt-Hours Per Day
(6)	20	x	3	=	60 → 1	x	12000	=	12000
(12)	20	x	3	=	60 → 1	x	19500	=	19500
(25)	20	x	3	=	60 → 1	x	36000	=	36000
(50)	20	x	6	=	120 → 2	x	36000	=	72000

DETERMINATION OF CREW OPERATING TIME

Assume the following crew time is required for stacking articles in the dishwasher, initiating and monitoring operation, and subsequent removal of articles upon completion of the drying cycle:

	Loading Time (min)		Periodic Monitor (min)		Unload Time (min)		Crew Time Per Use (min)		Number Times Used Per Day		Crew Time Per Day Min → Hrs
(6)	2	+	.5	+	1.5	=	4.0	x	3	=	12.0 → .20
(12)	4	+	.5	+	3.5	=	8.0	x	3	=	24.0 → .40
(25)	8	+	.5	+	7.5	=	16.0	x	3	=	48.0 → .80
(50)	8	+	.5	+	7.5	=	16.0	x	6	=	96.0 → 1.60

10-YEAR OPERATING TIME OF EQUIPMENT

Daily operating time is multiplied by 3650 to obtain equipment operating time over a 10-year period:

(6) 1 hr/day x 3650 = 3650 hrs in 10 years
(12) 1 hr/day x 3650 = 3650 hrs in 10 years
(25) 1 hr/day x 3650 = 3650 hrs in 10 years
(50) 2 hrs/day x 3650 = 7300 hrs in 10 years

DETERMINATION OF SURFACTANT REQUIREMENT

Assume use of surfactant to facilitate removal of water from utensils and expedite drying process, added at a ratio of .25 fluid ounces to 1 gallon of water, or 1 part surfactant to 500 parts water (1/500 = .002).

RESUPPLY WEIGHT OF SURFACTANT

	Water Per Day (lbs)		Surfactant Ratio		Daily Surfactant Weight (lbs)		Number Days in Resupply Period		Resupply Weight (lbs)		Number of Resupplies in 10 Years		10-Year Resupply Weight (lbs)
(6)	697.40	x	.002	=	1.3948	x	14	=	19.527	x	260	=	5077.072
	697.40	x	.002	=	1.3948	x	90	=	125.532	x	40	=	5021.280
	697.40	x	.002	=	1.3948	x	180	=	251.064	x	20	=	5021.280
(12)	1157.11	x	.002	=	2.3142	x	14	=	32.399	x	260	=	8423.688
	1157.11	x	.002	=	2.3142	x	90	=	208.278	x	40	=	8331.120
	1157.11	x	.002	=	2.3142	x	180	=	416.556	x	20	=	8331.120
(25)	2137.78	x	.002	=	4.2756	x	14	=	59.858	x	260	=	15563.184
	2137.78	x	.002	=	4.2756	x	90	=	375.804	x	40	=	15032.160
	2137.78	x	.002	=	4.2756	x	180	=	769.608	x	20	=	15032.160
(50)	4275.56	x	.002	=	8.5511	x	14	=	119.715	x	260	=	31126.004
	4275.56	x	.002	=	8.5511	x	90	=	769.599	x	40	=	30783.960
	4275.56	x	.002	=	8.5511	x	180	=	1539.198	x	20	=	30783.960

RESUPPLY VOLUME OF SURFACTANT

	Water Per Day (lbs)		Surfactant Ratio		Daily Surfactant Volume (cu ft)		Number Days in Resupply Period		Resupply Volume (cu ft)		Number of Resupplies in 10 Years		10-Year Resupply Volume (cu ft)
(6)	11.176	x	.002	=	.02235	x	14	=	.31290	x	260	=	81.354
	11.176	x	.002	=	.02235	x	90	=	2.01150	x	40	=	80.460
	11.176	x	.002	=	.02235	x	180	=	4.02300	x	20	=	80.460
(12)	18.383	x	.002	=	.03677	x	14	=	.51478	x	260	=	133.843
	18.383	x	.002	=	.03677	x	90	=	3.30930	x	40	=	132.372
	18.383	x	.002	=	.03677	x	180	=	6.61860	x	20	=	132.372
(25)	34.258	x	.002	=	.06852	x	14	=	.95928	x	260	=	249.413
	34.258	x	.002	=	.06852	x	90	=	6.16680	x	40	=	246.672
	34.258	x	.002	=	.06852	x	180	=	12.33360	x	20	=	246.672
(50)	68.519	x	.002	=	.13704	x	14	=	1.91856	x	260	=	498.826
	68.519	x	.002	=	.13704	x	90	=	12.33360	x	40	=	493.344
	68.519	x	.002	=	.13704	x	180	=	24.66720	x	20	=	493.344

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$625,000	$625,000	$625,000
B.	Tooling	500,000	500,000	700,000
C.	Fabrication	600,000	650,000	700,000
D.	Qualification	1,000,000	1,000,000	1,000,000
E.	Documentation	50,000	50,000	50,000
	TOTALS →	2,775,000	2,925,000	3,075,000

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept #- 6.3.14 Title: Dispenser For Disposable Galley Utility Wipes

Assumptions:

Formulae:

Significant Factors:

General Information:

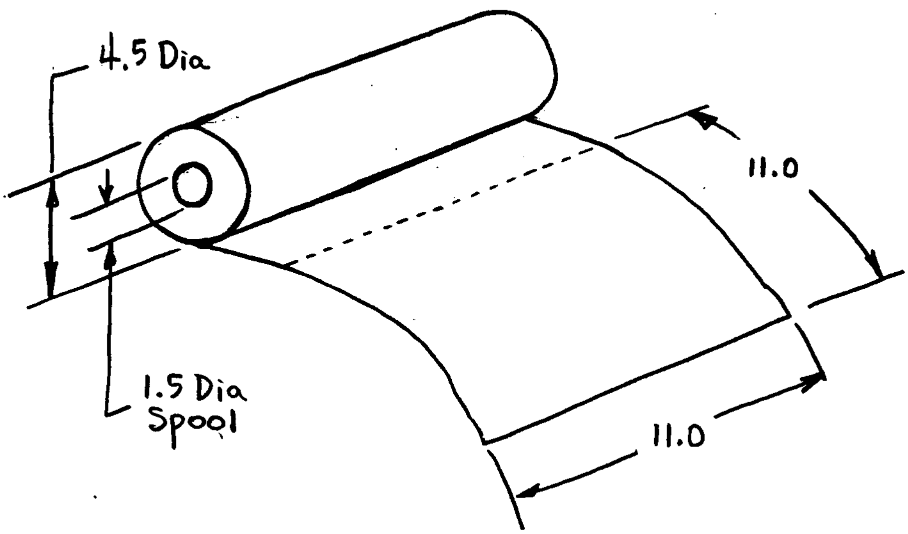
Interface with space vehicle general debris processing techniques.

References:

None

Dispenser Weight = 3.0 lbs.
Volume 5 x 5 x 12 inches = 700 cu.in. ÷ 1728 = .405 cu.ft.

Commercial roll of 77 paper wipes, 11 x 11 inch sheet size (perforated)



Weight per sheet = .0082 lbs.
Weight per roll = .70 lbs.

Volume per roll 4.5 Dia x 11 inches = $3.1417 \times 2.25^2 \times 11$
= 174.86 cu in ÷ 1728
= .10069 cu ft

DETERMINATION OF DISPENSER REQUIREMENTS

Assume installation of dispensers in following quantities:

1 dispenser for 6-man crew size
2 dispensers for 12-man crew size
4 dispensers for 25- and 50-man crew size

INSTALLED WEIGHTS AND VOLUMES

	Dispenser Weight and Volume		Suggested Quantity		Installed Weight and Volume
(6)	3.0 lbs	x	1	=	3.0 lbs
	.405 cu ft	x	1	=	.405 cu ft
(12)	3.0 lbs	x	2	=	6.0 lbs
	.405 cu ft	x	2	=	.810 cu ft
(25) and (50)	3.0 lbs	x	4	=	12.0 lbs
	.405 cu ft	x	4	=	1.620 cu ft

DETERMINATION OF WIPE REQUIREMENTS

A. Assume 1 sheet per hand wash, for drying hands, based on galley-sink usage schedule (same as that outlined for Concept 6.3.11):

	Prior to Meal Prep		During Meal Prep		After Meal Prep		After Clean-Up		Number of Times Per Meal Period		Number of Meal Periods		Normal Washes Per Day		33% Contingency Use		Total Washings Per Day
(6)	1	+	0	+	1	+	1	=	3	x	3	=	9	+	3	=	12
(12)	1	+	1	+	1	+	1	=	4	x	3	=	12	+	4	=	16
(25)	1	+	2	+	1	+	1	=	5	x	3	=	15	+	5	=	20
(50)	1	+	4	+	1	+	1	=	7	x	3	=	21	+	7	=	28

B. Assume 1 sheet per 3 man-meals during preparation of meals:

	Number of Meal Periods		Number of Meals		Meals Per Day		Meal Wipe Ratio		Number of Sheets Required
(6)	3	x	6	=	18	÷	3	=	6
(12)	3	x	12	=	36	÷	3	=	12
(25)	3	x	25	=	75	÷	3	=	25
(50)	3	x	50	=	150	÷	3	=	50

C. Assume 1 sheet per 3 returned meal trays for wiping food residue from a rubber scraper, if used, or directly from trays:

	Number of Meal Periods		Number of Meals		Meals Per Day		Tray Wipe Ratio		Number of Sheets Required
(6)	3	x	6	=	18	÷	3	=	6
(12)	3	x	12	=	36	÷	3	=	12
(25)	3	x	25	=	75	÷	3	=	25
(50)	3	x	50	=	150	÷	3	=	50

D. Assume extra 20% of total for contingency factor.

Total wipe requirements per day are as follows:

	A		B		C		Sub Total		D		Total Sheets Per Day
(6)	12	+	6	+	6	=	24	+	5	=	29
(12)	16	+	12	+	12	=	40	+	8	=	48
(25)	20	+	25	+	25	=	70	+	14	=	84
(50)	28	+	50	+	50	=	128	+	25	=	153

QUANTITY OF WIPES FOR MISSIONS

	Total Sheets Per Day		Number Days In Resupply Period		Resupply Quantity Sheets		Number of Resupplies In 10 Years		10 Year Resupply Quantity
	29	x	14	=	406	x	260	=	105,560
(6)	29	x	90	=	2610	x	40	=	104,400
	29	x	180	=	5220	x	20	=	104,400
	48	x	14	=	672	x	260	=	174,720
(12)	48	x	90	=	4320	x	40	=	172,800
	48	x	180	=	8640	x	20	=	172,800
	84	x	14	=	1176	x	260	=	305,760
(25)	84	x	90	=	7560	x	40	=	302,400
	84	x	180	=	15,120	x	20	=	302,400
	153	x	14	=	2142	x	260	=	556,920
(50)	153	x	90	=	13,770	x	40	=	550,800
	153	x	180	=	27,540	x	20	=	550,800

Note: It appears logical to provide complete commercial rolls for resupply missions in lieu of sheet quantities.

CONVERSION OF WIPE QUANTITIES TO COMMERCIAL ROLLS FOR RESUPPLY

	Number Days In Resupply Period	Number Days In Resupply Quantity Period		Number of Sheets Per Roll		Number of Rolls Required		* Resupply Nearest Full Roll		Number of Resupplies In 10 Years		10 Year Resupply Full Rolls
	14	406	÷	77	=	5.2	→	5	x	260	=	1300
(6)	90	2610	÷	77	=	33.9	→	34	x	40	=	1360
	180	5220	÷	77	=	67.8	→	68	x	20	=	1360
	14	672	÷	77	=	8.7	→	9	x	260	=	2340
(12)	90	4320	÷	77	=	56.1	→	56	x	40	=	2240
	180	8640	÷	77	=	112.2	→	112	x	20	=	2240
	14	1176	÷	77	=	15.3	→	15	x	260	=	3900
(25)	90	7560	÷	77	=	98.2	→	98	x	40	=	3920
	180	15120	÷	77	=	196.4	→	196	x	20	=	3920
	14	2142	÷	77	=	27.8	→	28	x	260	=	7280
(50)	90	13770	÷	77	=	178.8	→	179	x	40	=	7160
	180	27540	÷	77	=	357.6	→	358	x	20	=	7160

*Note: Adjusting resupply requirements to nearest full single roll has slight effect in increasing or decreasing the contingency quantity.

RESUPPLY WEIGHTS (FOR COMMERCIAL ROLLS)

	Number Days In Resupply Period	Resupply Nearest Full Rolls		Weight Per Roll (lbs)		Resupply Weight (lbs)		Number of Resupplies In 10 Years		10 Year Resupply Weight (lbs)
(6)	14	5	x	.70	=	3.5	x	260	=	910.0
	90	34	x	.70	=	23.8	x	40	=	952.0
	180	68	x	.70	=	47.6	x	20	=	952.0
(12)	14	9	x	.70	=	6.3	x	260	=	1638.0
	90	56	x	.70	=	39.2	x	40	=	1568.0
	180	112	x	.70	=	78.4	x	20	=	1568.0
(25)	14	15	x	.70	=	10.5	x	260	=	2730.0
	90	98	x	.70	=	68.6	x	40	=	2744.0
	180	196	x	.70	=	137.2	x	20	=	2744.0
(50)	14	28	x	.70	=	19.6	x	260	=	5096.0
	90	179	x	.70	=	125.3	x	40	=	5012.0
	180	358	x	.70	=	250.6	x	20	=	5012.0

RESUPPLY VOLUMES (FOR COMMERCIAL ROLLS)

	Number Days In Resupply Period	Resupply Nearest Full Rolls		Volume Per Roll (cu ft)		Resupply Volume (cu ft)		Number of Resupplies In 10 Years		10 Year Resupply Volume (cu ft)
(6)	14	5	x	.10069	=	.50345	x	260	=	130.897
	90	34	x	.10069	=	3.42346	x	40	=	136.938
	180	68	x	.10069	=	6.84692	x	20	=	136.938
(12)	14	9	x	.10069	=	.90621	x	260	=	235.615
	90	56	x	.10069	=	5.63864	x	40	=	225.546
	180	112	x	.10069	=	11.27728	x	20	=	225.546
(25)	14	15	x	.10069	=	1.51035	x	260	=	392.691
	90	98	x	.10069	=	9.86762	x	40	=	394.705
	180	196	x	.10069	=	19.73524	x	20	=	394.705
(50)	14	28	x	.10069	=	2.81932	x	260	=	733.023
	90	179	x	.10069	=	18.02351	x	40	=	720.940
	180	358	x	.10069	=	36.04702	x	20	=	720.940

DETERMINATION OF CREW OPERATING TIME

Because of the myriad of possible functions involving impromptu usage of utility wipes, crew operating time can be considered indeterminate; however, in acknowledgement that time is expended each time a wipe is employed during the clean-up operations, an assumption is made of 30 seconds (.5 minute) per wipe:

	Number of Wipes Used Per Day		Time Per Wipe (min.)		Crew Time Per Day Minutes		Hours
(6)	29	x	.5	=	14.5	→	.24
(12)	48	x	.5	=	24.0	→	.40
(25)	84	x	.5	=	42.0	→	.70
(50)	153	x	.5	=	76.5	→	1.28

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	(6)	(12)	(25)
A. Engineering	$ 7,500	$ 7,500	$ 7,500
B. Tooling	5,000	5,000	5,000
C. Fabrication	(1) 1,000	(2) 2,000	(4) 4,000
D. Qualification	10,000	10,000	10,000
E. Documentation	5,000	5,000	5,000
TOTALS →	$ 28,500	$ 29,500	$ 31,500

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.3.15 Title: Dispenser For Reusable Galley Utility Wipes

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle water reclamation system (presuming existence of a general laundry facility).

References:

None

Dispenser Weight = 5.0 lbs
Volume 13 x 13 x 5 inches = 845 cu.in. ÷ 1728 = .489 cu.ft.

Reusable Cloth Wipe Weight = .075 lbs
Volume (folded) 6 x 6 x .08 inches = 2.88 cu.in. ÷ 1728 = .001672 cu ft

DETERMINATION OF DISPENSER REQUIREMENTS

Assume installation of dispensers in following quantities:

1 dispenser for 6-man crew size
2 dispensers for 12-man crew size
4 dispensers for 25- and 50-man crew size

DISPENSER WEIGHTS AND VOLUMES

	Unit Weight and Volume		Suggested Quantity		Dispenser Weight and Volume
(6)	5.0 lbs	x	1	=	5.0 lbs
	.489 cu ft	x	1	=	.489 cu ft
(12)	5.0 lbs	x	2	=	10.0 lbs
	.489 cu ft	x	2	=	.978 cu ft
(25) and (50)	5.0 lbs	x	4	=	20.0 lbs
	.489 cu ft	x	4	=	1.956 cu ft

DETERMINATION OF WIPE REQUIREMENTS

A. Assume 1 sheet per hand wash, for drying hands, based on galley-sink usage schedule (same as that outlined for Concept 6.3.11):

	Prior to Meal Prep		During Meal Prep		After Meal Prep		After Clean-Up		Number of Times Per Meal Period		Number of Meal Periods		Normal Washes Per Day		33% Contingency Use		Total Washings Per Day
(6)	1	+	0	+	1	+	1	=	3	x	3	=	9	+	3	=	12
(12)	1	+	1	+	1	+	1	=	4	x	3	=	12	+	4	=	16
(25)	1	+	2	+	1	+	1	=	5	x	3	=	15	+	5	=	20
(50)	1	+	4	+	1	+	1	=	7	x	3	=	21	+	7	=	28

B. Assume 1 sheet per 3 man-meals during preparation of meals:

	Number of Meal Periods		Number of Meals		Meals Per Day		Meal Wipe Ratio		Number of Sheets Required
(6)	3	x	6	=	18	÷	3	=	6
(12)	3	x	12	=	36	÷	3	=	12
(25)	3	x	25	=	75	÷	3	=	25
(50)	3	x	50	=	150	÷	3	=	50

C. Assume 1 sheet per 3 returned meal trays for wiping food residue from a rubber scraper, if used, or directly from trays:

	Number of Meal Periods		Number of Meals		Meals Per Day		Tray Wipe Ratio		Number of Sheets Required
(6)	3	x	6	=	18	÷	3	=	6
(12)	3	x	12	=	36	÷	3	=	12
(25)	3	x	25	=	75	÷	3	=	25
(50)	3	x	50	=	150	÷	3	=	50

D. Assume extra 20% of total for contingency factor.

Total wipe requirements per day are as follows:

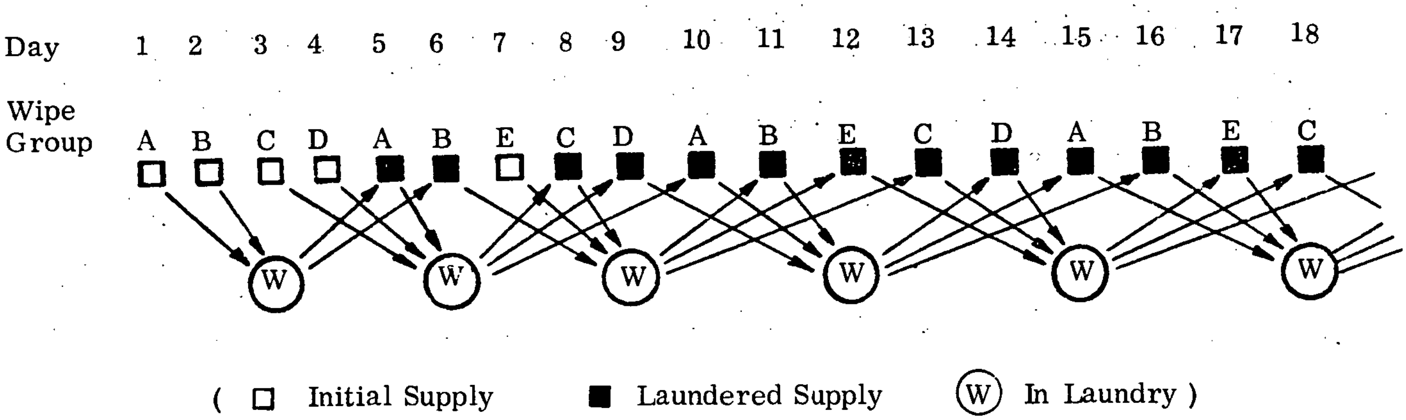
	A		B		C		Sub Total		D		Total Sheets Per Day
(6)	12	+	6	+	6	=	24	+	5	=	29
(12)	16	+	12	+	12	=	40	+	8	=	48
(25)	20	+	25	+	25	=	70	+	14	=	84
(50)	28	+	50	+	50	=	128	+	25	=	153

RATIONALE FOR SUPPLIES OF REUSABLE WIPES

Assume existence of laundering facilities on the space vehicle, and that general laundering is accomplished every third day with a two-day lapse for return of articles from laundry.

The following figure exemplifies the assumed schedule of usage and laundering for a group-quantity of wipes, indicating availability of proper quantities for day-to-day clean-up functions. If the group quantity is *29 wipes for A through E inclusive (typical of 6-man crew size), then 58 wipes are taken from initial supply for the first and second days (Group A and B) after which they are sent to laundry. An additional 58 wipes (Group C and D) are taken from initial supply to satisfy the third and fourth days after which they are sent to laundry. In the interim, the 58 wipes of Group A and B have been returned and are used on the fifth and sixth day, then back to laundry. Since all heretofore used wipes are not available, the remaining 29 wipes (Group E) are taken from initial supply for the seventh day clean-up requirements. The cycle continues with laundered group quantities until deteriorated and replenished during a subsequent resupply mission.

(*Group quantity of wipes varies with crew size.)



Each wipe is laundered 1 time per 5 days of mission duration.

Assume that the useful life of these wipes, which are not subjected to any abrasive action, is approximately 90 launderings or approximately 450 days.

REPLACEMENT SCHEDULES FOR WIPES

For 14-day Resupply:	Replace each 32 missions (448 days), 8 times in 10 years.
For 90-day Resupply:	Replace each 5 missions (450 days), 8 times in 10 years.
For 180-day Resupply:	Replace each 2.5 missions (450 days), 8 times in 10 years.

QUANTITY OF WIPES FOR INITIAL SUPPLY

	Wipes Per Day		Days Before Wash		Wipes In Laundry		2-Day Quantity On Hand		Initial Supply Wipes
6	29	x	3	=	87	+	58	=	145
12	48	x	3	=	144	+	96	=	240
25	84	x	3	=	252	+	168	=	420
50	153	x	3	=	459	+	306	=	765

QUANTITY OF WIPES FOR RESUPPLY

	Number Days In Resupply Period	Initial Supply		Average Resupply		Number of Resupplies In 10 Years		10 Year Resupply
(6)	14	145 ÷ 32	=	4.53	x	260	=	1177.8
	90	145 ÷ 5	=	29.00	x	40	=	1160.0
	180	145 ÷ 2.5	=	58.00	x	20	=	1160.0
(12)	14	240 ÷ 32	=	7.50	x	260	=	1950.0
	90	240 ÷ 5	=	48.00	x	40	=	1920.0
	180	240 ÷ 2.5	=	96.00	x	20	=	1920.0
(25)	14	420 ÷ 32	=	13.13	x	260	=	3413.8
	90	420 ÷ 5	=	84.00	x	40	=	3360.0
	180	420 ÷ 2.5	=	168.00	x	20	=	3360.0
(50)	14	765 ÷ 32	=	23.91	x	260	=	6216.6
	90	765 ÷ 5	=	153.00	x	40	=	6120.0
	180	765 ÷ 2.5	=	306.00	x	20	=	6120.0

WEIGHTS OF WIPES NEEDED

	Number Days In Resupply Period	Initial Supply Wipes	Weight Per Wipe (lbs)	Initial Supply Weight (lbs)		Average Resupply Weight (lbs)	Number of Resupplies In 10 Years	10 Year Resupply Weight (lbs)
(6)	14	145 x	.075 =	10.875 ÷	32 =	.3398 x	260 =	88.358
	90	145 x	.075 =	10.875 ÷	5 =	2.175 x	40 =	87.000
	180	145 x	.075 =	10.875 ÷	2.5 =	4.350 x	20 =	87.000
(12)	14	240 x	.075 =	18.000 ÷	32 =	.5625 x	260 =	146.250
	90	240 x	.075 =	18.000 ÷	5 =	3.600 x	40 =	144.000
	180	240 x	.075 =	18.000 ÷	2.5 =	7.200 x	20 =	144.000
(25)	14	420 x	.075 =	31.500 ÷	32 =	.9844 x	260 =	255.936
	90	420 x	.075 =	31.500 ÷	5 =	6.300 x	40 =	252.000
	180	420 x	.075 =	31.500 ÷	2.5 =	12.600 x	20 =	252.000
(50)	14	765 x	.075 =	57.375 ÷	32 =	1.7930 x	260 =	466.170
	90	765 x	.075 =	57.375 ÷	5 =	11.475 x	40 =	459.000
	180	765 x	.075 =	57.375 ÷	2.5 =	22.950 x	20 =	459.000

VOLUMES OF WIPES NEEDED

	Number Days In Resupply Period	Initial Supply Wipes	Volume Per Wipe (cu ft)	Initial Supply Volume (cu ft)		Average Resupply Volume (cu ft)	Number of Resupplies In 10 Years	10 Year Resupply Volume (cu ft)
(6)	14	145 x	.001672 =	.2424 ÷	32 =	.00757 x	260 =	1.968
	90	145 x	.001672 =	.2424 ÷	5 =	.04848 x	40 =	1.939
	180	145 x	.001672 =	.2424 ÷	2.5=	.09696 x	20 =	1.939
(12)	14	240 x	.001672 =	.4012 ÷	32 =	.01253 x	260 =	3.258
	90	240 x	.001672 =	.4012 ÷	5 =	.08024 x	40 =	3.210
	180	240 x	.001672 =	.4012 ÷	2.5=	.16048 x	20 =	3.210
(25)	14	420 x	.001672 =	.7022 ÷	32 =	.02194 x	260 =	5.704
	90	420 x	.001672 =	.7022 ÷	5 =	.14044 x	40 =	5.618
	180	420 x	.001672 =	.7022 ÷	2.5=	.28088 x	20 =	5.618
(50)	14	765 x	.001672 =	1.2791 ÷	32 =	.03997 x	260 =	10.392
	90	765 x	.001672 =	1.2791 ÷	5 =	.25582 x	40 =	10.233
	180	765 x	.001672 =	1.2791 ÷	2.5=	.51164 x	20 =	10.233

INSTALLED WEIGHTS AND VOLUMES

	Dispenser Units		Initial Supply Wipes		Installed Total
(6)	5.0 lbs	+	10.88 lbs	=	15.88 lbs
	.489 cu ft	+	.2424 cu ft	=	.7394 cu ft
(12)	10.0 lbs	+	18.00 lbs	=	28.00 lbs
	.978 cu ft	+	.4012 cu ft	=	1.3792 cu ft
(25)	20.0 lbs	+	31.50 lbs	=	51.50 lbs
	1.956 cu ft	+	.7022 cu ft	=	2.6582 cu ft
(50)	20.0	+	57.38 lbs	=	77.38 lbs
	1.956 cu ft	+	1.2791 cu ft	=	3.2351 cu ft

DETERMINATION OF CREW OPERATING TIME

Because of the myriad of possible functions involving impromptu usage of utility wipes, crew operating time can be considered indeterminate; however, in acknowledgement that time is expended each time a wipe is employed during the clean-up operations, an assumption is made of 30 seconds (.5 minute) per wipe.

	Number of Wipes Used Per Day		Time Per Wipe (min)		Crew Time Per Day Minutes		Crew Time Per Day Hours
(6)	29	x	.5	=	14.5	→	.24
(12)	48	x	.5	=	24.0	→	.40
(25)	84	x	.5	=	42.0	→	.70
(50)	153	x	.5	=	76.5	→	1.28

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

	(6)	(12)	(25)
A. Engineering	$ 10,000	$ 10,000	$ 10,000
B. Tooling	5,000	5,000	5,000
C. Fabrication	(1) 1,000	(2) 2,000	(4) 4,000
D. Qualification	10,000	10,000	10,000
E. Documentation	5,000	5,000	5,000
SUB-TOTALS →	31,000	32,000	34,000
F. Procure Cloth Wipes ($1.00 each)	(145) 145	(240) 240	(420) 420
TOTALS →	$ 31,145	$ 32,240	$ 34,420

ASSOCIATED LAUNDERING REQUIREMENTS

Assume existence of remotely located laundering facility in space vehicle.

Base operating time requirements on estimates of:

(A) 25-30 minutes for wash/rinse/spin-dry of 10-15 pounds of cloth articles → 2 minutes (.033 hrs) per pound

(B) 15-20 minutes for electric drying of 10-15 pounds of cloth articles → 1.5 minutes (.025 hrs) per pound

Base power requirements on estimates of:

(A) Automatic Washing Machine rating of 1500 watts

(B) Automatic Drying Machine rating of 6000 watts, (i.e., 4500W heat element, 1500W motor)

Base water requirements on estimates of 5-6 pounds of water per pound for washing plus 15 pounds of water per pound for rinsing.

Therefore, the following assumptions will be used where applicable:

(A) Laundering: 20 lbs water per 1 pound cloth articles
50 watt-hours per 1 pound cloth articles

(B) Drying: 150 watt-hours per 1 pound cloth articles

Determination of associated water and power requirements with laundering schedule adjusted for DAILY AVERAGE; (i.e., if laundering occurs every third day and a 3-day soiled quantity is washed and dried at such time, then the adjusted daily average for laundering estimates is equal to the daily usage rate).

(6)	(12)	(25)	(50)
29 per day	48 per day	84 per day	153 per day

ASSOCIATED DAILY WATER NEED

	Average Wipes		Weight Per Wipe		Average Cloth Weight		Ratio Water to Cloth		Average Water Weight
(6)	29	x	.075 lbs	=	2.18 lbs	x	20	=	43.60 lbs
(12)	48	x	.075 lbs	=	3.60 lbs	x	20	=	72.00 lbs
(25)	84	x	.075 lbs	=	6.30 lbs	x	20	=	126.00 lbs
(50)	153	x	.075 lbs	=	11.48 lbs	x	20	=	229.60 lbs

ASSOCIATED DAILY POWER NEED

	Average Wipes		Weight Per Wipe		Average Cloth Weight		Wash and Dry Watt-Hour Ratio to Cloth		Average Energy
(6)	29	x	.075 lbs	=	2.18 lbs	x	200	=	436.0 watt-hrs
(12)	48	x	.075 lbs	=	3.60 lbs	x	200	=	720.0 watt-hrs
(25)	84	x	.075 lbs	=	6.30 lbs	x	200	=	1260.0 watt-hrs
(50)	153	x	.075 lbs	=	11.48 lbs	x	200	=	2296.0 watt-hrs

CONCEPT BACK-UP INFORMATION SHEET
FOOD SYSTEM STUDY

Concept # 6.3.16 **Title:** Stowage of Cleaning Equipment

Assumptions:

Formulae:

Significant Factors:

General Information:

Interface with space vehicle electrical power system and structural design.

References:

None

DETERMINATION OF STORAGE CABINET VOLUME REQUIREMENT

* (Assume storage of 1-week supplies in galley area; weekly replenishment from remote general storage facility with space vehicle.)

Ref. Concept Number	*Stored Articles	Volume - Cubic Feet			
		(6)	(12)	(25)	(50)
6.1.2	Vacuum Cleaner Unit	.2604	.2604	.2604	.2604
	11 bags @ .00156 cu ft	.01716	.01716		
	21 bags @ .00156 cu ft			.03276	
	32 bags @ .00156 cu ft				.04992
6.1.3	Vacuum Cleaner Unit	2.604	2.604	2.604	2.604
	11 bags @ .00793 cu ft	.08723	.08723	.08723	
	11 bags @ .01157 cu ft				.12727
6.1.7	140 towelettes @ .0004884 cu ft	.06837			
	210 towelettes @ .0004884 cu ft		.10256		
	280 towelettes @ .0004884 cu ft			.13675	.13675
	— — — — OR — — — — — —				
6.1.8	14 wash cloths @ .001672 cu ft	.02341			
	21 wash cloths @ .001672 cu ft		.03511		
	28 wash cloths @ .001672 cu ft			.04682	.04682
	Cleaning Fluid	.22715	.35511	.48307	.48307
6.1.10	Astrovac Cleaning Unit	2.604	2.604	2.604	2.604
	3 sponges @ .000309 cu ft	.00093			
	4 sponges @ .000309 cu ft		.00124		
	7 sponges @ .000309 cu ft			.00216	.00216
	Cleaning Fluid	.05243	.08197	.11151	.11151
6.2.1	1 pkg of 300 napkins @ .081 cu ft	.081			
	2 pkg of 300 napkins @ .081 cu ft		.162		
	4 pkg of 300 napkins @ .081 cu ft			.324	
	8 pkg of 300 napkins @ .081 cu ft				.648
	— — — — OR — — — — — —				
6.2.2	120 napkins @ .001672 cu ft	.2006			
	240 napkins @ .001672 cu ft		.4012		
	500 napkins @ .001672 cu ft			.836	
	1000 napkins @ .001672 cu ft				1.672
6.2.3	126 towelettes @ .0004884 cu ft	.06154			
	252 towelettes @ .0004884 cu ft		.12308		
	525 towelettes @ .0004884 cu ft			.25641	
	1050 towelettes @ .0004884 cu ft				.51282

(continued)

Ref. Concept Number	*Stored Articles	Volume - Cubic Feet			
		(6)	(12)	(25)	(50)
6.2.4	63 bags @ .000156 cu ft 126 bags @ .000156 cu ft 273 bags @ .000156 cu ft	.00983	.01966	.04259	.04259
6.3.1	5 bags @ .01446 cu ft 10 bags @ .01446 cu ft 20 bags @ .01446 cu ft	.07230	.07230	.14460	.28920
6.3.2	21 bags @ .00289 cu ft 42 bags @ .00289 cu ft 84 bags @ .00289 cu ft	.06069	.06069	.12138	.24276
6.3.7	Debris Transporter Unit	3.906	5.208	7.812	10.416
6.3.11	Cleaning Fluid	.03696	.04994	.06160	.08624
6.3.13	Surfactant	.16345	.25739	.47964	.95928
6.3.14	3 rolls of 77 wipes @ .10069 cu ft 5 rolls of 77 wipes @ .10069 cu ft 8 rolls of 77 wipes @ .10069 cu ft 14 rolls of 77 wipes @ .10069 cu ft	.30207	.50345	.80552	1.40966
	OR				
6.3.15	145 wipes @ .001672 cu ft 240 wipes @ .001672 cu ft 420 wipes @ .001672 cu ft 765 wipes @ .001672 cu ft	.24244	.40128	.70224	1.27908
TOTALS (Excluding 6.1.7, 6.2.1 and 6.3.15)		10.69015	12.74193	16.79169	21.91970

DETERMINATION OF ELECTRICAL POWER USAGE

Assume that 6 ultraviolet lamps (15W) are operating continuously except when doors are opened which removes power for safety:

6 lamps @ 15 watts = 90 watts x 24 hours = 2160 watt-hours per day

10-YEAR OPERATING TIME OF EQUIPMENT

Daily operating time is multiplied by 3650 to obtain equipment operating time over a 10-year period.

24 hours/day x 3650 = 87,600 hours in 10 years

DETERMINATION OF TOTAL COST FOR INITIAL LAUNCH

Assume costs for initial launch equipment, excluding expendables, to be as follows:

		(6)	(12)	(25)
A.	Engineering	$ 25,000	$ 25,000	$ 25,000
B.	Tooling	20,000	20,000	20,000
C.	Fabrication	15,000	20,000	25,000
D.	Qualification	10,000	10,000	10,000
E.	Documentation	5,000	5,000	5,000
	TOTALS →	$ 75,000	$ 80,000	$ 85,000

FUNCTIONAL SUBSYSTEM AREA 7.0

PROVIDE FOR RECORDING OF FOOD

FUNCTIONAL SUBSYSTEM
AREA 7.0

Narrative information for this functional subsystem area is presented in Final Report, Volume I, Section III, paragraph 7.0.