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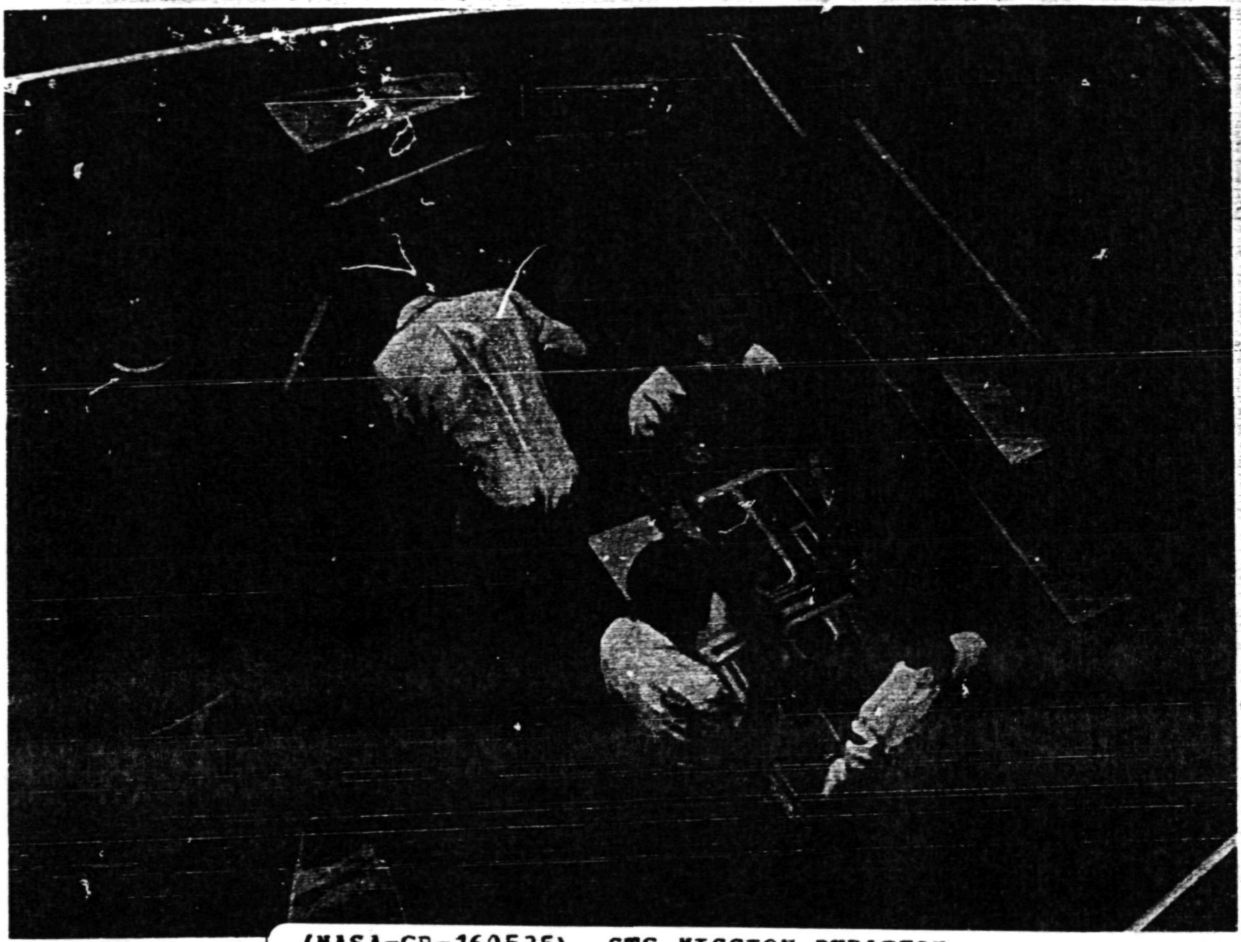

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STS Mission Duration Enhancement Study (Orbiter Habitability)

CONTRACT NAS9-15903

DECEMBER 1979

Rockwell International

Shuttle Orbiter Division

Space Systems Group

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FINAL REPORT

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CONTRACT NAS 9-15903

DECEMBER 1979

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FOREWORD

This final report for an STS Mission Duration Enhancement Study (Orbiter Habitability) is submitted by Rockwell International Corporation through its Space Systems Group to NASA's Lyndon B. Johnson Space Center in response to DRL Number T-1559 Line Item Nos. 3, 4, and 5 of Contract NAS 9-15903 dated June 15, 1979.

This report was prepared by A. Dean Carlson, Study Manager of Advanced Systems of the Shuttle Orbiter Division with contributions from C. C. Johnson, Consultant, Ken Henn, Rich Demers, Tom Healy and Frank Chapel.

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I. INTRODUCTION

When the Space Shuttle becomes operational in the 1980's, it will provide routine manned operation in low-earth orbits. The initial capability will be for missions of about seven days' duration. Extending the mission duration would provide, at the earliest possible time and for a relatively low investment cost, a space platform that could support a wide variety of missions and attract an increasing number of users.

Studies are now underway concerning a power extension package (PEP) for augmenting the orbiter's electrical power system to support mission durations in excess of seven days. Mission cost effectiveness can be significantly improved if mission duration is extended at small weight and cost increases. Rockwell studies have shown that the cost per day on-orbit can be sharply reduced, provided the penalties in kit weight, volume, and cost are not excessive. A primary issue in extending the on-orbit staytime of the orbiter vehicle is to reduce the use of consumables. Many subsystem options are available for providing this capability, each having a different weight, cost, or volume penalty. A major concern in accomplishing extended duration missions is the effectiveness of the crew in performing their tasks. The habitability considerations and those improvements which are implemented will have a significant effect on this new operational capability.

A key issue of this study was the analysis and definition of improvements in habitability which can be recommended for implementation in steps to supply timely support of mission needs. Each step can provide developments which can be used in subsequent steps and can reduce costs. A major part of the analysis was to identify improvements and establish approaches by which the most effective of these can be implemented.

The objective of this study was to investigate means of enhancing the orbiter's habitability and to provide a suitable environment for longer duration and/or larger crew.

Rockwell's Shuttle Orbiter Division conducted the STS Mission Duration Enhancement Study (Orbiter Habitability) in compliance with the contract statement of work. Rockwell conducted the study at its Downey facility under the direction of M. W. Jack Bell, Director, Advanced Systems (AS). Mr. Carlson directed the technical tasks and controlled the resources of the study. He was assisted in this contract by C. C. Johnson, a consultant who is retired from NASA/JSC and lives in the Houston area.

The following section presents the technical plan which describes what was done on each task of the contract and how we accomplished each of the tasks. A schedule is presented showing the time phasing of each task and the major outputs.

II. TECHNICAL PLAN

This study was divided into four tasks. In the following paragraphs, the purpose of the task is presented and the technical approach describes how the work was done and what the end products were. A schedule is also presented showing the task start and completion times, schedule interrelationships and key milestones.

TASK 1 - MID-DECK HABITABILITY IMPROVEMENTS

The purpose of this task was to investigate and develop concepts for improving the habitability of the orbiter mid-deck for Flights 2 through 4 with a two-person crew. This resulted in recommendations that can be implemented without major revisions to the orbiter and can be accomplished in a relatively short time at a low cost without impacting the Orbital Flight Test Program Schedule.

The habitability improvement concepts developed under this task was evaluated to determine relative benefit produced, weight, and schedule impact. This evaluation provided the basis for prioritizing concept implementation.

The major effort of Consultant, C. C. Johnson, was: (1) Review of existing design concepts, RID's and crew station reviews (2) Review of Shuttle Mission Trainer and crew module improvements with astronauts (3) Definition of concepts for improvements. This resulted in recommendations that can be implemented without major revisions to the orbiter and can be accomplished in a relatively short time at a low cost without impacting the Orbital Flight Test Program schedule.

TASK 2 - DEFINITION OF HABITABILITY TERMS

The purpose of this task was first to investigate past studies and investigations, for use of terms that have been used to deal with volumetric requirements for crew size versus mission duration. We then established definitions and terms for use as a baseline for future studies and investigations.

The technical approach was to define key terms such as habitable volume, acceptable performance limit, and minimum tolerance limit and describe the volume areas between the limits and below the minimum tolerance limit. Graphs were made to establish a common requirement per man of volume versus duration for minimum and acceptable habitable conditions.

TASK 3 - INCREASED DURATION CONCEPTS

The purpose of this task was to investigate and develop concepts for increasing the habitability and duration for operational flights with four or more crew members. This resulted in design concepts with estimates of enhancement to be achieved, the delta stowage volume, the number of sleep stations, and increased weight.

The technical approach was to prepare preliminary concepts and descriptions to increase duration, habitability and crew size by two basic approaches. The first was to move the airlock into the payload bay and use the available space for storage and/or sleep stations. The second was to expand the size of the tunnel adapter also for stowage and/or sleep stations, the stowage volume, weight and crew duration was calculated to determine the estimated impact to the orbiter.

TASK 4 - MID-DECK GENERAL ARRANGEMENT DRAWING

The purpose of this task was to produce an accurately dimensioned interior arrangement drawing of the orbiter mid-deck and the known major elements located there. This drawing will be used as a baseline for assessment of future changes of habitability improvements. No drawing such as this existed before.

The approach was to first pull key existing production drawings and layouts to determine primary and secondary structure and the major elements. The final interior arrangement drawing that was produced, is a three-view drawing (J size, 36 inches by roll) to quarter-scale with views and sections of unique installations that will show the configuration for Flight 5, OV-102 with accurate dimensions and all applicable assembly drawings referenced. It contains primary and secondary structure, mid-deck avionic bays, major stowage areas, airlock, waste management area, structural hardpoints, and other major elements that could impact future changes to the mid-deck, and be capable of use for future studies. Rockwell prepared a full size reproductible drawing and a half size reproductible that includes the above, plus galley, bunks, and stowage lockers.

SCHEDULE

The schedule is shown in Figure 1. The study contract was for six months with go-ahead on June 15, 1979.

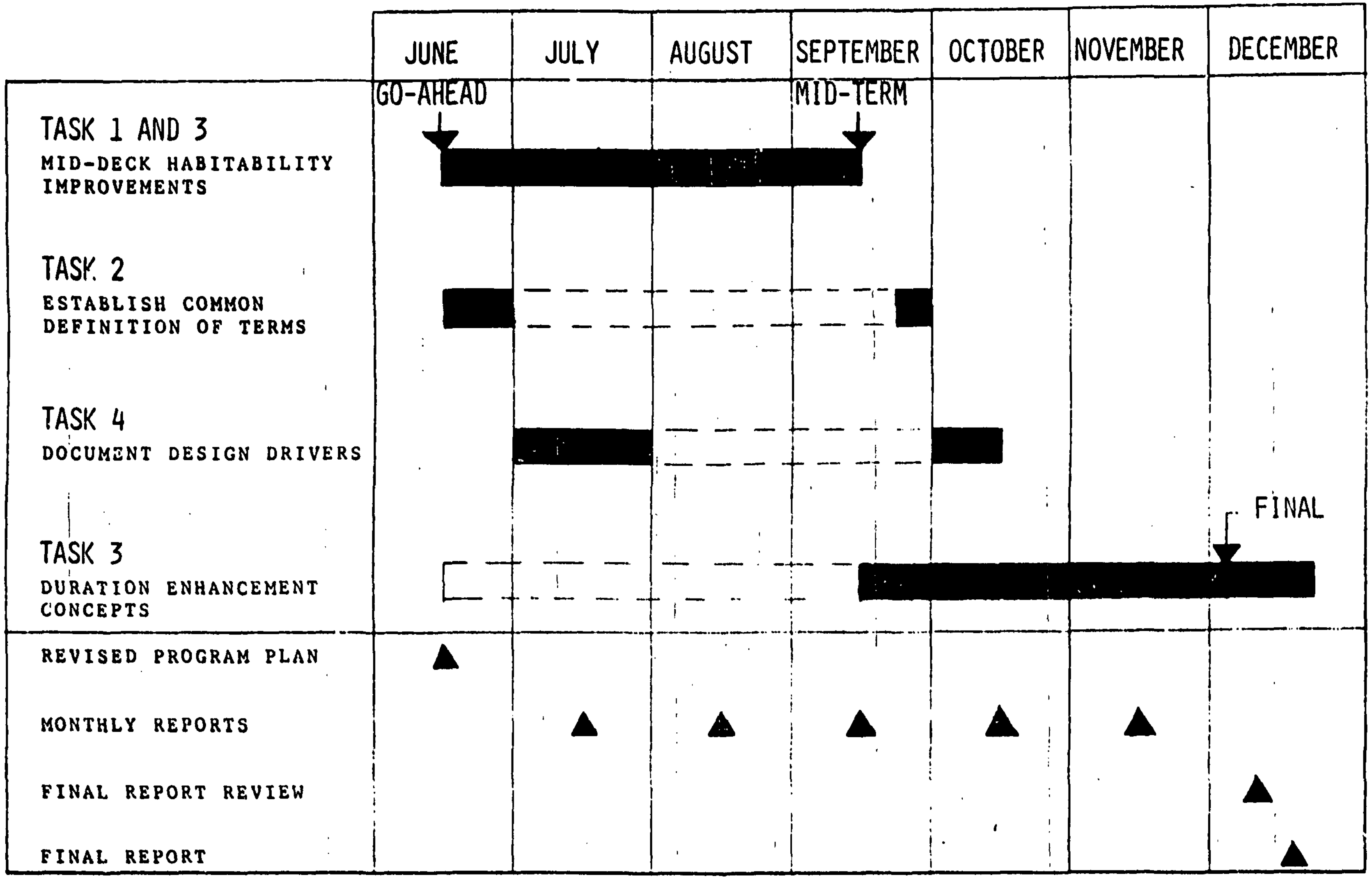


FIGURE 1 - STUDY SCHEDULE

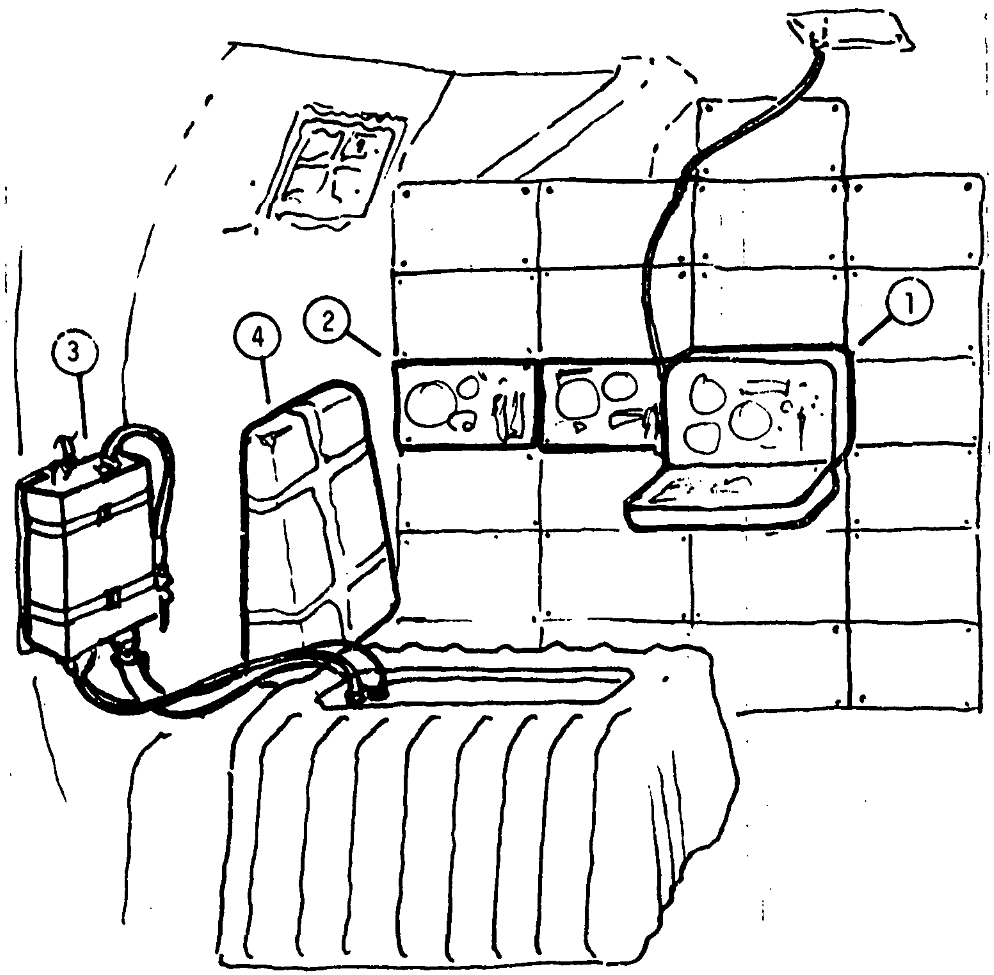
III. MID-DECK HABITABILITY IMPROVEMENTS

After considering what could have the maximum effect on habitability without major changes, the activity concentrated on improvements in procedures and hardware that would reduce the interference of daily living chores with mission objectives.

Habitability provisions are often thought of only as contributions to crew comfort and convenience, but Skylab experience showed that the effect of habitability improvement could be measured as on-orbit man-hours made available to Orbiter or Payload operations. A great deal of time is required by routine, daily living chores such as unstowing equipment and setting up "shop" after arriving on-orbit, meal preparation and personal hygiene. Some of the ways to reduce the time required by these chores is to continue "walk-throughs" in the one-G trainer in the areas of "routine" housekeeping so that small shortcomings in procedures are discovered and rectified before flight. Assigning housekeeping tasks ahead of time to the crew, and training until procedures are streamlined, will speed up these time consuming duties.

The mid-deck baseline on-orbit arrangement before the galley is installed is shown in Figure 2.

A great deal of on-orbit time could also be saved by launching as many items as possible in their on-orbit use positions. This would include the water dispenser, food warmer, sleeping bags, clothing, personal gear, and trash bags. For example: It took 8-10 minutes to remove the water dispenser (GFE) from its stowage locker, install it, and hook-up the hoses, etc., on a preliminary walk-through. It has been determined that the existing water dispenser bracket and mounting is strong enough for launch and recovery but the attaching straps need buckles instead of velcro and the water valves



① FOOD WARMER UNSTOWED AND RESTOWED ON-ORBIT. POSITION BLOCKS SEVERAL LOCKERS. ALSO INTERFERES WITH SLEEP STATIONS

② FOOD TRAYS ON "WRONG" SIDE OF FOOD WARMER.

③ WATER DISPENSER UNSTOWED AND RESTOWED ON-ORBIT. REHYDRATION HOSE NOT WITHIN CONVENIENT REACH OF COOK.

④ ACCESS TO FILTERS AND SHADES AND MEAL PREPARATION MUTUALLY INTERFERE.

FIGURE 2 - PRE-GALLEY BASELINE FOOD PREPARATION LAYOUT

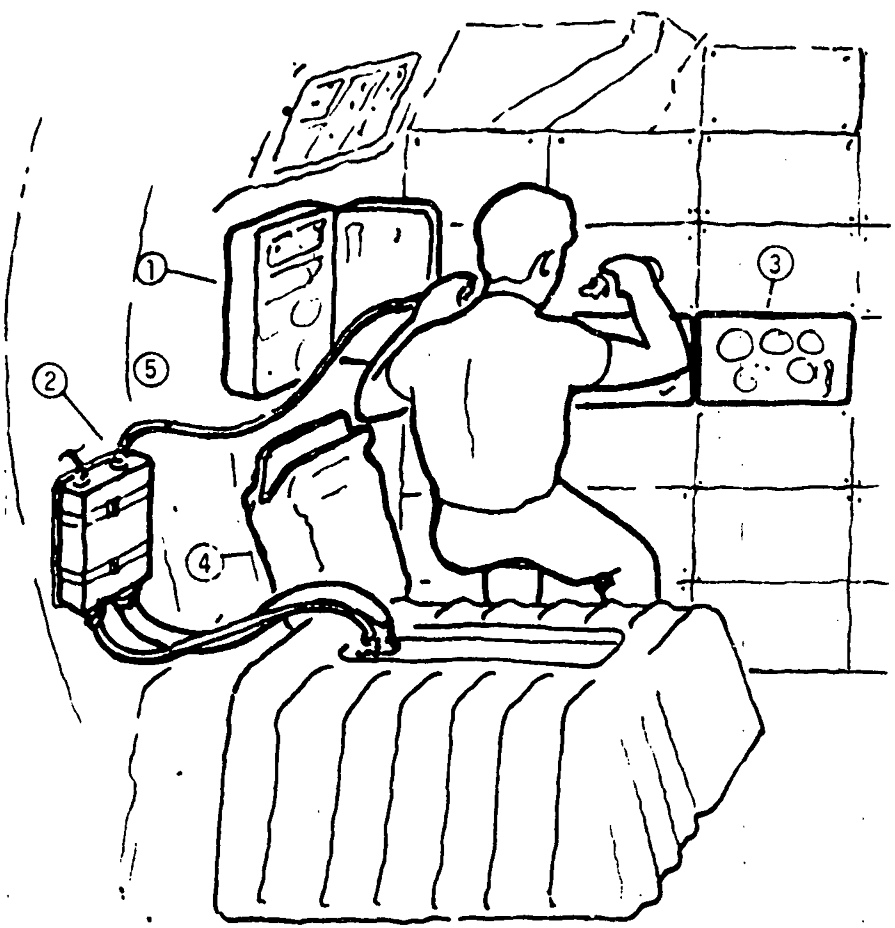
and hoses need positive restraints. Also, the water hose needs to be longer. The food warmer installed on the front of a locker when on-orbit, overlaps several other lockers making access to them difficult, without relocating the food warmer temporarily. The food warmer also overlaps the same space as the sleeping bags necessitating relocating the food warmer to a different location to install the sleeping bag. A recommended food preparation layout (pre-galley) is shown in Figure 3.

Relocating the sleeping bags fore and aft of the DFI on the first four flights would give more privacy and allow the sleeping bags to be launched and recovered in position instead of mounting them on the stowage lockers and having to take them down and put them up everyday.

The existing baseline sleep station for early flights is shown in Figure 4 and the recommended arrangement is shown in Figure 5. Note the use of "soft" fabric lockers for personal gear, and the lack of sleeping bags. The temperature of the crew cabin will allow them to sleep in their clothes for thermal comfort, if they desire. The recommended sleep restraints are shown in Figure 6.

Figure 7 shows an alternate sleeping station arrangement for sleeping up to four on post-DFI flights. This arrangement has an acoustic and light shield, sleep restraints and soft lockers for personal gear, lights and ventilation ducts. This concept of "half sleep stations" would allow unimpeded access to floor storage, which is very difficult now with the horizontal baseline sleep station. An alternative concept showing three vertical sleep stations was also produced, but is not shown in the enclosed figures.

Figure 8 shows the window shade stowage and seat stowage for four seats for the vertical sleeping arrangements. This seat stowage would provide an



(1) FOOD WARMER. RELOCATE AND LAUNCH IN SITU.

(2) WATER DISPENSER. LENGTHEN HOSE AND LAUNCH ENTIRE UNIT IN SITU.

(3) FOOD TRAYS. MOVE TO MORE CONVENIENT LOCATION.

(4) ADD TRASH BAG. LAUNCH IN SITU.

(5) SHADES AND FILTERS. RELOCATE TO BETWEEN DECKS. (SEE LATER FIGURE)

FIGURE 3 - PRE-GALLEY RECOMMENDED FOOD PREPARATION LAYOUT

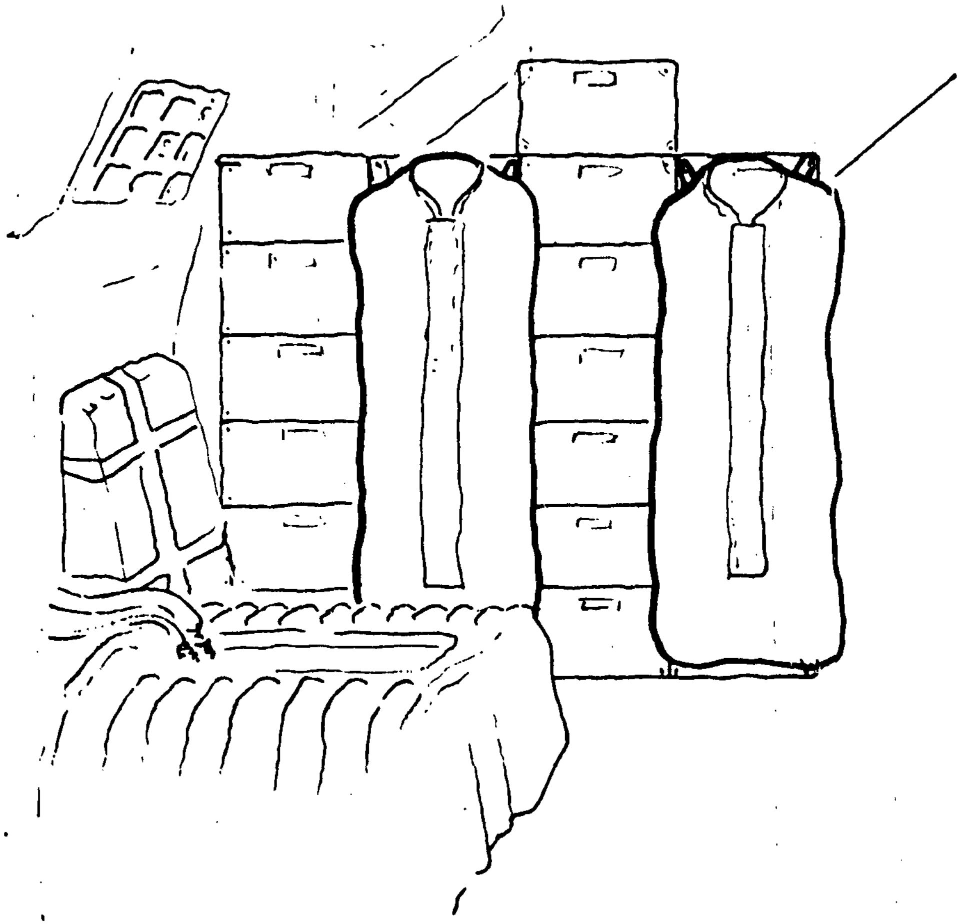
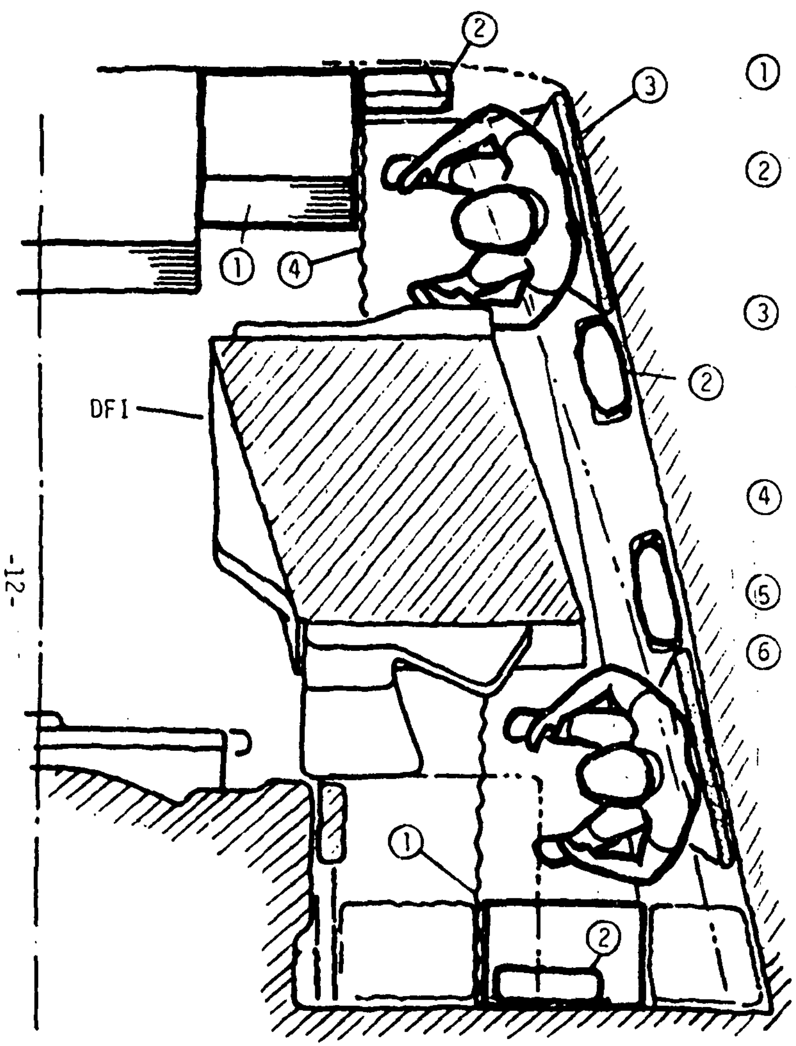


FIGURE 4 - BASELINE DFI FLIGHT, SLEEP STATION ARRANGEMENT



1. "SHORT" LOCKER, IF ADDITIONAL LOCKER VOLUME REQUIRED
2. 'SOFT', FABRIC LOCKERS FOR PERSONAL GEAR. LAUNCH IN SITU.
3. ALTERNATE SLEEP RESTRAINT WITH PROVISIONS FOR PERSONAL STOWAGE. LAUNCH IN SITU. (SEE LATER FIGURE)
4. FABRIC CURTAIN FOR LIGHT AND VENTILATION CONTROL
5. LIGHT
6. VENTILATION DUCT

SLEEP IN CLOTHING FOR THERMAL COMFORT

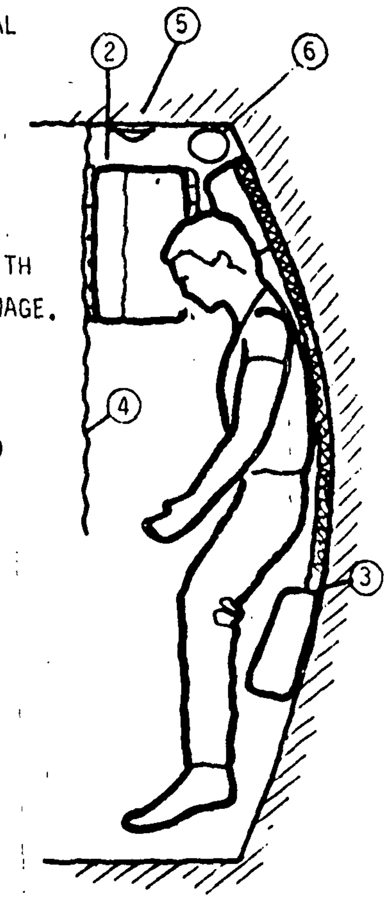


FIGURE 5 - RECOMMENDED DFI FLIGHT SLEEP STATION ARRANGEMENT

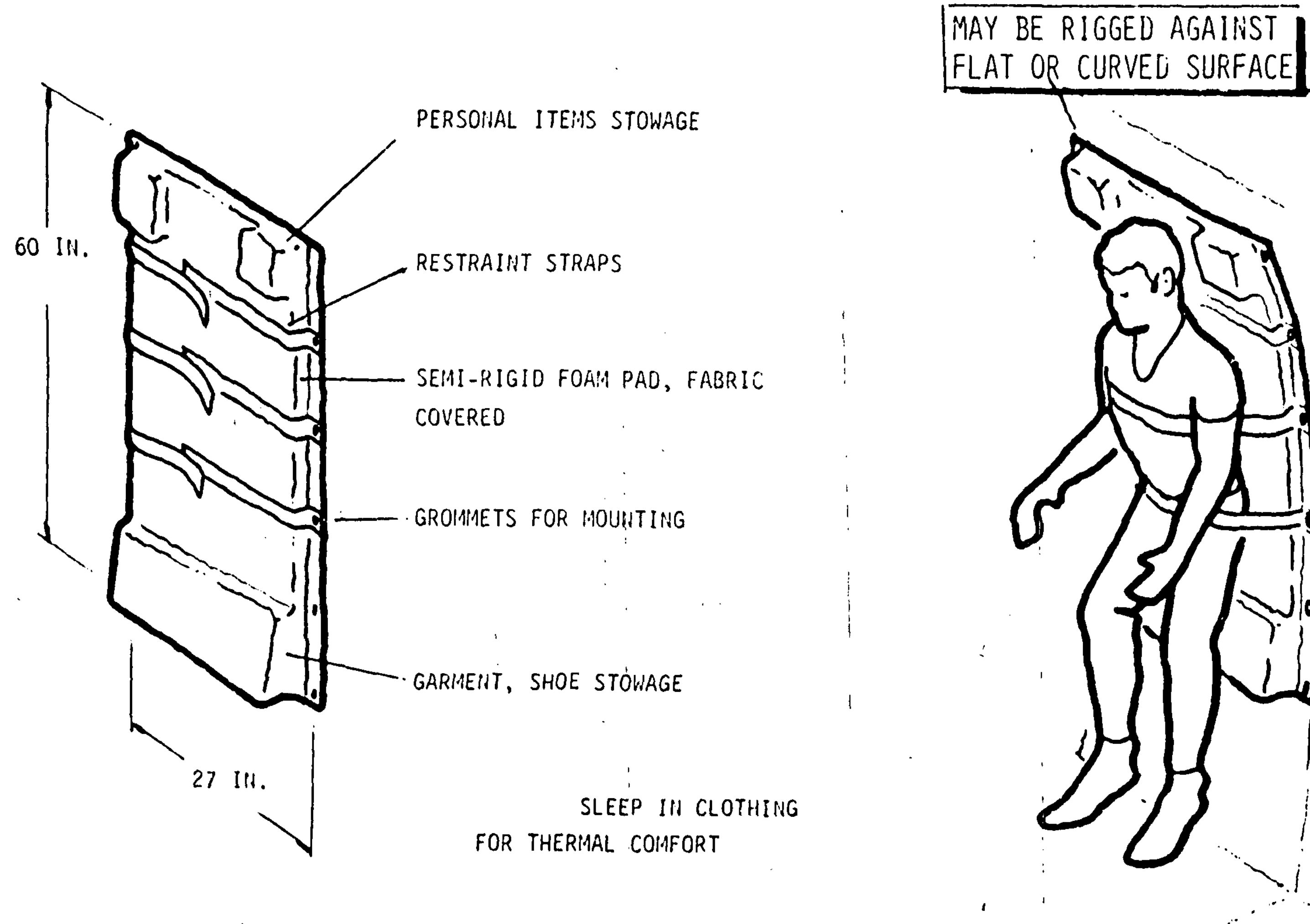


FIGURE 6 - RECOMMENDED SLEEP RESTRAINTS (ALL MISSIONS)

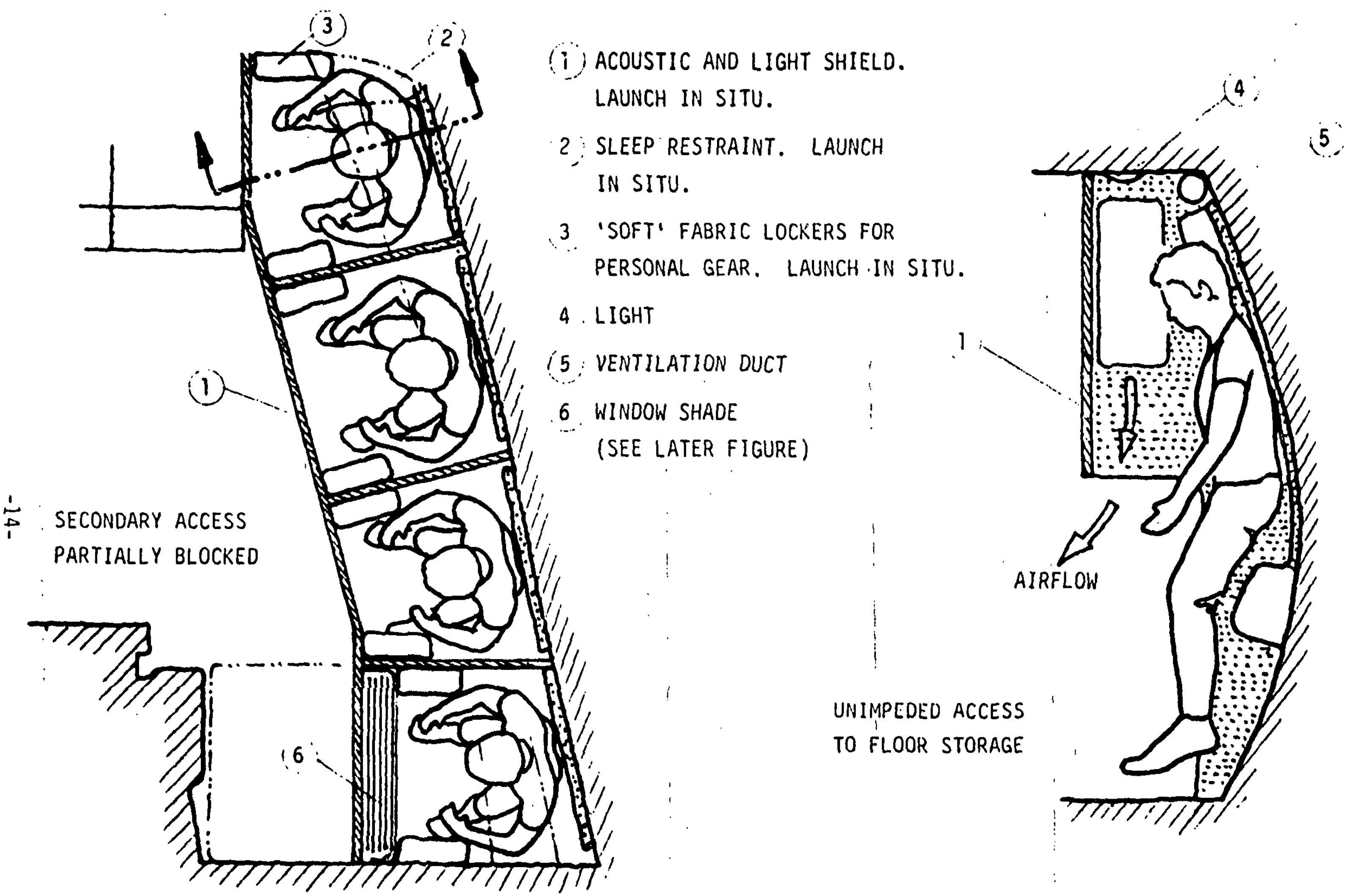
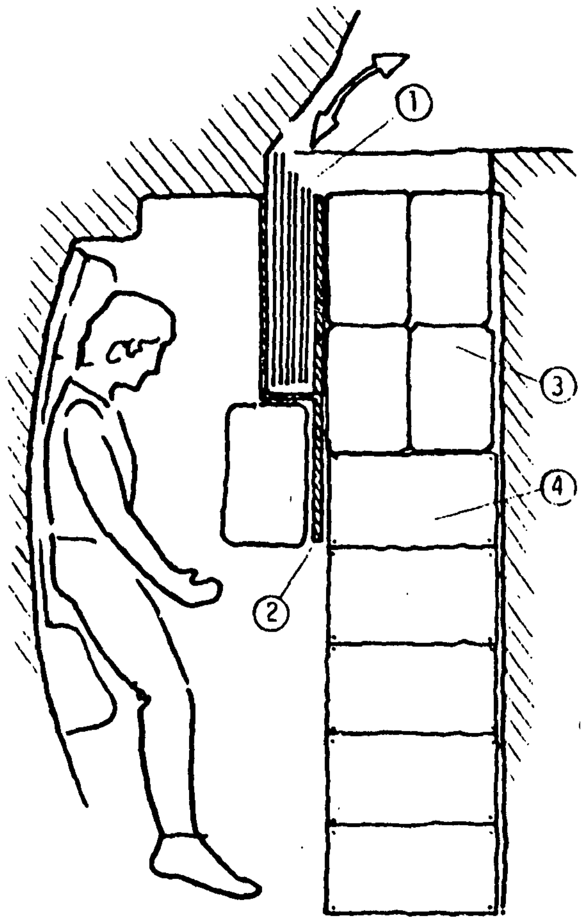


FIGURE 7 - ALTERNATE POST-DFI SLEEP STATION ARRANGEMENT



(1) SHADES AND FILTERS. LAUNCH IN SITU. IN PADDED, NON-METALLIC RECEPTACLE. READILY ACCESSIBLE TO FLIGHT DECK

(2) ACOUSTIC AND LIGHT BARRIER OF SLEEP STATIONS

(3) PASSENGER SEATS (AFTER T & G)

(4) STANDARD LOCKERS

NOTE:
SECONDARY ACCESS HATCH IS PARTIALLY BLOCKED BY SHADES AND FILTERS AND COMPLETELY BLOCKED BY PASSENGER SEATS.

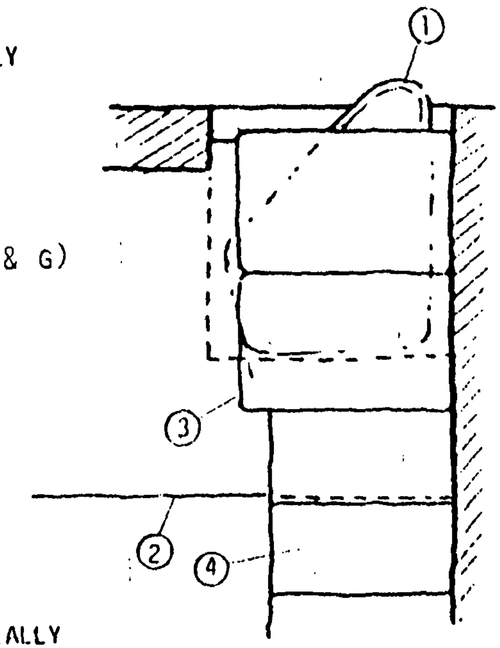


FIGURE 8 - RECOMMENDED STOWAGE FOR SHADES, FILTERS AND SEATS

alternate stowage location after the Text and Graphics and the GPS is installed in stowage Volume "C". Relocating the window shades and filters to a location nearer the flight deck (outboard portion of the R. H. inter-deck hatch) would do two things. First, it would make them much more accessible from the flight deck and, second, it would free-up space that could be used for stowage or for other purposes.

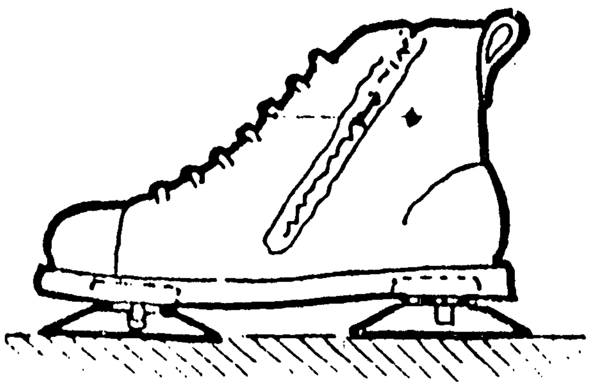
The vacuum shoe is shown in Figure 9 in its three configurations. The shoe has gotten increasingly complicated and the need to return to the initial design concept, with its reduced mass and bulk on the feet in zero-G, should be considered. Storage space and weight will be greatly saved by the smaller lighter shoe.

The existing adjustable platform design for smaller crew members that will be used on the flight deck takes up valuable stowage space and is quite bulky. A new design, preferably built-in, that could be launched in position flush with the flight deck, would be a better solution.

Some of the miscellaneous observations that have been collected during the contract are as follows: Some items not intended as restraints or handholds will be so used and probably damaged. There does not seem to be any provisions for temporary storage of personal gear. It seems doubtful that many items can be restowed once unpacked from the stowage lockers because they are packed-in so tight. The menu also seems to emphasize a great amount of items of rehydratable food, where more "ready-to-eat" foods might save time.

The use of a large patch of velcro on the crew's suit would also be a great aid being able to temporarily stow items. This could be sewn to one of

RECOMMENDED

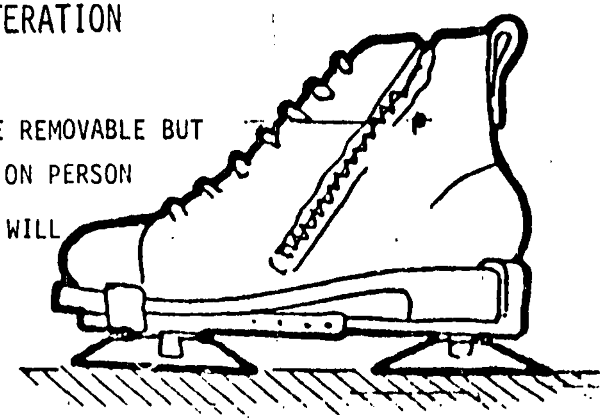


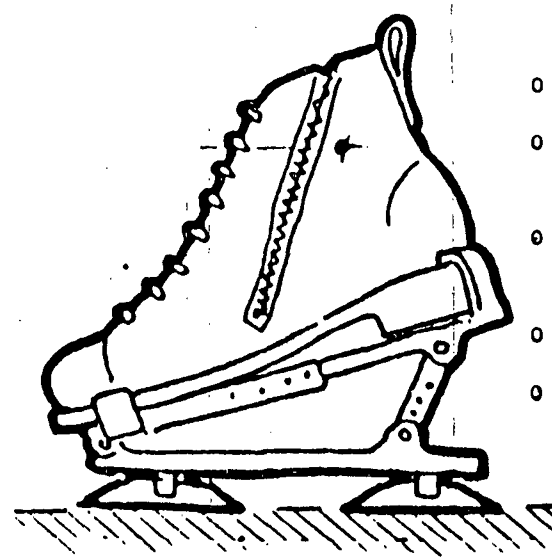
PROTOTYPE

- VACUUM CUPS REMOVABLE AND STOWABLE IN PANTS POCKETS
- FLEXIBLE INSTEP ALLOWS STOOPING
- LIGHTWEIGHT, BUT REQUIRES CUSTOM SHOE

FIRST ITERATION

- STOCK SHOES
- VACUUM DEVICE REMOVABLE BUT NOT STOWABLE ON PERSON
- RIGID INSTEP WILL NOT ALLOW STOOPING
- HEAVY AND DANGEROUS





SECOND ITERATION

- STOCK SHOES
- VACUUM DEVICE REMOVABLE BUT NOT STOWABLE ON PERSON
- RIGID INSTEP WILL NOT ALLOW STOOPING
- ANKLE TO DECK HEIGHT EXCESSIVE
- VERY HEAVY AND DANGEROUS

FIGURE 9 - VACUUM CUP SHOE DEVELOPMENTS

the pockets on the pant leg or in anyplace it would work best for the astronaut.

As a result of his analyses during the study, C. C. Johnson defined several recommendations that pertain to this task.

A group needs to be set up to acquire and analyze flight experience data on a continuing basis. Equipment and crew performance would be compiled similar to the method used on the Skylab program, otherwise the ability to incorporate experience of previous flights to future flights would be seriously hampered and timely incorporation of improvements would not occur. This group would develop a "habitability handbook" to use as a data base for habitability technology. Another thing to be considered is to have the capability to correct hardware deficiencies at KSC (and possibly Vandenburg) that will allow for habitability changes to be made without a lot of paper-work and long-lead time approvals. The present system is time consuming and expensive and would not allow for discovered deficiencies to be rectified before the next flight.

The training and weight procedures that pertain to habitability and daily living chores need to be periodically revised and updated to reflect lessons learned in previous flights.

A study outside the mainstream design effort should also be done periodically, to recommend improvements for habitability of all the crew quarters in the orbiter.

IV. DEFINITION OF HABITABILITY TERMS

Investigation into the major studies of habitability has revealed that most original studies on habitable volume required/person were done in the 1960's. Most of the valid studies were performed by a small number of investigators and subsequent studies merely elaborated or used the data from the original studies. Another factor is that other studies that deal with long-term confinement or crew environment do not address volumetric requirements of the crew in their investigation. The documents reviewed are listed in Tables 3 and 4 .

In previous studies of the habitability of space vehicles and space stations for long duration flight, each researcher used his own terms in describing volume and all its variations. They all used ft^3/person as the required measure of volume, but terms used for volume are not consistent nor, in most cases, are the terms defined by the investigators. Terms such as minimum acceptance, tolerance and unacceptable have been used by the investigators to describe the lower level of volume required per person, and other terms such as free, living, optimal, acceptable, performance, tolerance, and unacceptable have also been used.

It is also unclear how some of the researchers calculated the volume in each investigation, and uncertainty exists as to what was in the volume to which they referred. Some listed the room or capsule dimensions and the ft^3, implying that all major objects in the volume were not subtracted from the volume, while others seemed to differentiate between work and "living" space. All of the above discrepancies may account for some of the curves being different when plotted against the same volume scale. Considering the different objectives, techniques calculations, and conclusions of the researchers, it is surprising that some of the curves, especially at the minimum tolerance level, are as close as they are.

Celentano(1), (2) was the first one to study in depth the volumetric requirements for habitability and maintenance of human performance in long duration space missions that was reviewed. He based his work mainly on experimental simulation in mockups of space cabins, and came up with 3 curves which are shown in Figure 10. His 3 curves were defined as optimal, performance, and tolerance.

Breeze(3) used a mathematical model to determine volume requirements based on anthropometric data and suggested volume for various durations that resulted in a curve shown on Figure 10. Davenport(4) used an adaption of this mathematical approach of Breeze, however, he hypothesized that the volume requirements per person go up with the size of the crew as well as duration. Davenport is the only one to address the body size percentile of the astronauts, but used only 90th percentile in his calculations. His three curves are shown on Figure 10. Frazer(5), (6) examined more than 60 studies of operational and experimentally induced restrictive confinement and graded the psychological and physiological impairment and came up with 3 curves shown on Figure 10, which he identified as unacceptable, tolerance, and acceptable volumes. Curves generated by Price(7) and Jenkins(8) have not been included for reference because it is not clear how they were derived. The data from each researcher has been complied without modification and the curves have been plotted against the same scale on Figure 10 and used the same way for comparison. Also shown on Figure 10 are points showing Mercury, Gemini, Apollo, Skylab, and points for nuclear sub and a death row cell for reference.

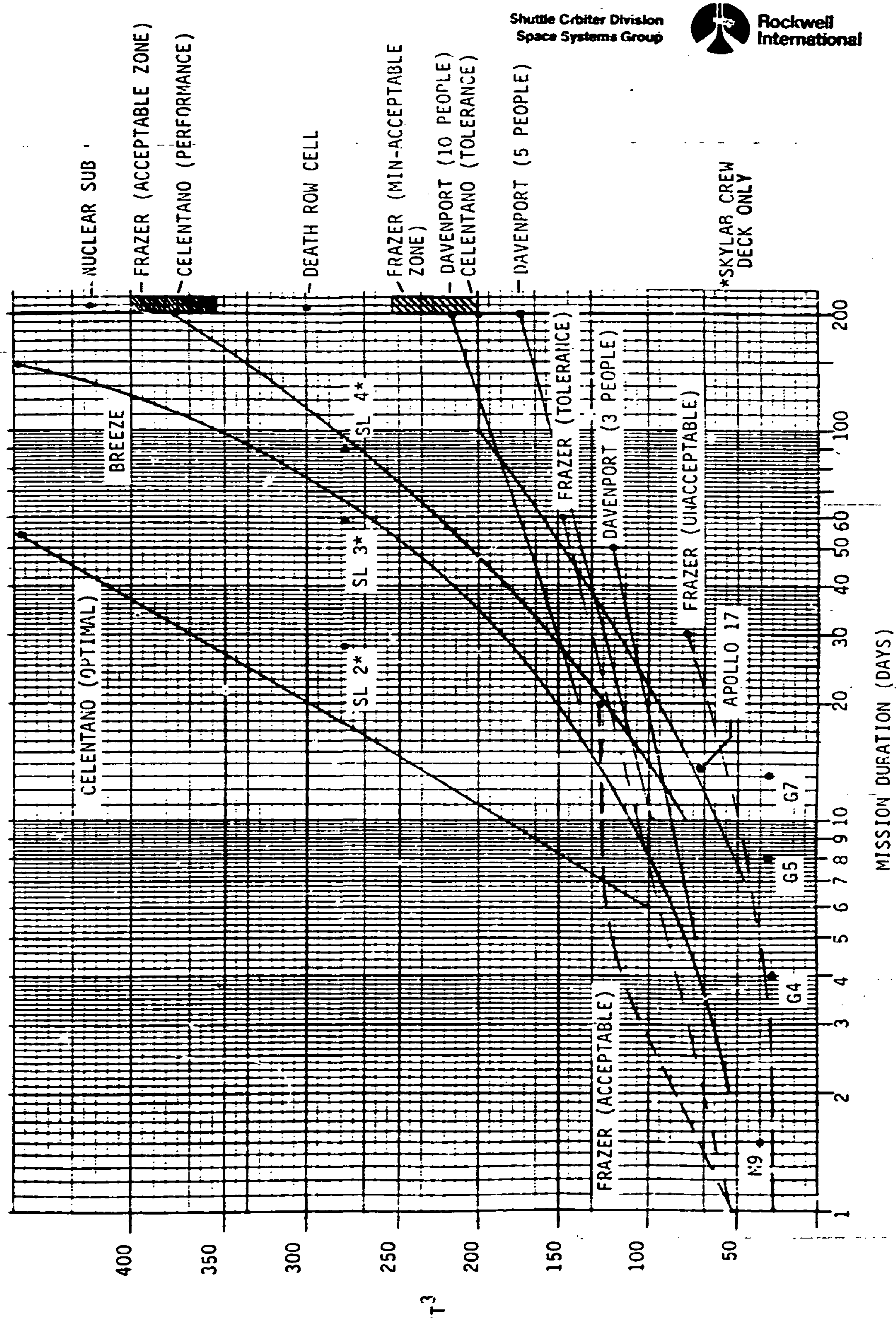


FIGURE 10 - RESEARCHERS ESTIMATES OF VOLUME REQUIREMENTS PER PERSON

Usable standard descriptive terms are needed for comparison and evaluation for future design of space vehicles and crew cabin changes and improvements in the Space Shuttle Orbiter. In this task, existing terms and definitions for volume have been sorted out to arrive at a terminclogy and a descriptive definition for each term for use in future analysis and evaluations.

DEFINITION OF TERMS

The terms that have been selected are as descriptive as possible for each of the volumes to eliminate confusion. The terms selected and defined are: habitable volume, acceptable performance limit and minimum tolerance limit.

Habitable Volume

Sometimes known as "free volume" or "living volume", "free volume" is a nebulous term that implies the volume of all unused space. This is insufficiently specific or descriptive for use in a space vehicle design. Therefore, "habitable volume" has been selected for the required volume since it best describes the situation in a space vehicle. It means to inhabit or live. This habitable volume would be the volume used for eating, sleeping, recreation, food preparation, waste management, personal hygiene, privacy, and would include private, public, and service areas.

Working volume may or may not be habitable; if it is a specific, dedicated work area such as a control room, it will not be considered. If it is a volume that could be utilized part time for other than work (dual use volume), it should be considered habitable volume. Habitable volume is that volume remaining after subtracting stowage, subsystem, furnishings and specific work areas from the pressure volume.

TABLE 1 - CREW MODULE VOLUME ITEMS

IN HABITABLE VOLUME	NOT IN HABITABLE VOLUME
• DUAL USE WORKING AREAS	• DEDICATED WORKING AREAS
• SLEEPING AREAS (INCLUDES BUNKS)	• SUBSYSTEMS (AVIONICS, ECLSS, WIRING, WASTE MANAGEMENT, ETC.)
• RECREATION AREAS	• STRUCTURE
• FOOD PREPARATION AREAS	• GALLEY
• WASTE MANAGEMENT COMPARTMENT	• SMALL "NOOKS AND CRANNIES" (SMALLER THAN ONE FOOT DIA.)
• PERSONAL HYGIENE AREA	• AIR LOCK

Habitable volume does not include stowage areas, dedicated work areas, air lock, subsystem areas, furnishings or areas that cannot be utilized. This would not include every "nook and cranny" but only those that would allow maneuvering room for the crew. It is recommended that any volume which would accept a 12 inch diameter sphere as a minimum be included. This is a volume that at least a part of a body could be inserted into and used (i.e., head, foot, hand). In applying this definition of habitable volume to the orbiter crew module, Table 1 shows the types of items considered inside and outside the habitable volume. This would be the pressure volume of the crew module less the volume of items in Table 1 which will result in the habitable volume.

Acceptable Performance Limit

This is the quantitative level of habitable volume shown on the graphs (Figures 11 and 12) at which the crew will function effectively and efficiently. At this level the crew can fulfill the performance requirements of the assigned tasks and have negligible or non-existent perceptual deprivation effects.

Volume Between Acceptable Performance Limit and Minimum Tolerance Limit

This volume is the area shown on the graphs (Figures 11 and 12) between minimum tolerance limit and acceptable performance limit. The adequacy of this volume is dependent on motivation. In this volume the crew can perform their functions with very little degradation in performance near the top of the acceptable performance limit, but with decreasing capabilities of crew performance as the minimum tolerance limit is approached.

Minimum Tolerance Limit

This is the quantitative level of habitable volume shown on the graphs (Figures 11 and 12) at which a severe penalty in crew performance is paid. This limit is the bottom threshold of acceptance, especially of confinement on a long-term mission.

Below Minimum Tolerance Limit

This volume is the area shown on the graphs (Figures 11 and 12) below the minimum tolerance limit and is defined as not-acceptable except for very short missions. Trying to function below the minimum tolerance limit would generally result in physical constraint, physiological debilitation and psychological/social deterioration for personnel, and they probably cause a great deal of friction, irritation, and possible claustrophobia.

VOLUME REQUIREMENTS

Figure 11 shows the volumetric requirement curves derived from the work of the previous investigators. The acceptable performance limit curve was averaged from the Frazer "acceptable" curve, the Celentano "performance" curve and Breeze's curve. Celentano's "optimal" curve was not used since it appears to be much in excess of acceptable performance requirements.

The minimum tolerance limit curve was averaged from Frazer's "tolerance" curve, Celentano's "tolerance" curve, and all three of Davenport's curves. It is felt that these limits provide a reasonable compromise of all of the more significant work that has been accomplished in the past. Frazer's unacceptable curve was not included in the averaging because it was truly "unacceptable", instead of a minimum.

In Figure 11 the logarithmic scale was chosen because it is easier to

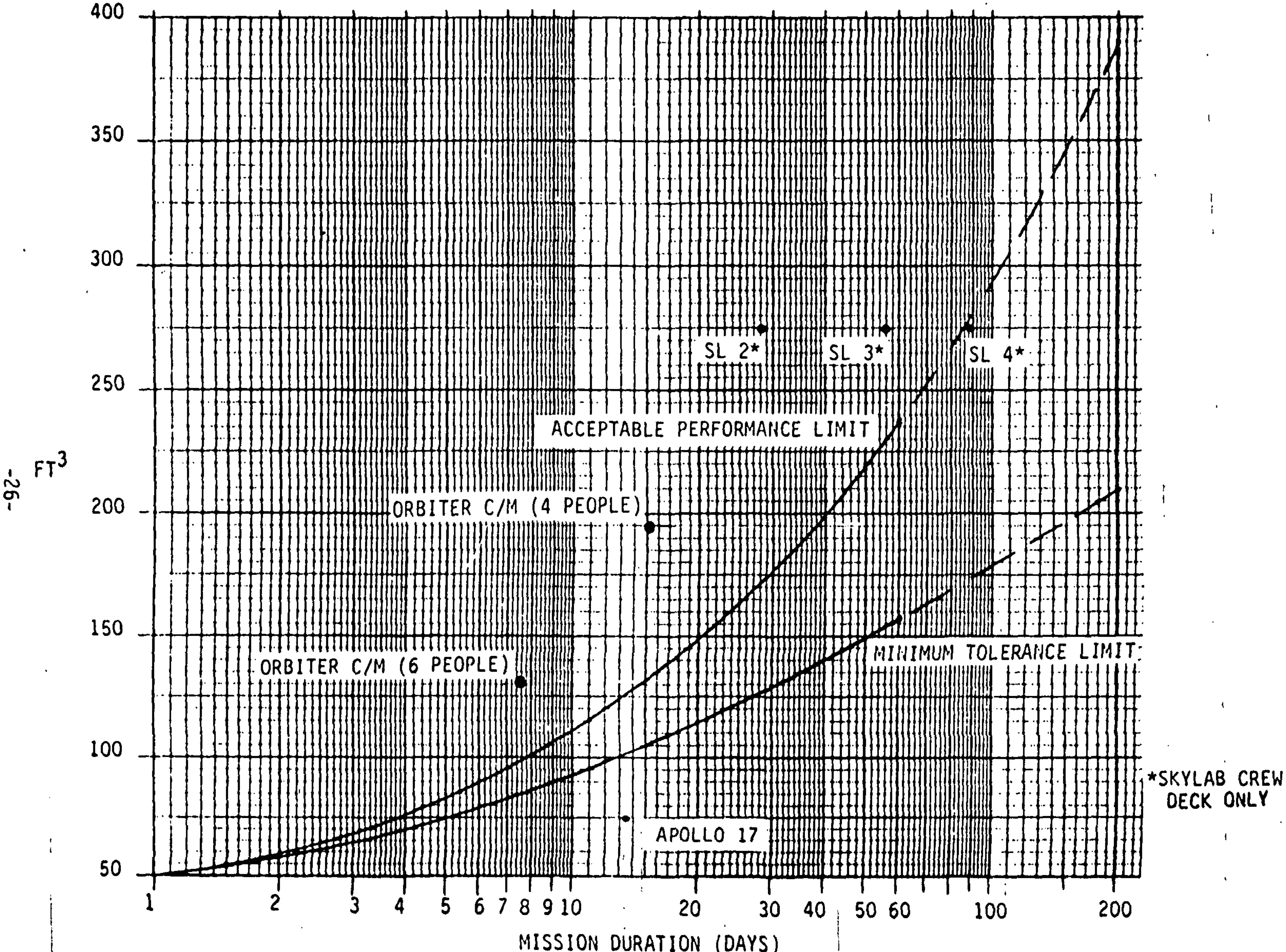


FIGURE 11 - HABITABLE VOLUME REQUIREMENTS PER PERSON

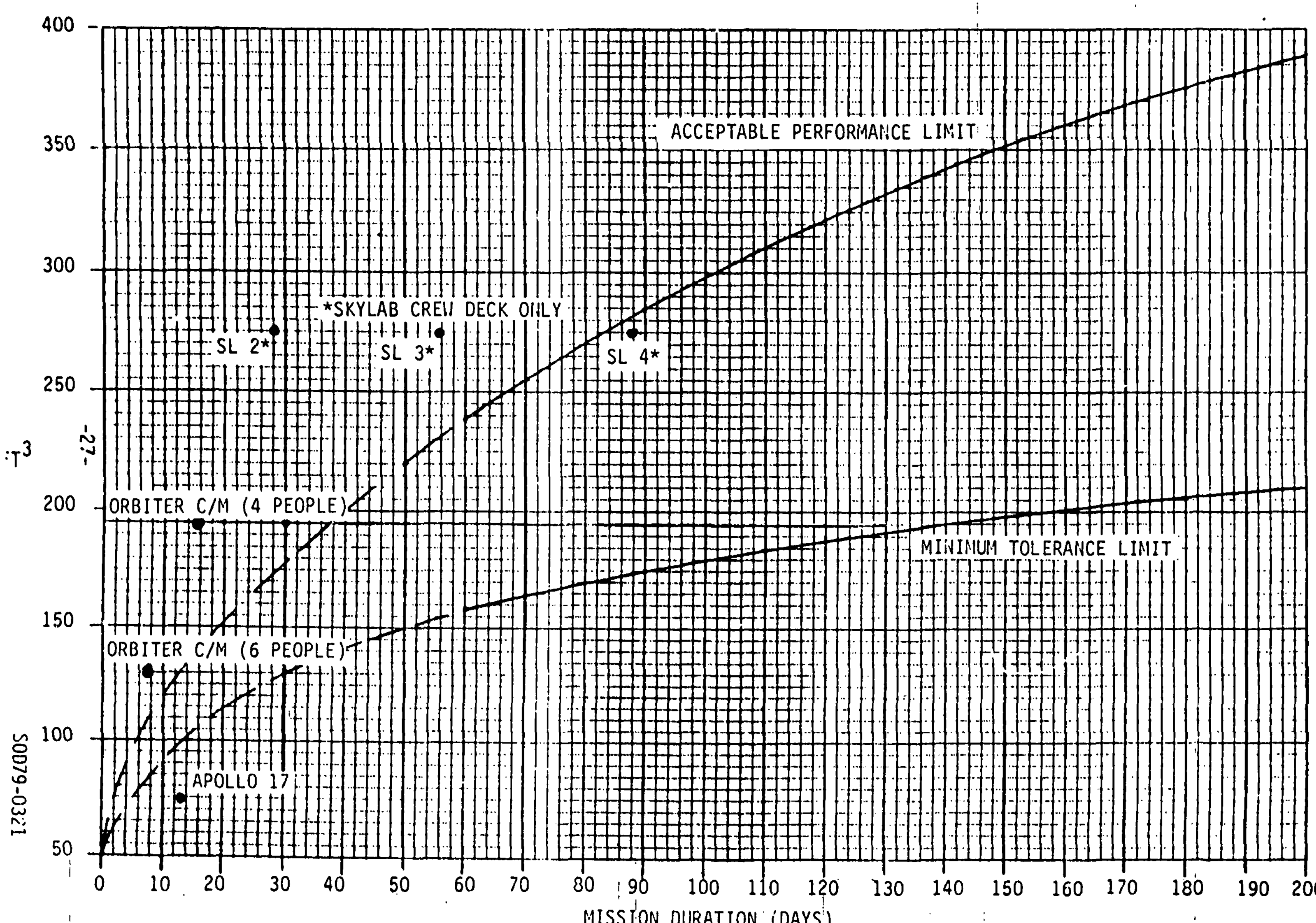


FIGURE 12 - HABITABLE VOLUME REQUIREMENTS PER PERSON

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read for shorter duration missions (up to sixty days). In Figure 12 the mission duration scale has been changed from a logarithmic scale to a linear scale to make the graph easier to read for the longer missions (sixty to two hundred days). When using the curves, the designer should strive to maintain habitable volume for the crew in excess of the acceptable performance limit. Falling into the adequate volume area of the curve will impose some degradation on the crew's performance.

The habitable volume of the orbiter crew module shown in Figure 13 and Figure 14, was calculated and the volumes are shown in Table 2 and the volume limits of the flight deck and the mid-deck are shown on Figures 13 and 14.

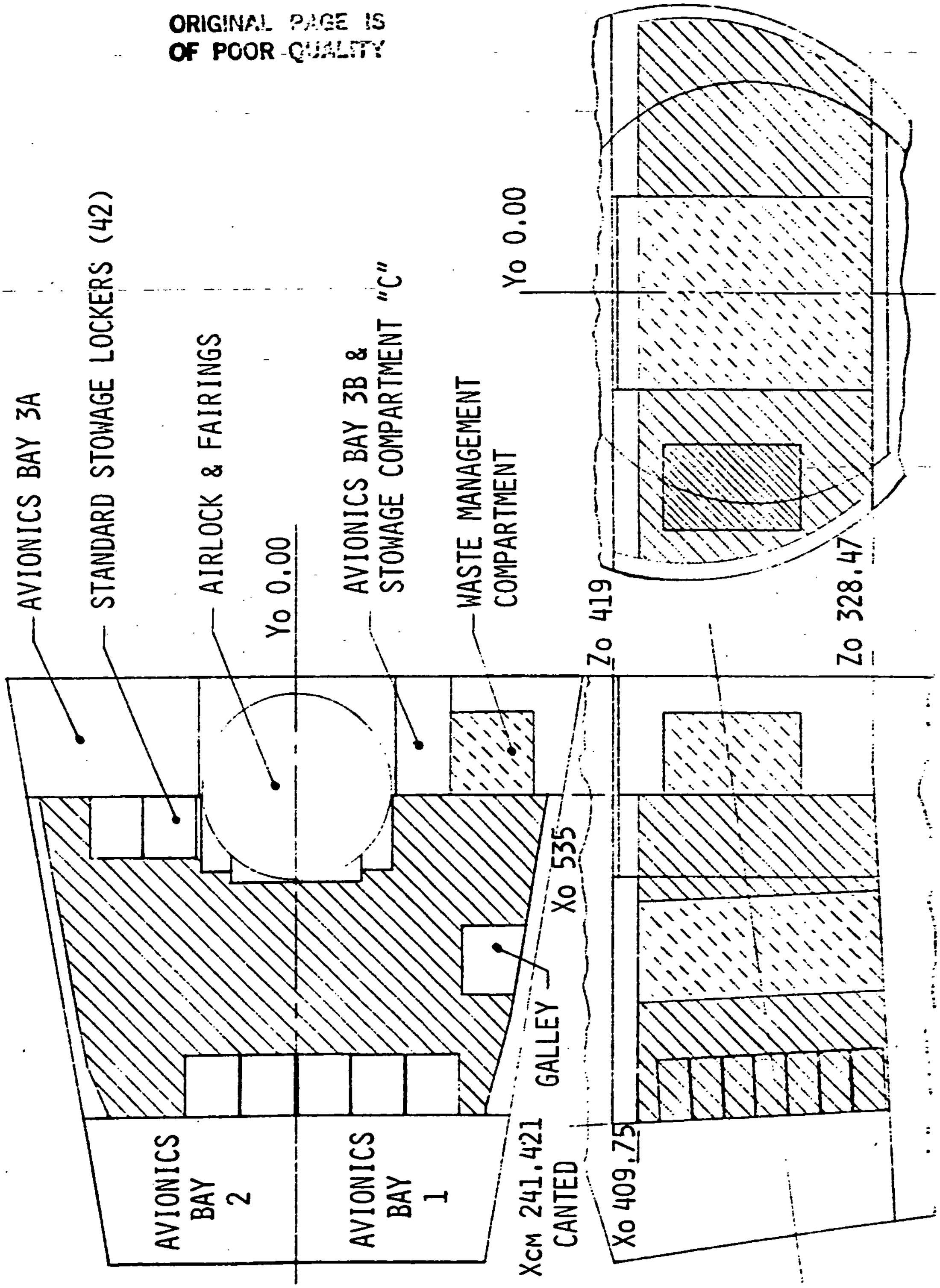

FIGURE 13 - MID-DECK HABITABLE VOLUME GEOMETRY

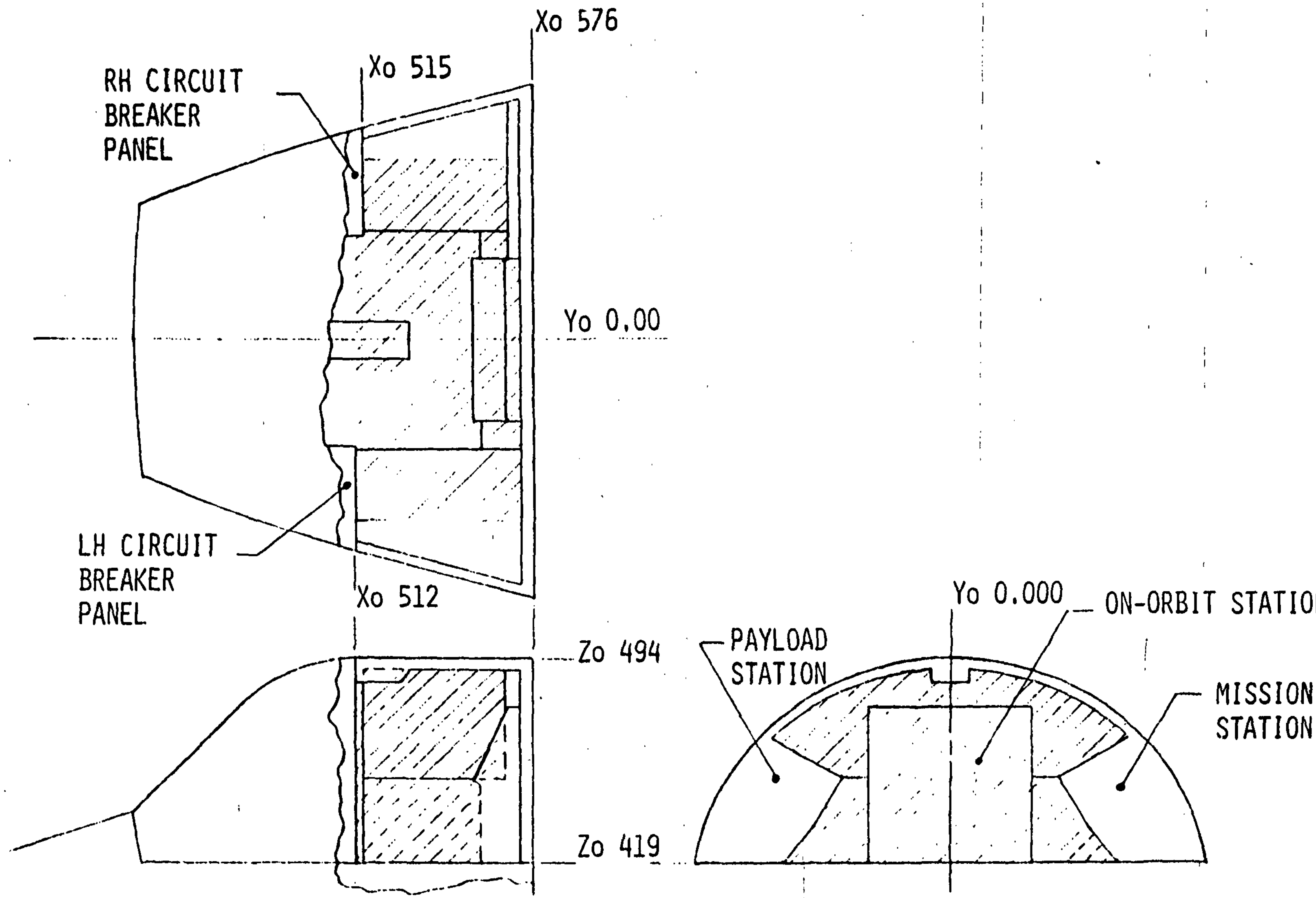

FIGURE 14 - FLIGHT DECK HABITABLE VOLUME GEOMETRY

TABLE 2 - C/M HABITABLE VOLUME

AFT FLIGHT DECK	194 ft^3
INTERDECK ACCESS HATCHES	8 ft^3
MID-DECK*	588 ft^3 (784 ft^3 AIR LOCK OUT)
TOTAL C/M HABITABLE VOLUME	790 ft^3

REFERENCE VOLUMES

42 MODULAR STOWAGE LOCKERS (INCLUDES INTERSPACES AND INACCESSIBLE RECESSES)	105 ft^3
GALLEY	19 ft^3
VOLUME ABOVE TOILET SEAT IN THE WASTE-MANAGEMENT COMPARTMENT	24 ft^3

*INCLUDES: AIRLOCK IN WITH ASSOCIATED FAIRINGS AND DUCTS, GALLEY, BUNKS, A FULL COMPLEMENT OF 42 MODULAR STOWAGE LOCKERS AND VOLUME IN THE WASTE-MANAGEMENT COMPARTMENT.

TABLE 3 - REFERENCES

(1) Celentano, J. T., Adams, B. B., "Habitability and Maintenance of Human Performance in Long Duration Space Missions," AAS-60-83, 1960.

(2) Celentano, J. T., Amorelli, D., et al, "Establishing a Habitability Index for Space Stations and Planetary Bases," AIAA 63-139, 1963.

(3) Breeze, R. K., "Space Vehicle Environmental Control Requirements Based on Equipment and Physiological Criteria," WADD-ASD-TR-61-161 (PT1), 1961.

(4) Davenport, E. W., Congdon, S. P., et al, "The Minimum Volumetric Requirements of Man in Space," AIAA 63-250, 1963.

(5) Frazer, T. M., "The Effects of Confinement as a Factor in Manned Space Flight," NASA-CR-511, 1966.

(6) Frazer, T. M., "The Intangibles of Habitability During Long Duration Space Missions," NASA-CR-1084, 1968.

(7) Price, H. E., et al, "Final Report of a Study of Crew Functions and Vehicle Habitability Requirements for Long-Duration Manned Space Flights (Vol. 2) NAS2-2419, 1965.

(8) Jenkins, L. E., et a., "Spacecraft Requirements for Manned AIAA," March 1968.

TABLE 4 - OTHER DOCUMENTS REVIEWED

- MSFC-STD 512A, dated December 1976, "Manned Systems for Weightless Environment."
- NASA SP-3006, dated 1973, "BIO-Astronautics Data Book."
- AIAA-78-1669, dated September 1978, "Space Shuttle Orbiter Habitability and its Extensibility."
- ASME-ENAS-31, dated July 1978, "Extended Duration Orbiter Life Support System Options."
- ED-2002-374, dated February 1968, "Habitability Study," AAU Program by Raymond Loewy, et al.
- SD70-340, dated September 1970, "Habitability Criteria Data Book for Manned Space Vehicles/Stations."

V. INCREASED DURATION CONCEPTS

The objective of this task (Task 3) was to find the most economical way to increase the duration of the orbiter, as it pertains to habitability. The main elements to be studied in this task was to find additional stowage and two additional sleep stations to permit the sleeping of six crew persons at the same time, instead of in shifts of three presently envisioned. The baseline sleep stations are three horizontal sleep stations and provisions for a vertical sleep station.

Figure 15 shows a graph of the stowage volume requirements with a four person and a six person crew with both LiOH and a representative Solid Amine Water desorbed (SAWD) CO^2 removal systems. With approximately 89 ft^3 of stowage volume for consumables and mission duration dependant, it shows that the stowage lockers are full at approximately 7 days with six crew persons and that the four person crew, stowage runs out at approximately 15 days. This indicates that one of the first "stepping stones" to longer duration, is to provide more stowage. Table 5 shows the breakdown of the stowage volume requirements for non-duration dependant volume and duration dependant volume. Mission unique equipment such as cameras, film, experiment equipment or special tools, need further definition to allow effective extrapolation for requirements.

Putting additional stowage in the baseline configured mid-deck would reduce drastically the remaining habitable volume to gain any significant volume at all. The easiest way to get a large increase in stowage space is to move the airlock out of the mid-deck into the payload bay and use the available space for stowage and/or sleeping stations.

Another way to obtain more volume is to take the baseline tunnel adapter and increase the length and/or the diameter to allow stowage or sleep stations.

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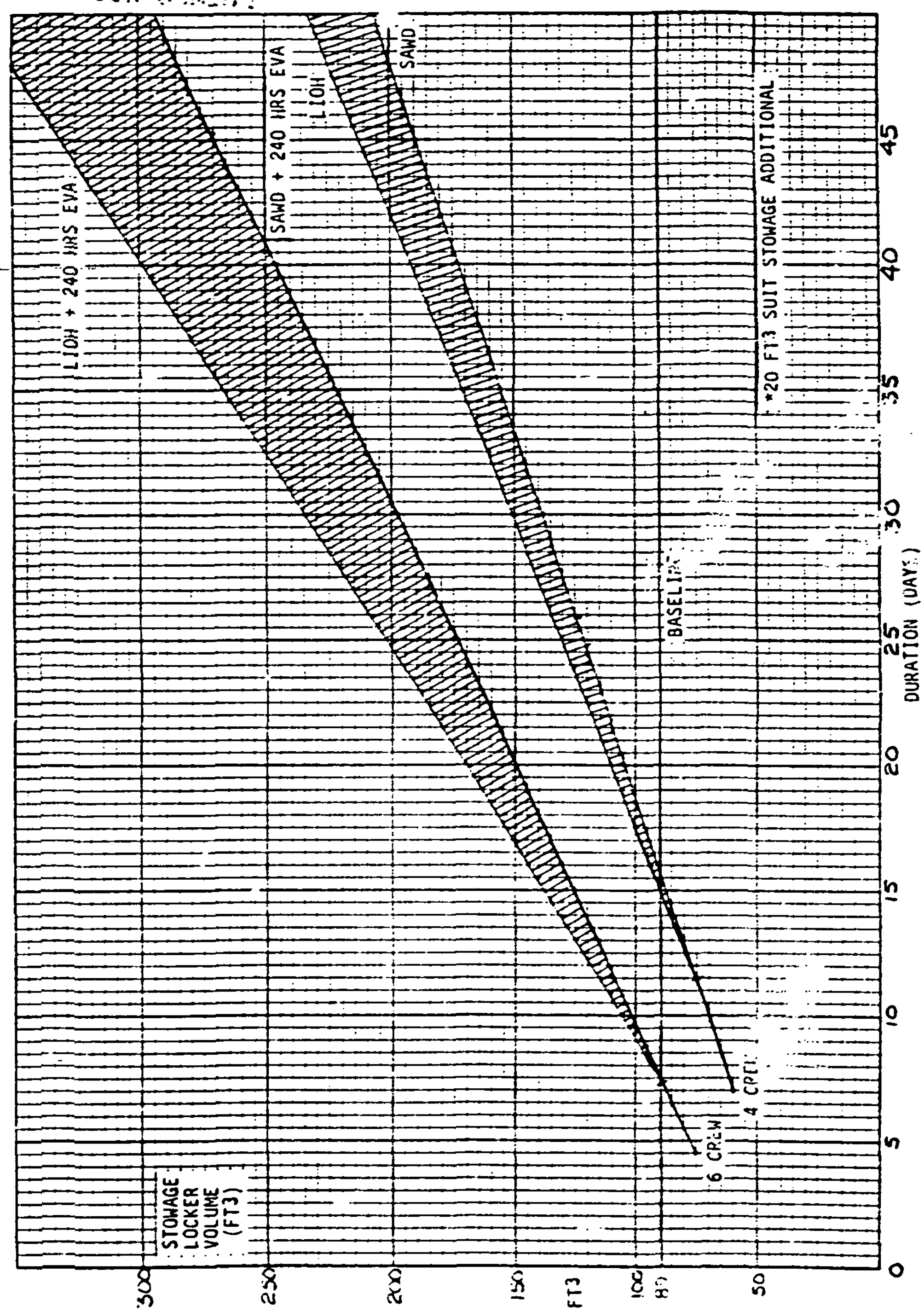


FIGURE 15 - STORAGE VOLUME REQUIREMENTS

TABLE 5 - STOWAGE VOLUME REQUIREMENTS

NON-DURATION DEPENDENT

	LOCKERS	SOFT, WORN, OTHER
SLEEPING BAG	.33	
CONTINGENCY FOOD	.52	
HYGIENE	.08	
RESCUE GEAR		
LIFE VEST		.2
EMERG. EGRESS HARNESS		.1
PERS. RESCUE SPHERE	1.0 (?)	
GARMENTS	.5	
HELMET		0.5 (?)
ACCESSORIES		
SEATS		2.3
SUB TOTAL	2.4	3.7
MISSION UNIQUE EQUIP.	TBD	
TOTAL	$6.1\ FT^3$/MAN	

DURATION DEPENDENT

		LOCKERS
FOOD, FOOD PACKAGING		.21
PERSONAL HYGIENE		.19
CLOTHING	.11	
WIPES, TISSUES, TOWELS	.08	
TRASH BAGS		.11
STOWAGE PACKAGING		.13
CONTINGENCY (10%)		.06
SUB TOTAL		.70
MISSION UNIQUE SUPPORT EQUIP.		.10
		$.8\ FT^3$/MAN-DAY

AFT MID-DECK (AMD) CONCEPTS

The aft mid-deck (AMD) concepts were tried first and will be identified by an AMD number on the enclosed figures.

In the following concepts, the use of this aft mid-deck volume does not exceed the volume of the airlock and it's protrusions when in the mid-deck, when possible, so as to not cut down on the amount of habitable volume of the mid-deck when the crew is awake. The forward edge of the interdeck access hatches is at Xo 507 and this almost coincides with the forward surface of the airlock, so this was selected as the forward surface of the stowage lockers/sleep stations. Because the ceiling is lower than the top of the airlock, there is space above the ceiling that can be used when the airlock is outside. This is very useful for sleeping vertical with tall (95 percentile) crew person and can be used for additional stowage in some configurations shown. The space available results in a cavity approximately 87 inches high, approximately 66 inches wide, and approximately 64 inches deep (fore and aft) with a volume of approximately 213 ft^3. This cavity is shown in Figure 16.

Special consideration was given to the Xo 576 bulkhead hatch movement from closed to open. This hatch translates on parallel arms instead of hinging like a trap door and uses less of the interior volume this way. The enclosed concepts assume that all of the crew sleeps at the same time (no shifts) and that the hatch would be closed during sleeping hours. With the hatch open or in use during sleeping hours, greatly reduces the use of this volume and would reduce approximately 25 ft^3 of some of the most usable space.

In the figures discussed in the subsequent paragraphs, lockers on the concepts are generally shown with a cross hatched area to indicate the stowage volume available. A 95 percentile (USAF) crew person is shown in most

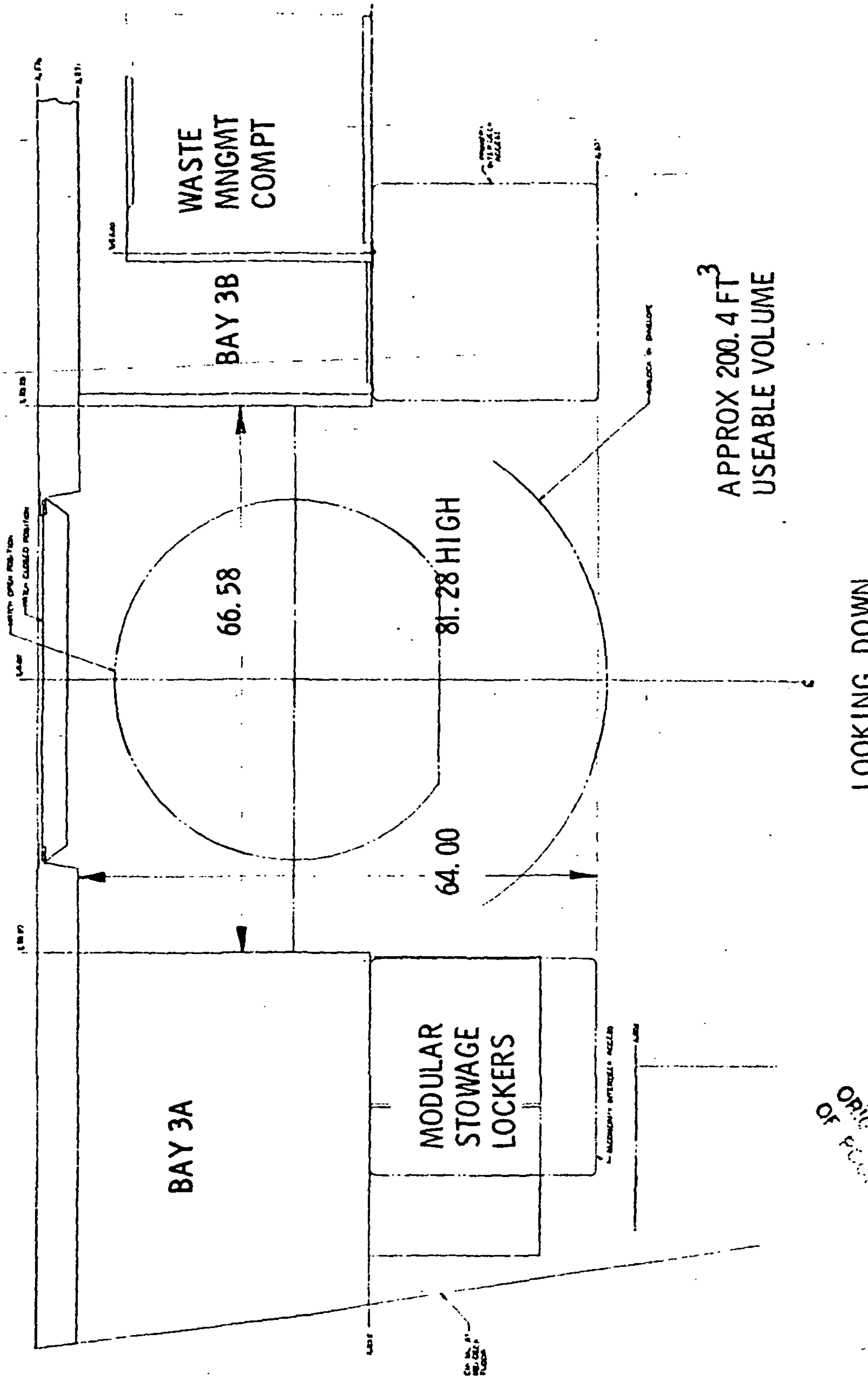


Figure 16 - Aft Mid-Deck Airlock Out Layout

views of the sleep stations to indicate the maximum space needed for sleep stations. With some exceptions, the dimensions of the sleep stations closely match the baseline horizontal sleep stations (30 wide x 26 front to back and at least 77 long). The concepts were first worked out on 1/8 scale views before reducing them to size in this report. The 1/8 scale views are enclosed in Appendix A.

Table 6 shows the AMD comparison of concepts 1 through 5 showing delta stowage volume, duration with a four and six person crew, weight and other factors to compare them with each other.

With the exception of Figures 17 and 23, the sleep stations are all horizontal with the feet and lower legs protruding into the mid-deck area. This is not necessarily a disadvantage as the use of these sleep stations indicate that all of the crew is sleeping at the same time and, thus, would not reduce the usefulness or habitability of the mid-deck. Sleeping the crew in front of the hatch makes maximum use of this volume since it has to be clear when the crew is awake and they are going between the C/M and the spacelab. This allows the space normally occupied by the hatch (open through closed) to be used to the maximum.

Figures 17 and 18 (AMD-1) shows two vertical sleep stations with approximately 88 ft^3 of stowage lockers with some personal stowage opening up into the sleep station. The retractable barrier would give a little more privacy when the hatch is closed. This concept has the highest volume of stowage versus weight of all the concepts in this study. The hatch would have to remain closed during sleeping to provide room for the crew's feet. A retractable curtain (or door) could be drawn across the opening to the hatch to give even more privacy.

TABLE 6 - AFT MID-DECK AIRLOCK OUT CONCEPT COMPARISONS

	AMD-1	AMD-2	AMD-3	AMD-4	AMD-5
△ STOWAGE VOLUME (MAX)	88	47	100	100	78
TOTAL DURATION 4 CREW (LiOH)	36	27	40	40	34
(SAWD)	41	30	45	45	38
TOTAL DURATION 6 CREW (LiOH)	21	15	23	23	19
(SAWD)	25	18	28	28	23
NUMBER OF SLEEP STATIONS	2	2	2	2	2
FT^3 PER MAN/SLEEP STATION	32	27	43	43	32
STOWABLE OR PERMANENT	STOW	PERM	STOW	PERM	STOW
PRIVACY & QUIET	GOOD	GOOD	FAIR	FAIR	FAIR
△ FT^3 HABITABLE VOLUME	105	147	93	93	105
WEIGHT OF LOCKERS/SLEEP STA.	249	235	432	432	261
MAX. WEIGHT WITH STOWAGE (30 LBS. PER FT^3)	2800	1705	3432	3432	2640

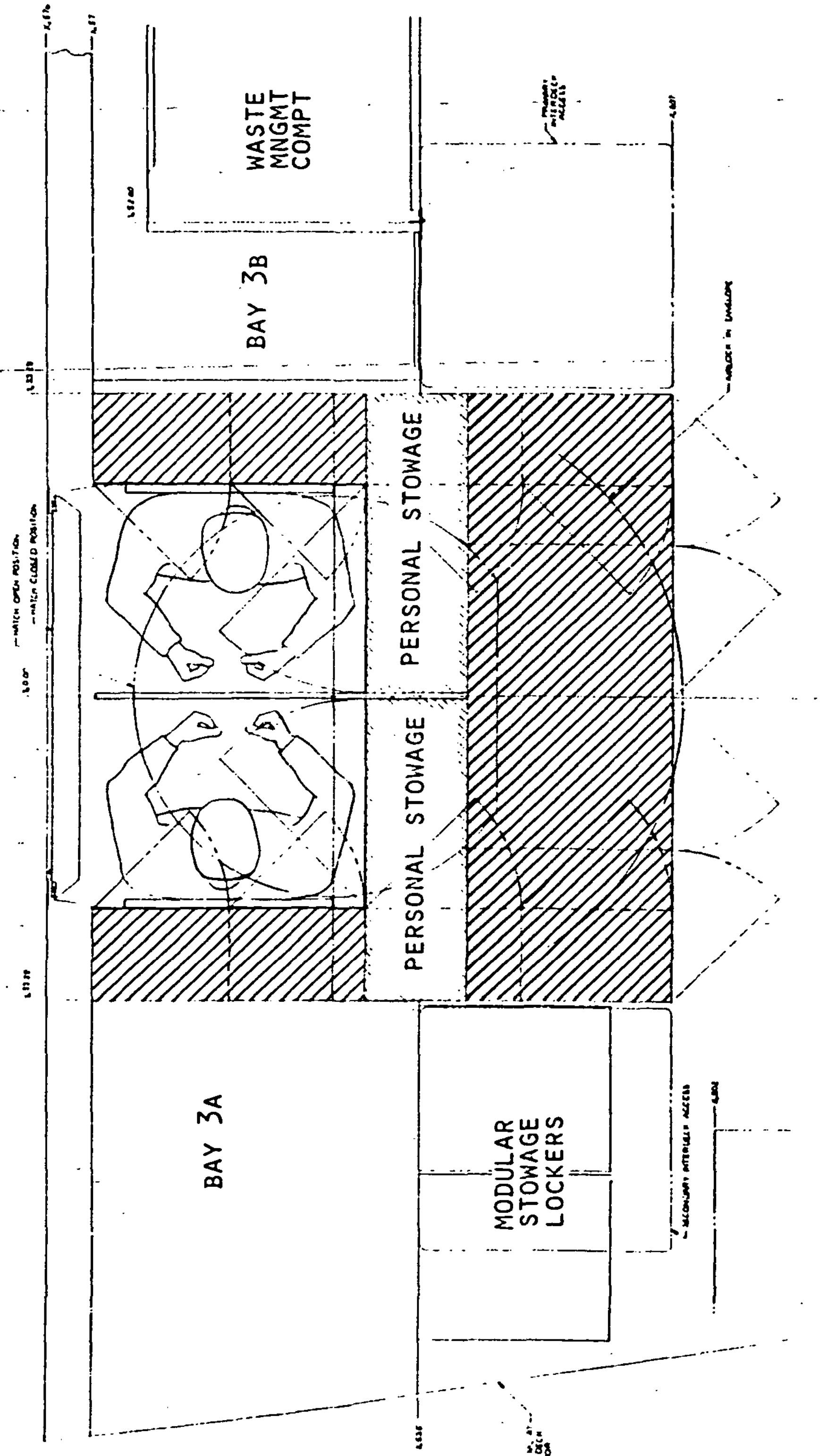


FIGURE 17 - AFT MID-DECK CONCEPT AMD-1

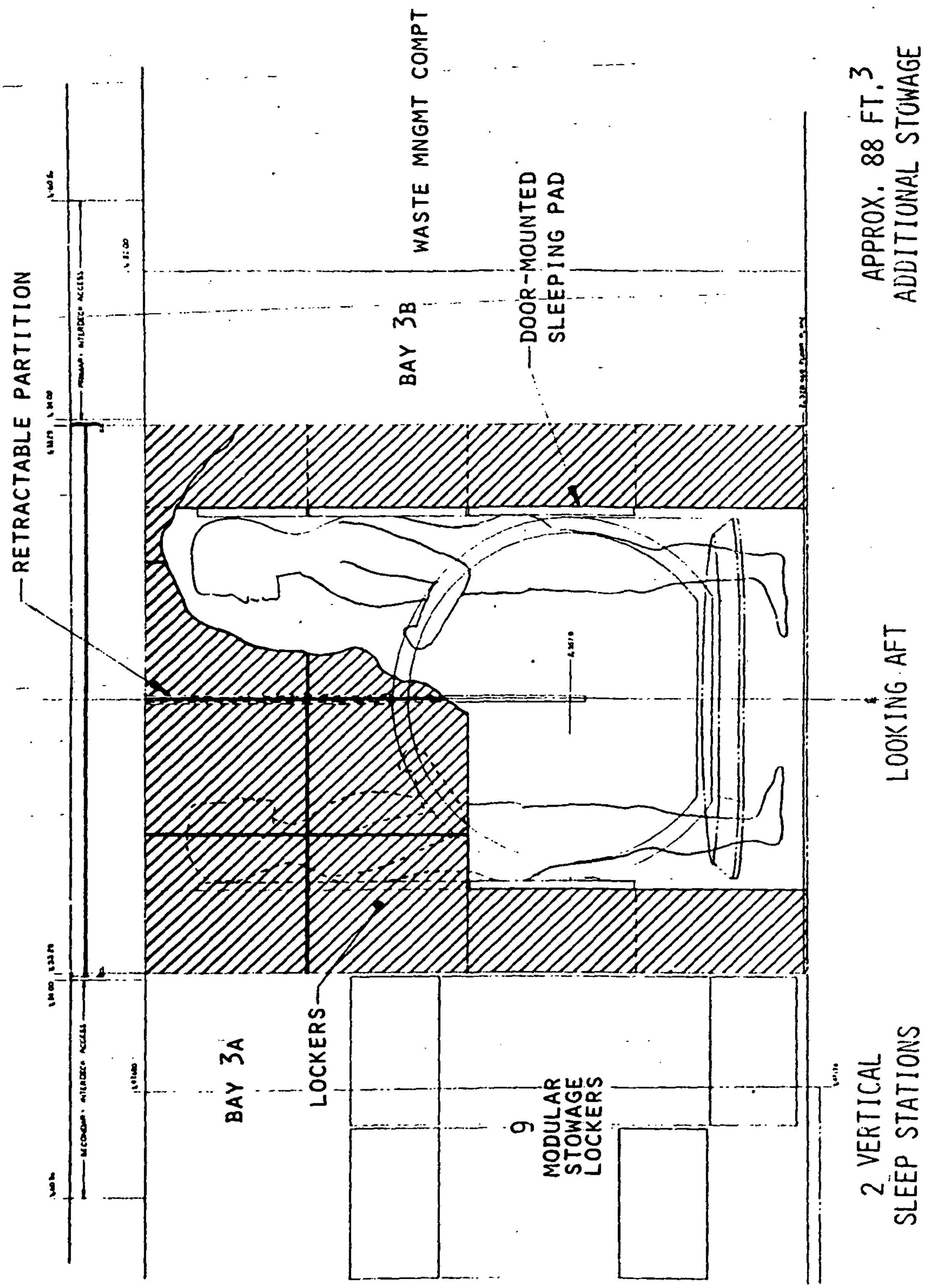


FIGURE 18 - AFT MID-DECK CONCEPT AMD-1

Figure 19 (AMD-2) shows two permanent horizontal sleep stations located above the hatch with approximately 47 ft^3 of stowage space with some personal stowage for the crew. The top lockers face down and the side lockers opening inward. Privacy is quite good in this concept but a great deal of stowage is lost to keep the sleep station permanent.

Figures 20 and 21 (AMD-3) shows two temporary sleep stations facing inward with a retractable accordian curtain to give some privacy when desired. This concept (and Figure 22) gives almost the same stowage capability (approximately 100 ft^3) as an all stowage concept. However, the sleeping pads would have to be stored to use the lockers fully.

Figure 22 (AMD-4) also shows two sleep stations, but these are fully retractable with an accordian curtain to give some privacy. This concept also gives approximately 100 ft^3 of storage space and may prove to be one of the more useful of all the concepts in regard to the maximum stowage.

Figure 23 (AMD-5) shows a variation of AMD-1 with the sleep stations moved forward to allow the hatch to remain open while sleeping. Some privacy and some stowage space is lost compared to AMD-1 but it is still a viable concept with approximately 78 ft^3 of stowage space.

EXPANDED TUNNEL ADAPTER (ETA) CONCEPTS

The second area of investigation was the use of an expanded tunnel adapter in the payload bay. The baseline configuration is to keep the airlock inside the C/M for all near-term flights, but to have the capability to put the airlock the aftside of the Xo 576 bulkhead or on top of the tunnel adapter. The proposed PEP has to be taken in consideration along with the existing tunnel and bellows, the airlock on top of the tunnel adapter, the MESA, PEP, and the MMU's on each side. The existing baseline tunnel

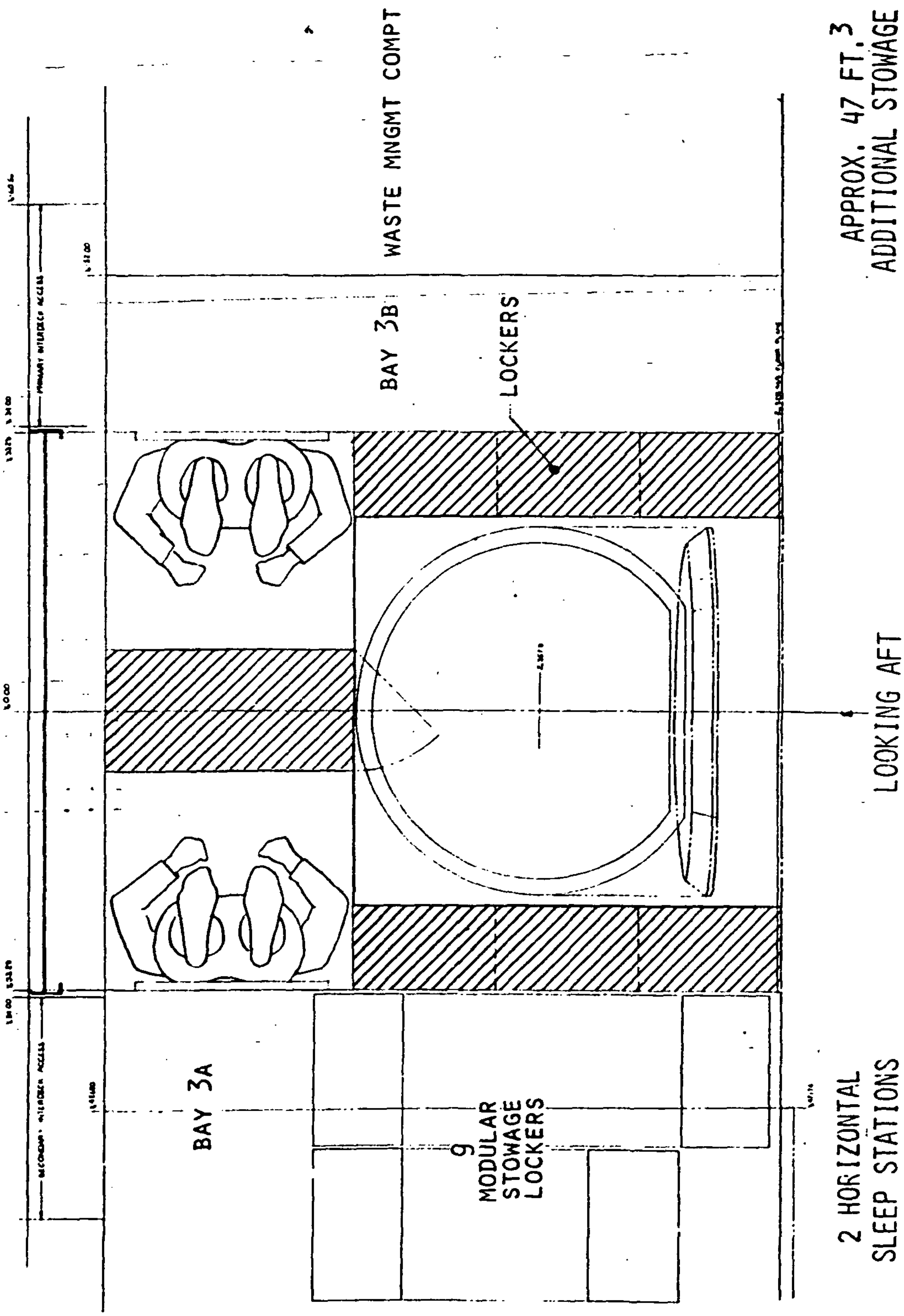


FIGURE 19 - AFT MID-DECK CONCEPT AMD-2

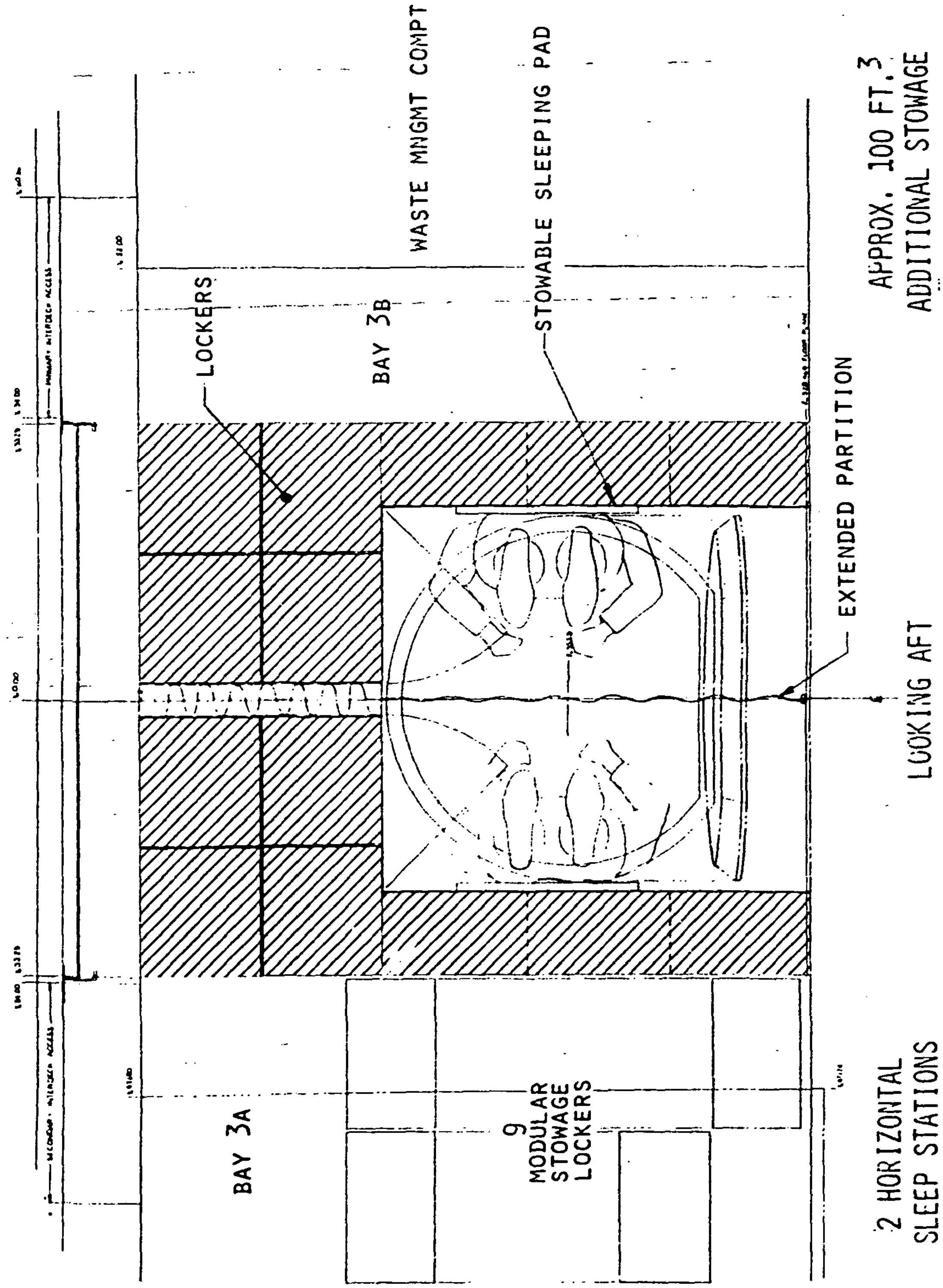


FIGURE 20 - AFT MID-DECK CONCEPT AMD-3

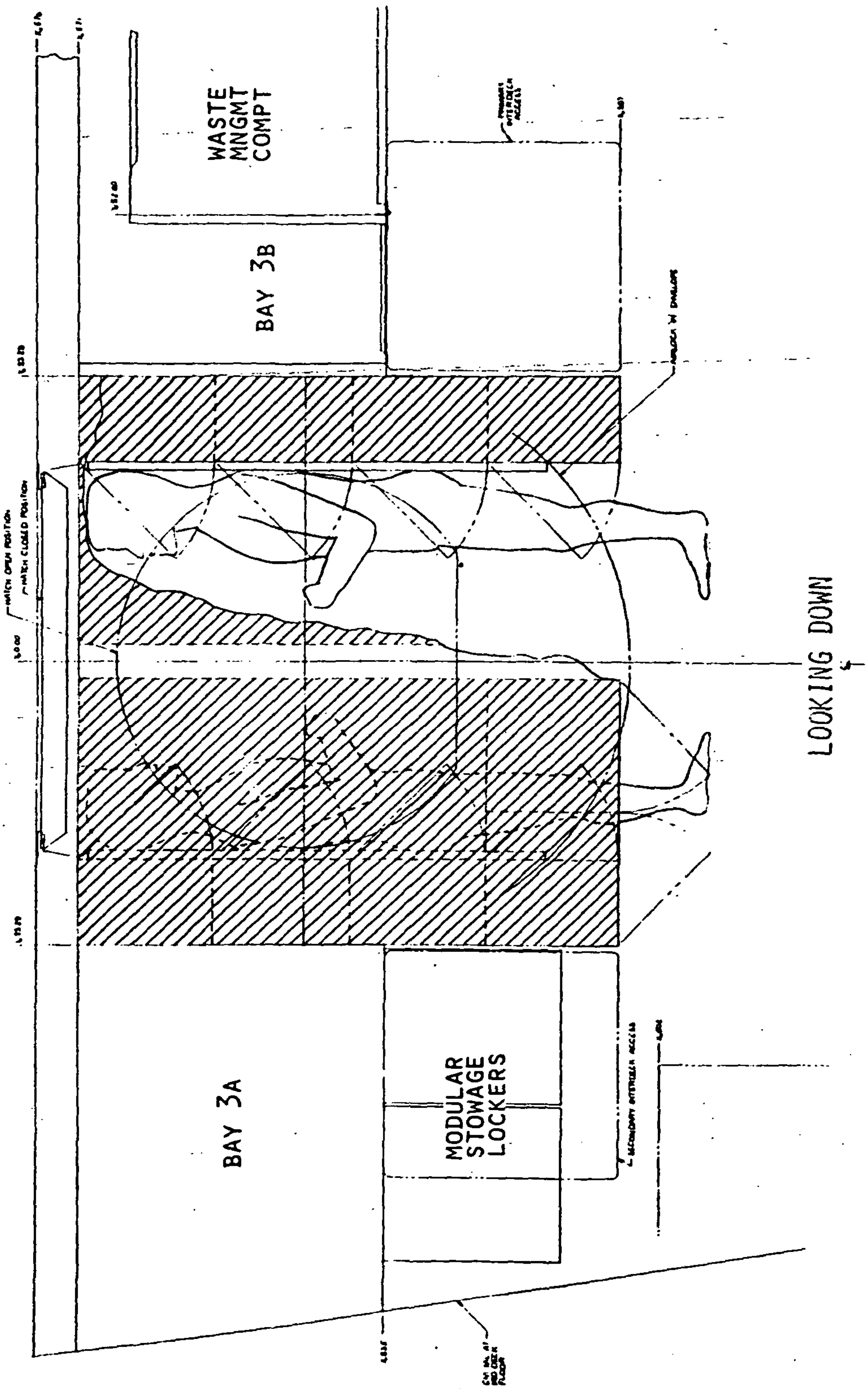


FIGURE 21 - AFT MID-DECK CONCEPT AMD-3

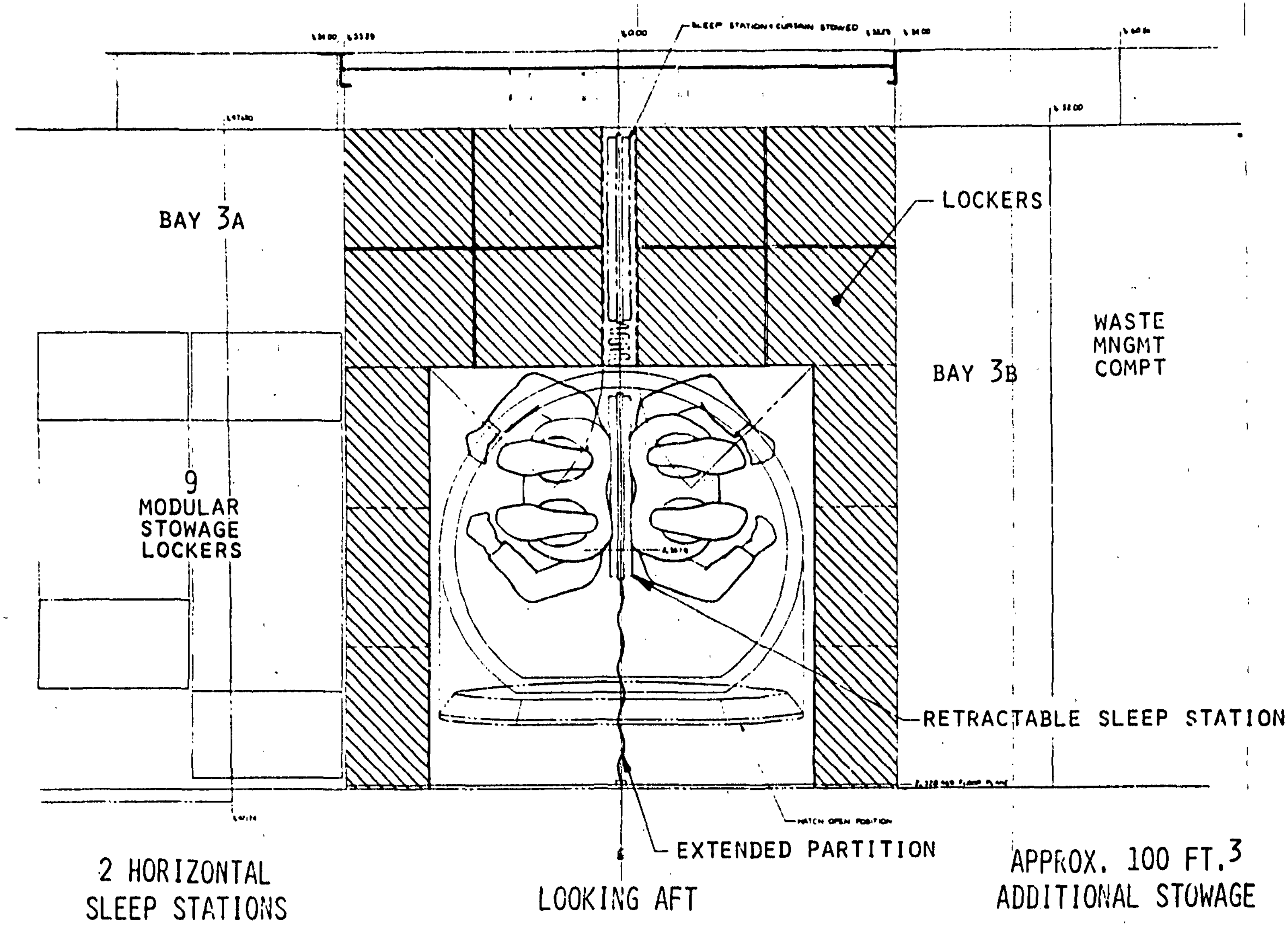


FIGURE 22 - AFT MID-DECK CONCEPT AMD-4

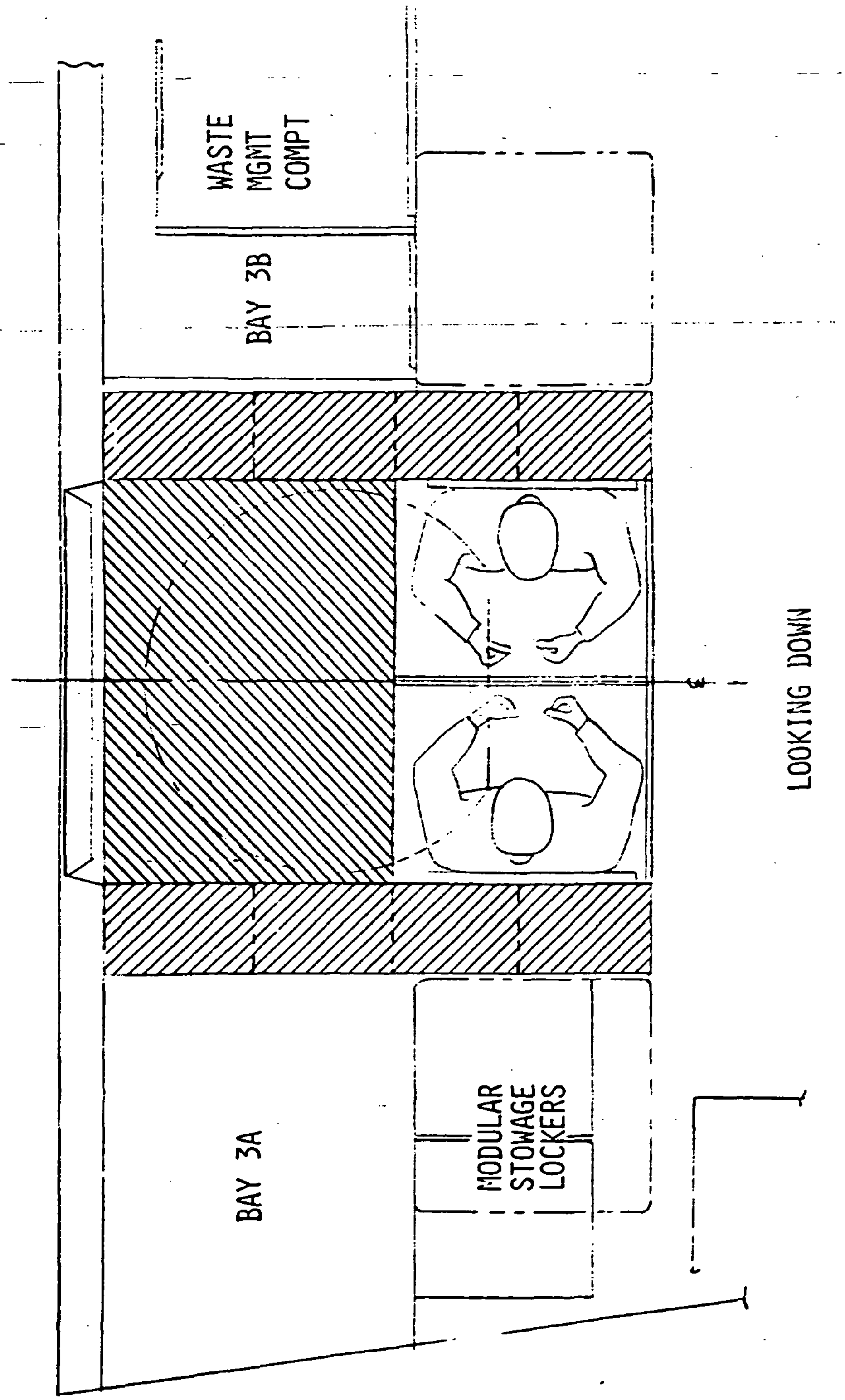


FIGURE 23 - AFT MID-DECK CONCEPT AMD-5

adapter weight is approximately 714 lbs., and is approximately 65 inches in diameter and 84 inches long, with 52 inches of that being a constant section. This is shown in Figures 24 and 25.

The airlock weighs approximately 1,000 lbs. complete with kit, and is cantilevered off of the Xo 576 bulkhead both inside and outside the C/M. When it is on top of the tunnel adapter for the third configuration, it has two struts going from the airlock to the Xo 576 bulkhead to help support the combined weight of the airlock and the tunnel adapter. The existing combined configuration of tunnel adapter and airlock weighs approximately 1,750 lbs. complete. Preliminary hand analysis by the stress group indicates that approximately 2,450 lbs. can be supported by this concept without overloading the Xo 576 bulkhead. (NOTE: A more complete and thorough computer stress analysis would need to be run to verify this.) This opens the possibility of increasing the volume of the tunnel adapter by increasing the diameter and/or the length.

Table 7 shows the concept comparison of the various exterior configurations tried, and shows the size, volume and weight of each.

The first variation tried (ETA-1), shown in Figure 26, was to keep the diameter and length of the tunnel adapter the same but make it of constant section instead of tapered ends. This allows the possibility of sleeping two crew persons and/or storage, but the volume increase was not significant for the weight. The second variation, ETA-2, as shown in Figure 27, still kept the tapered ends, but increased in diameter to 78 inches. This seems to be the maximum diameter and length possible without affecting the existing MMU's, MESA, PEP, airlock position, and payload frame caps. This configuration, along with several others, would remove 4 inches from the straight section

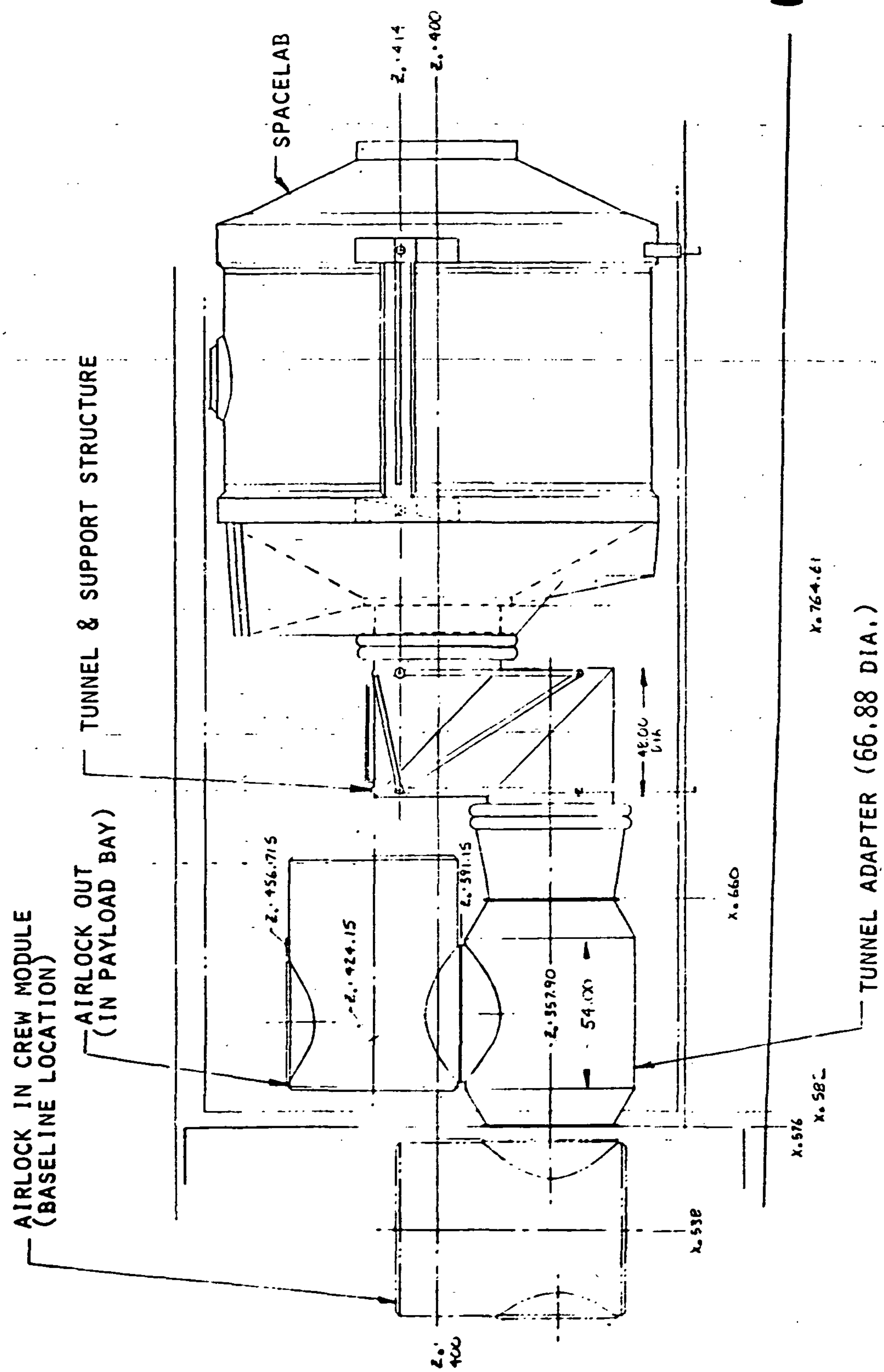


FIGURE 24 - BASELINE ORBITER TUNNEL ADAPTER INSTALLATION

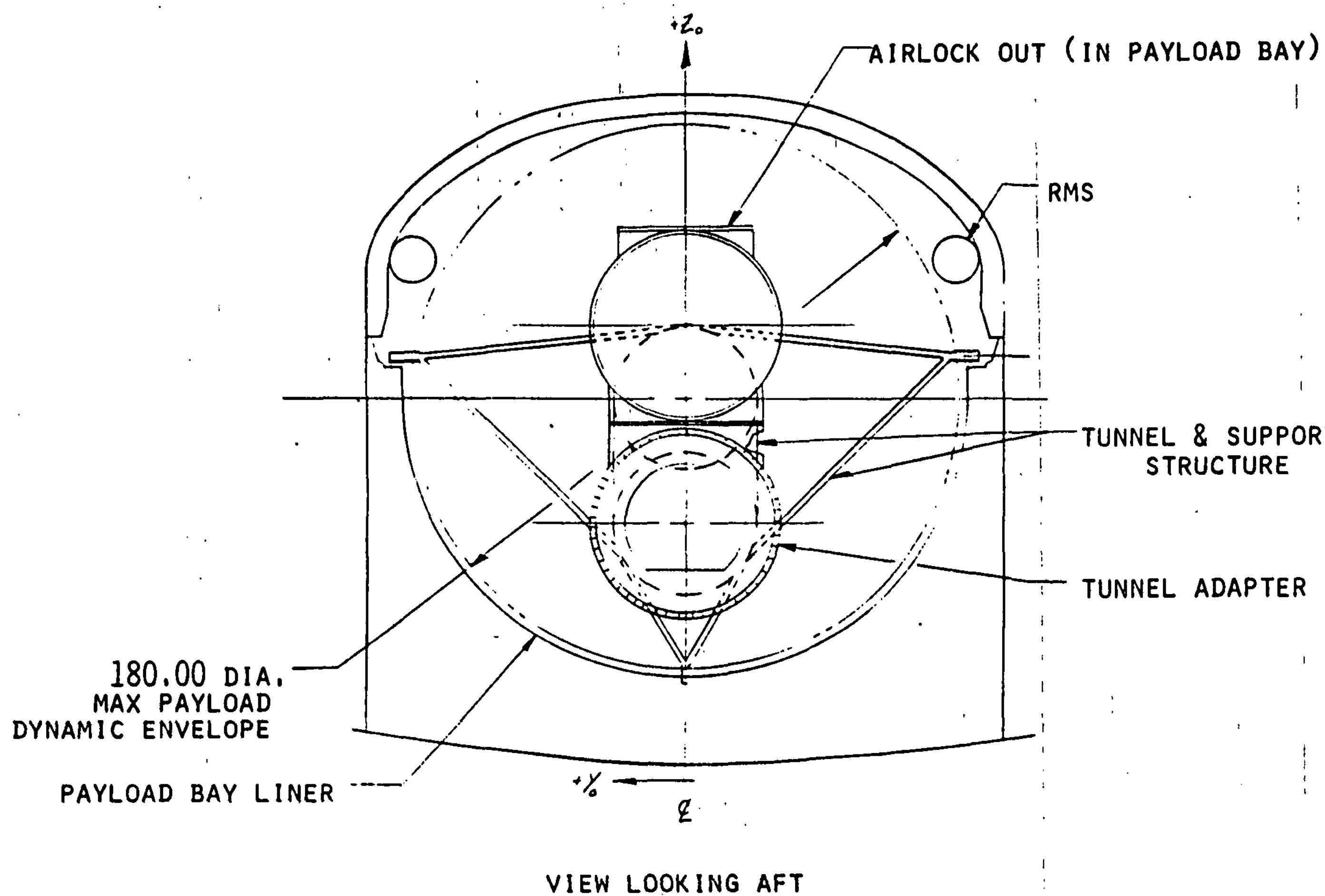


FIGURE 25 - BASELINE ORBITER TUNNEL ADAPTER INSTALLATION

TABLE 7 - ETA EXTERIOR CONCEPT COMPARISONS

	BASELINE T/A	ETA-1	ETA-2	ETA-3	ETA-4	ETA-5
DIAMETER OA	65	65	78	78	78	78/110
LENGTH OA	84	84	88	88	88	156
LENGTH (CONSTANT SECTION)	60	84	60	88	88	58/98
VOLUME INTERNAL (GROSS FT^3)	126	149	194	204	275	590
WEIGHT (MAX ALLOWED ON X_O 576 BULKHEAD AIRLOCK OUT)	2450	2450	2450	2450	2450	N/A
AIRLOCK	1036	1036	1036	1036	1036	N/A
ETA STRUCTURE	714	846	796	1044	1099	1702
ETA "PAYLOAD"	700	568	618	370	315	2740

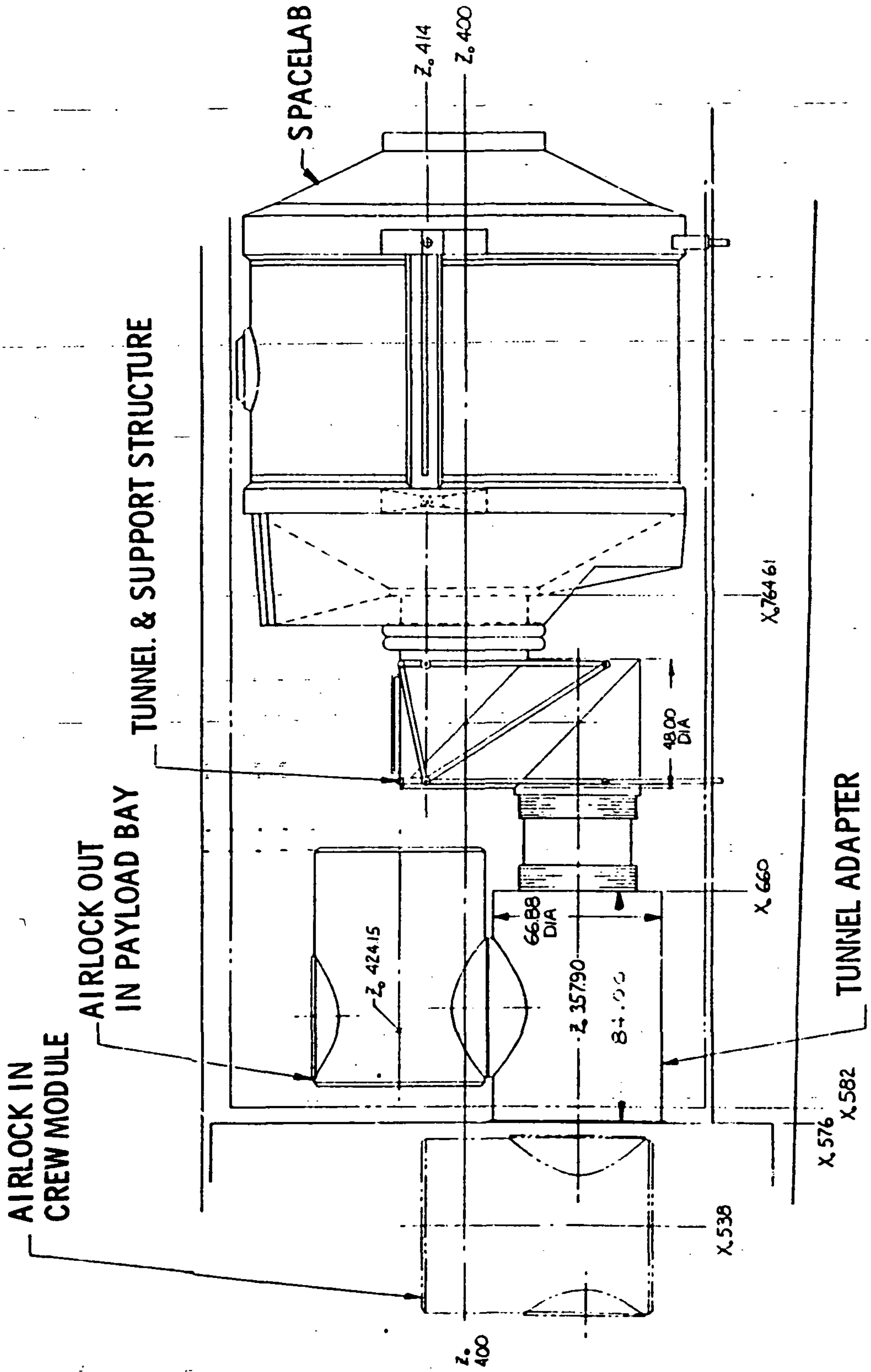


FIGURE 26 - EXTENDED TUNNEL ADAPTER CONCEPT ETA-1

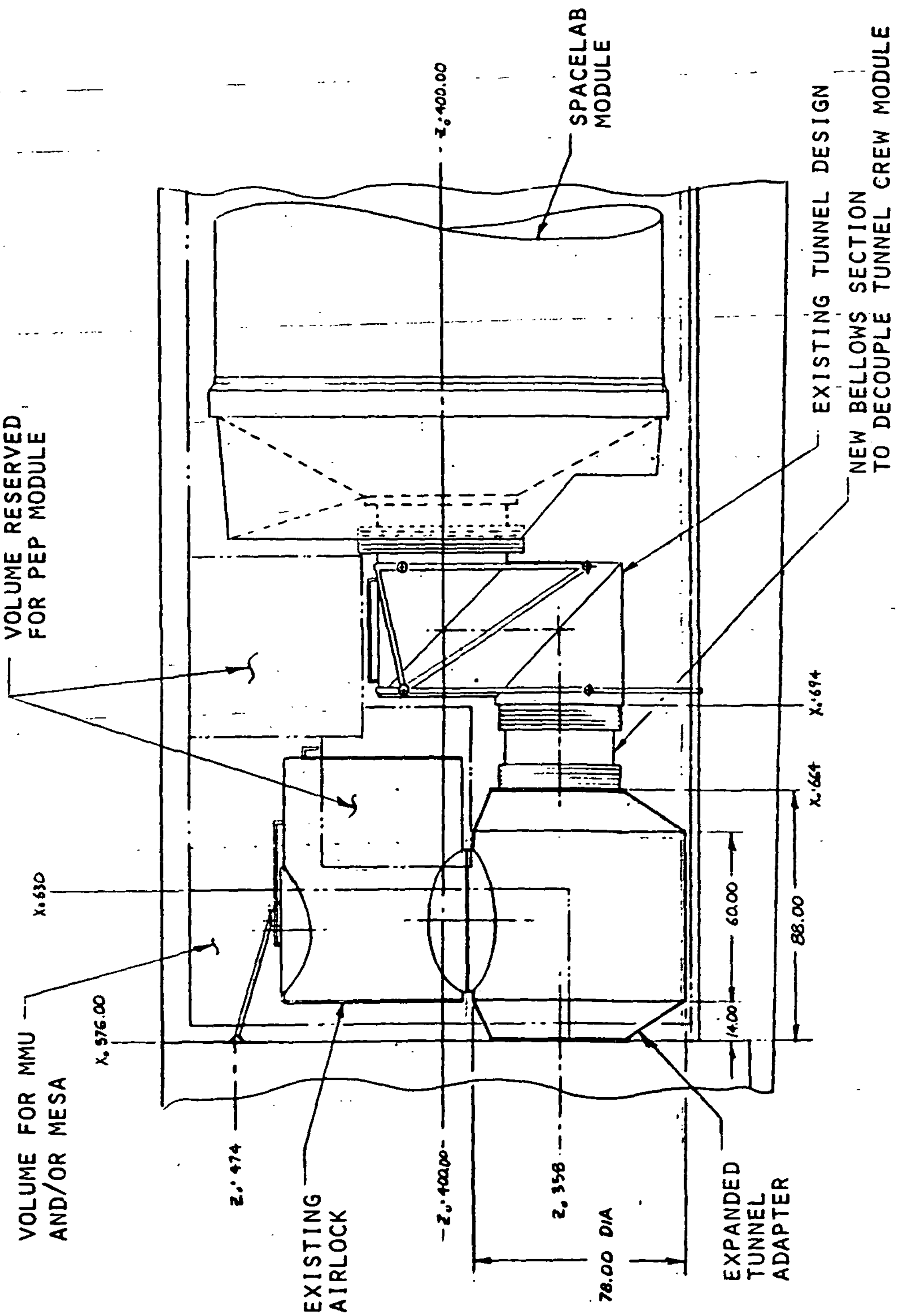


FIGURE 27 - ETA-2, 78 INCH DIA. ADAPTER WITH CONICAL BULKHEADS

of the tunnel bellows to gain extra length for the expanded tunnel adapter to allow the full length for sleeping stations. The tapered ends of ETA-2 would only allow stowage so a constant section version was tried.

ETA-3 is shown in Figure 28 and 29. This configuration seems to offer the most volume versus size and weight and was chosen to design interior concepts as shown later.

ETA-4, as shown in Figure 30, is the same as ETA-3 but utilizes a larger tunnel bellows. The change did not offer any significant advantage over ETA-3.

Hanging the expanded tunnel adapter off the Xo 576 bulkhead limits the weight that can be carried as interior "payload" without modifications to the Xo 576 bulkhead to carry more weight. This restriction caused an investigation of supporting an ETA from the sill longeron in the payload bay and eliminating the existing tunnels, putting bellows at the Xo 576 bulkhead and at the aft end of the ETA. This is shown in ETA-5 on Figure 31. Appendix B shows the concepts drawn to 1/8 scale before they were reduced for report form.

As stated previously, ETA-3 offered the greatest possibility for interior arrangement for stowage and/or sleep stations, so a number of interior concepts were tried to see what the trade-offs were.

In the interior of the ETA, one of the biggest problems is both of the hatches and their translations from open to closed limiting the amount of space used. All of the concepts shown, assume the hatches to the airlock and tunnel are closed during sleep, and that all the crew sleeps at the same time, allowing the use of the space of the hatch in the open postion. The central portion of the ETA also has to be kept clear for the free movement of the

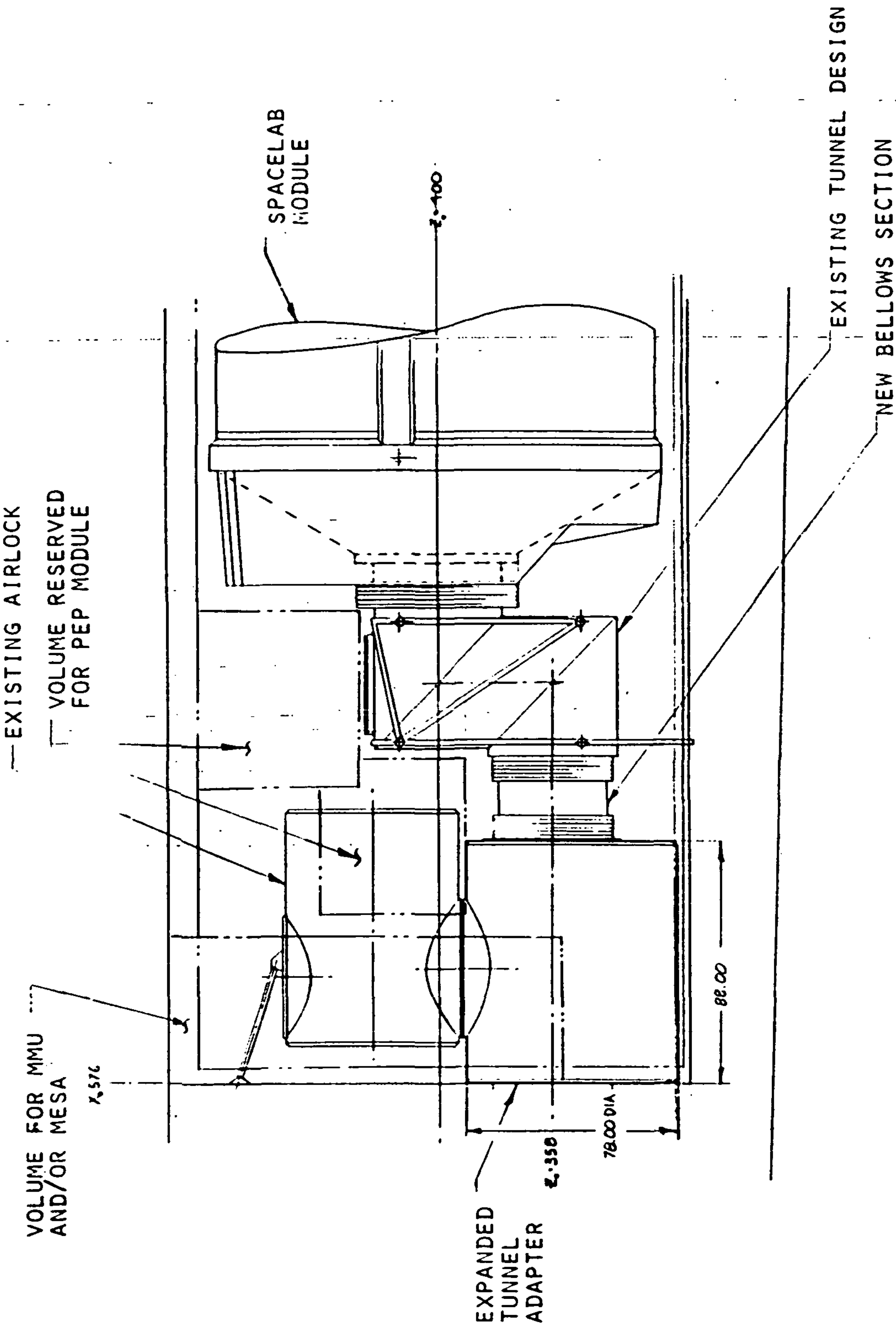


FIGURE 28 - ETA-3, 78 INCH DIA. ADAPTER WITH FLAT BULKHEAD

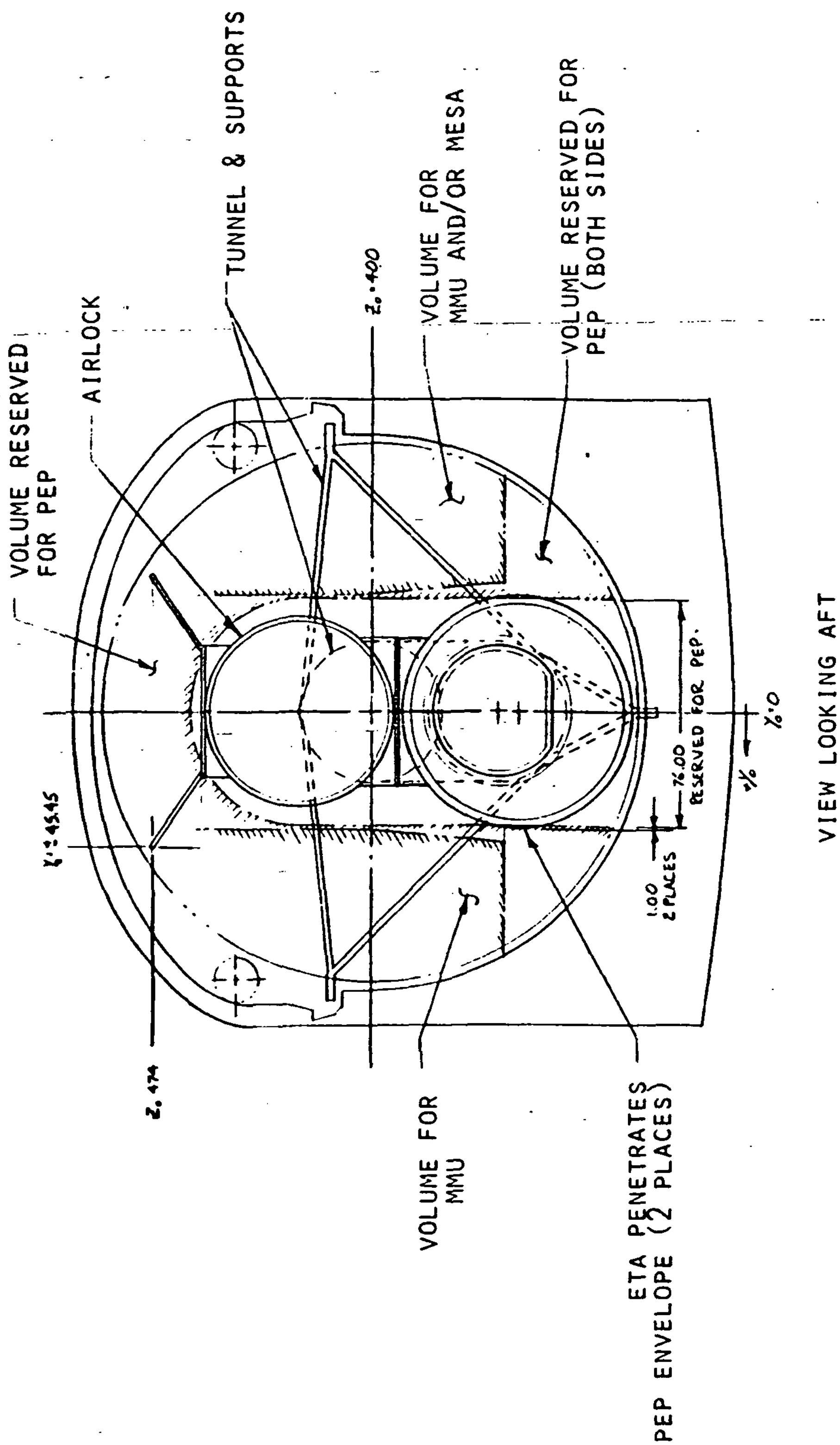


Figure 29 - ETA-3, 78 Inch Dia. Adapter With Flat Bulkheads

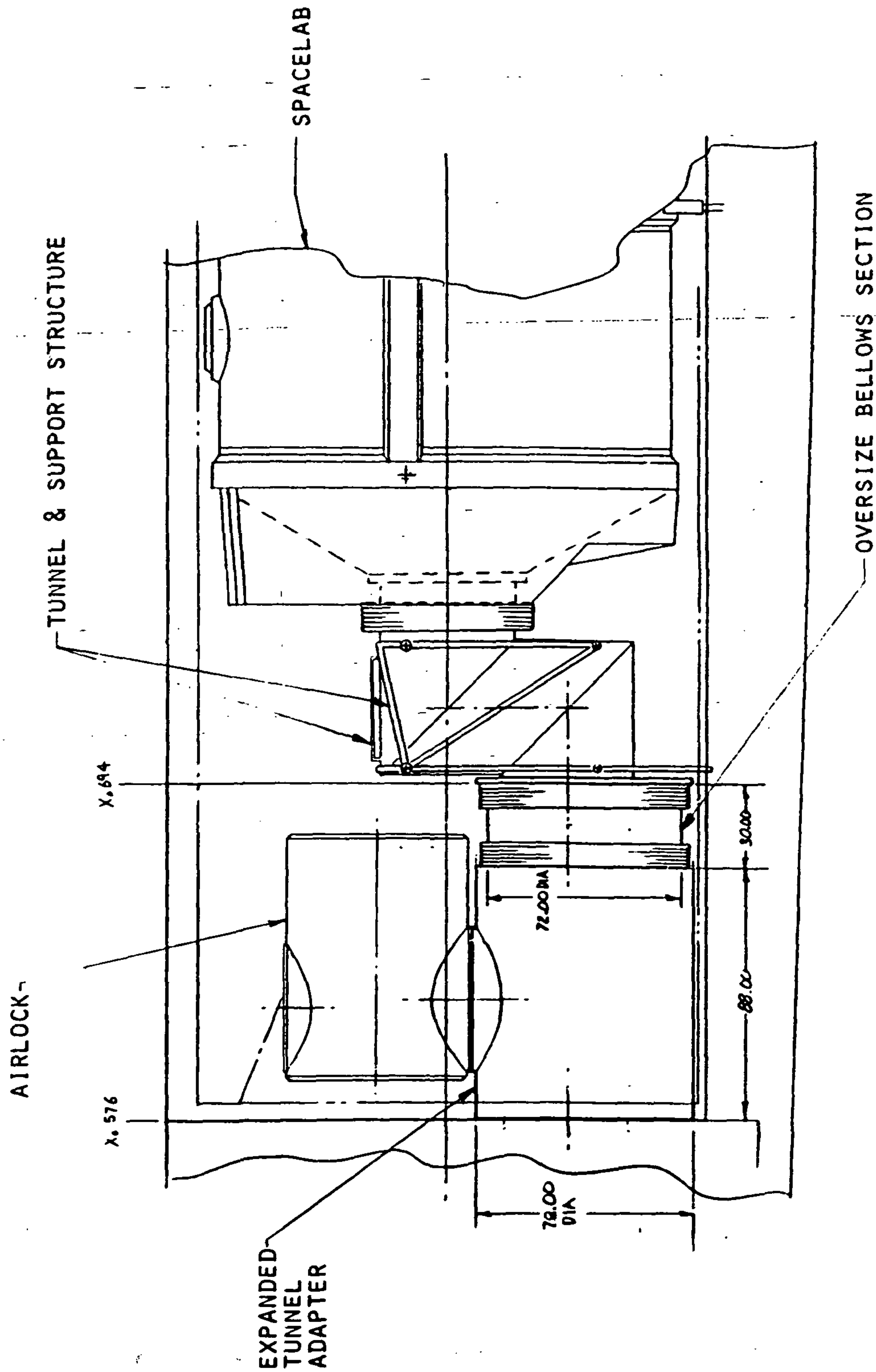


FIGURE 30 - ETA-4, 78 INCH DIA. ADAPTER WITH FLAT BULKHEADS AND LARGE BELLOWS

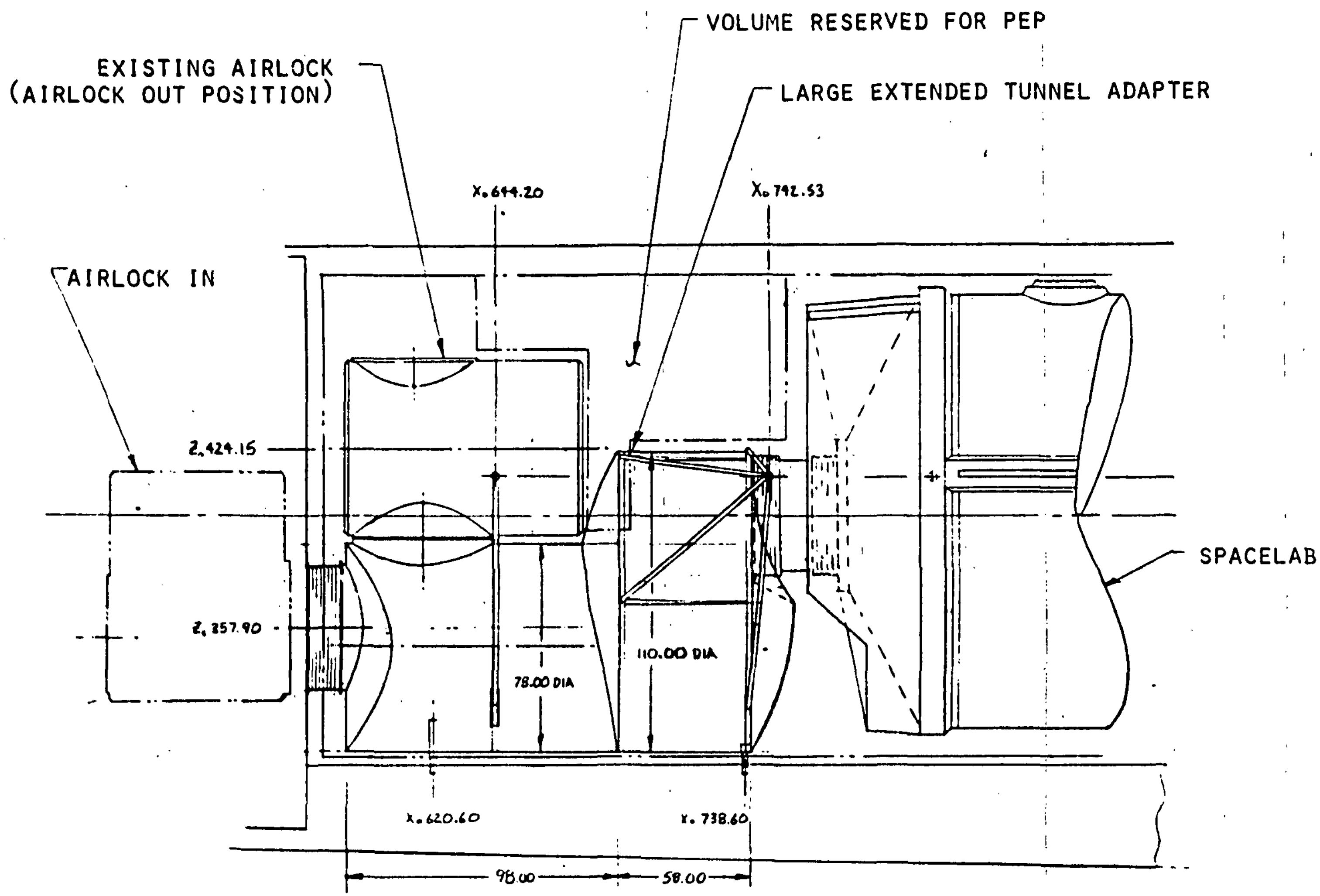


FIGURE 31 - ETA-5, 78 INCH DIA. ADAPTER INTEGRATED WITH TUNNEL

crew to the airlock and the spacelab.

The interior arrangements are called out as ETA-3A through ETA-3E as they are versions of ETA-3. A comparison chart is shown in Table 8, showing stowage, sleep stations, habitable volume, and weight to allow the reader to compare the concepts with each other.

Preliminary weight estimates are that this expanded tunnel adapter structure (ETA-3) would weigh approximately 1,044 lbs. with the airlock on top of the expanded tunnel adapter allowing for a "payload" of approximately 370 lbs. inside, and thus would limit the full use of the possible large stowage capability of the expanded tunnel adapter. Modifications would probably have to be made to the Xo 576 bulkhead to fully utilize the full capability of these concepts. ETA-3A, shown in Figure 32, shows an all stowage concept with approximately 68 ft^3 of stowage. While this is a significant volume, the limit of 370 lbs. of "payload" would severely limit the use of all this space with a possible maximum of 30 lbs. per cubic feet allowed on stowage lockers. ETA-3B, shown in Figure 33, shows a similar stowage volume (61 ft^3), but with two sleep stations on the locker fronts. These would have individual cushions on each locker door, with restraints to be added when in use as a sleep station. An accordian divider would provide some privacy for the two sleep stations when in use. ETA-3C, shown in Figure 34, sacrifices some stowage volume to provide some sleeping volume for the crew. This again has an accordian divider for privacy. ETA-3D, shown in Figure 35, has two dedicated sleep stations that do not utilize the stowage locker fronts and provide more privacy and quiet. The cylinder shape lends itself to using the outside curvature of the structure for use of individual sleep stations instead of lockers.

TABLE 8 - ETA-3 INFERIOR CONCEPT COMPARISONS

	-3A	-3B	-3C	-3D	-3E
△ STOWAGE VOLUME (MAX)	68	61	41	32	14
TOTAL DURATION 4 CREW (LiOH)	32	30	25	22	16
(SAWD)	36	33	27	24	17
TOTAL DURATION 6 CREW (LiOH)	18	17	14	12	9
(SAWD)	22	20	16	14	10
NUMBER OF SLEEP STATIONS	-	2	2	2	3
FT^3 PER MAN/SLEEP STATION	-	54	62	20	36
STOWABLE OR PERMANENT	-	STOW	STOW/PERM	PERM	PERM
PRIVACY & QUIET	-	GOOD	GOOD	VERY GOOD	FAIR
△ FT^3 HABITABLE VOLUME	95	108	126	127	106
*WEIGHT OF LOCKERS/SLEEP STA	186	211	184	142	116
*WEIGHT OF LOCKERS/SLEEP STA, ETA, & STOWAGE (30 LBS. PER FT^3)	3072	2837	2358	2201	2238

*NOTE: THE MAXIMUM "PAYLOAD" FOR CONCEPT ETA-3 IS LIMITED TO 370 LBS WITHOUT MODIFICATION TO THE Xo 576 BULKHEAD.

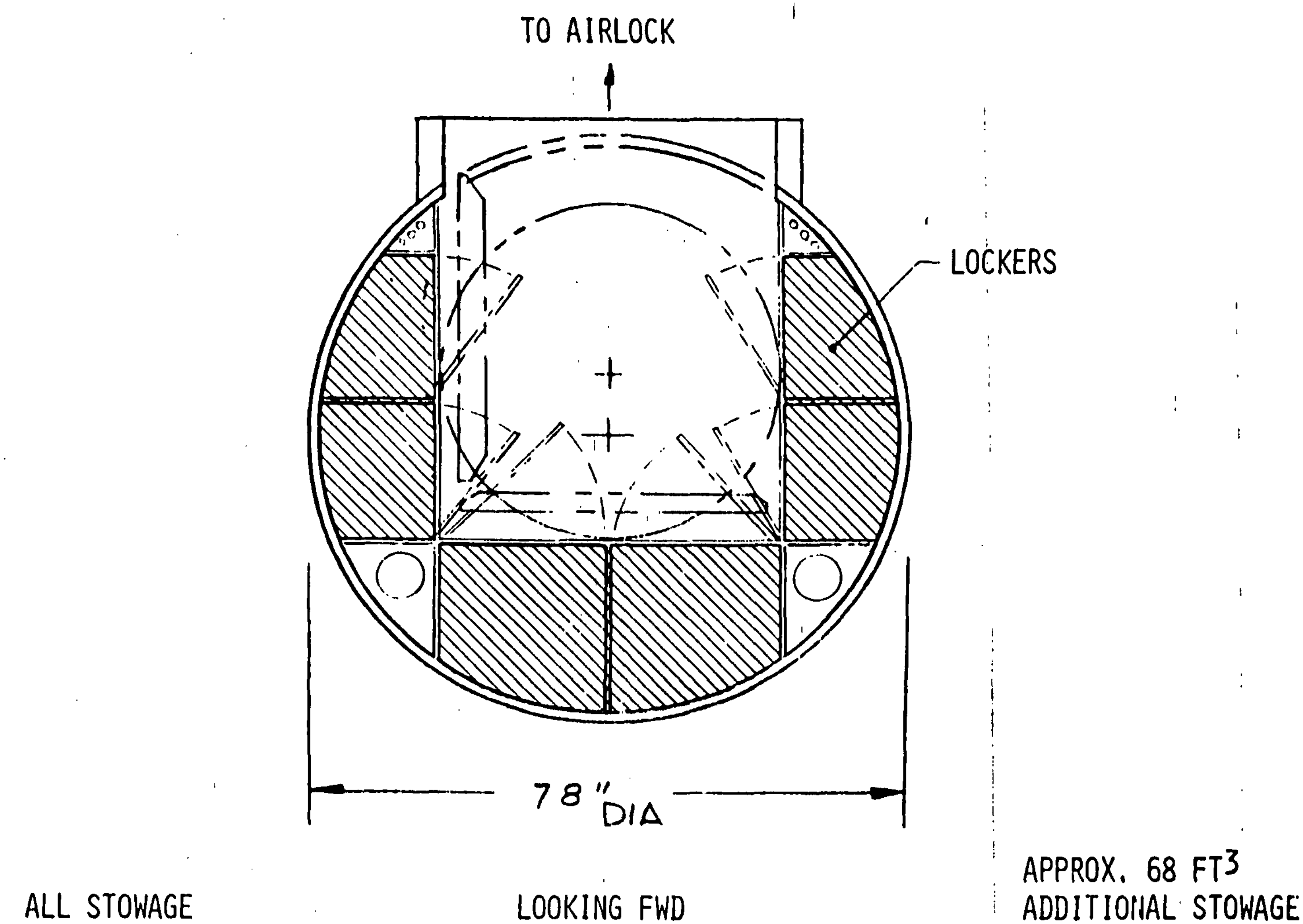
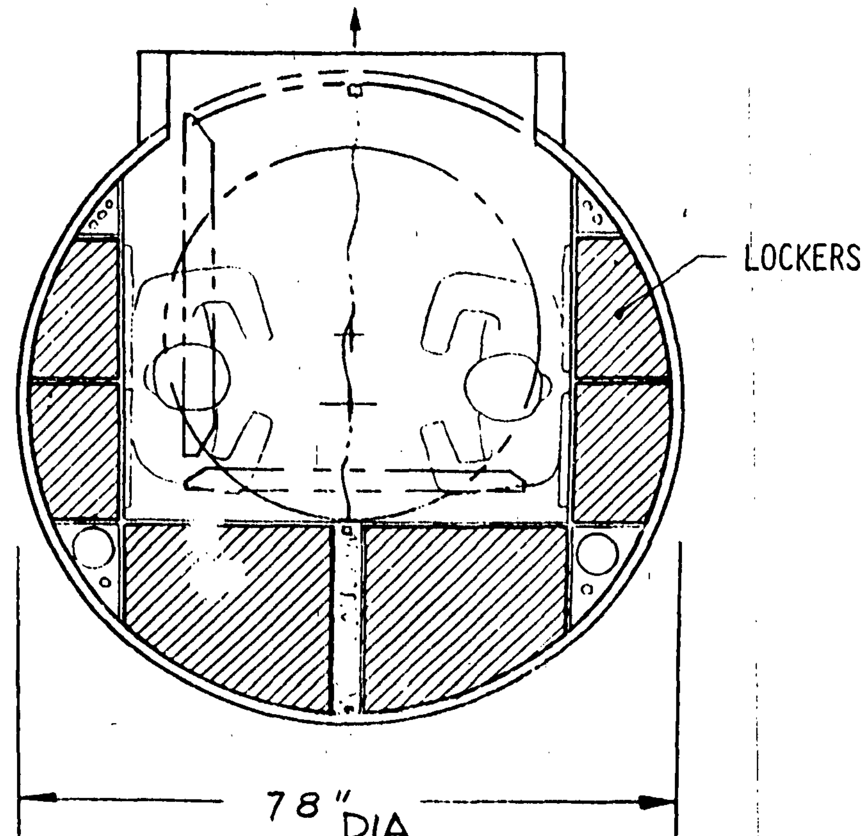


Figure 32 - Expanded Tunnel Adapter Concept ETA-3A

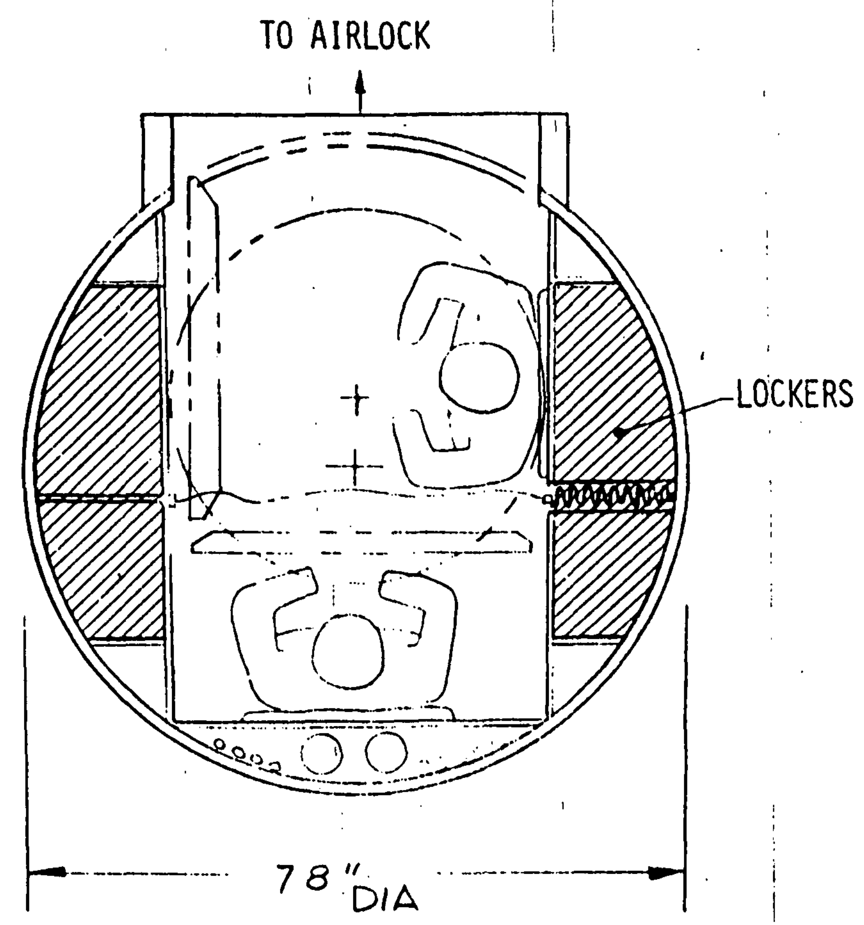


2 SLEEP STATIONS

LOOKING FWD

APPROX. 61 FT^3
ADDITIONAL STOWAGE

FIGURE 33 - EXPANDED TUNNEL ADAPTER CONCEPT ETA-3B



2 SLEEP STATIONS

LOOKING FWD

APPROX. 41 FT^3
ADDITIONAL STOWAGE

FIGURE 34 - EXPANDED TUNNEL ADAPTER CONCEPT ETA-3C

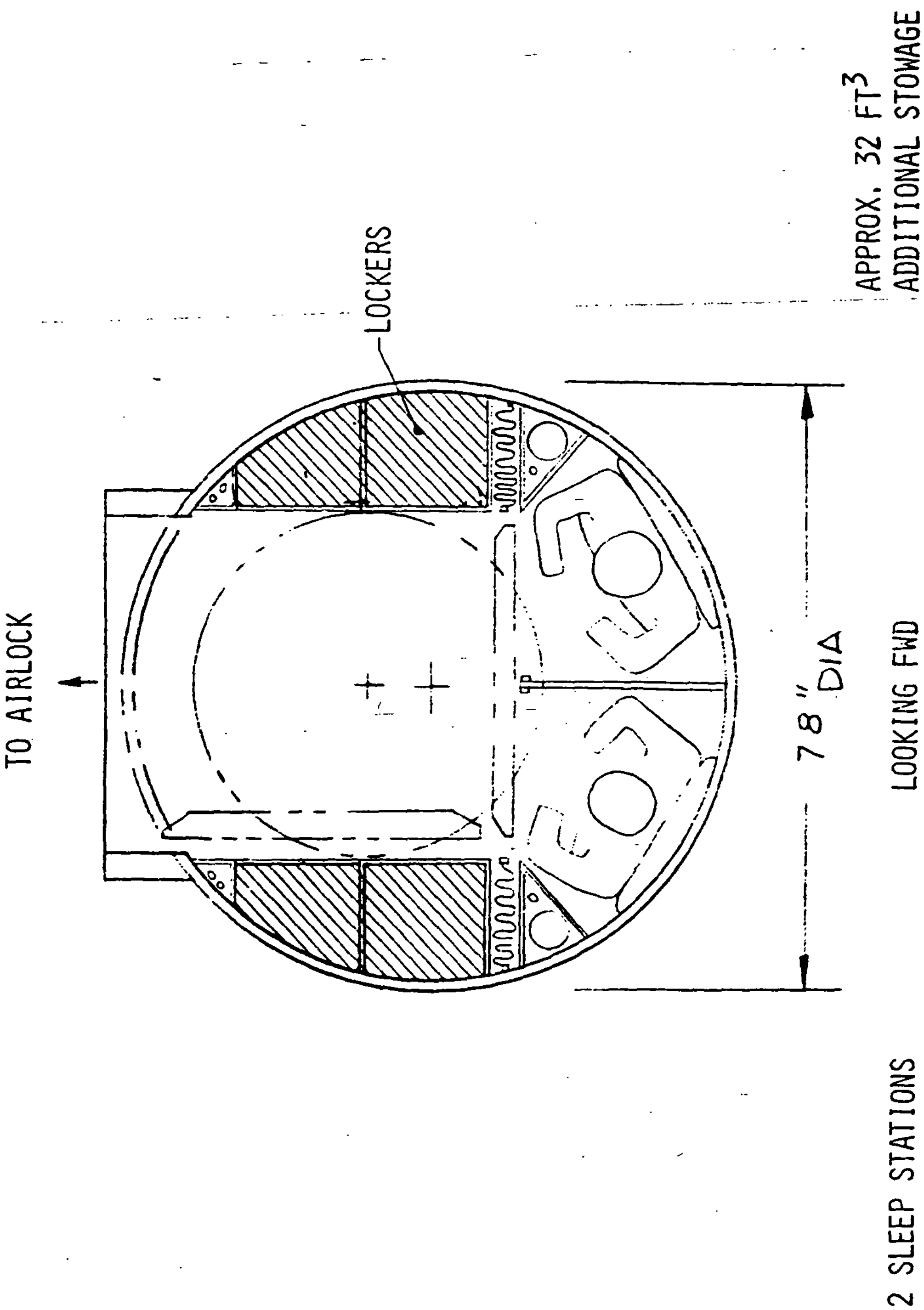


FIGURE 35 - EXPANDED TUNNEL ADAPTER CONCEPT ETA-3D

Figure 36 (ETA-3E) shows a three sleep station concept, but the disadvantage of this concept is that it reduces the stowage volume significantly. The reduced stowage volume would be better utilized for the use of personal stowage for the crew. The hatch opening kinimatics eat up a lot of volume and prevent a maximum use of the cylinder volume.

CONCEPT COMPARISONS

Figure 37 shows some interesting comparisons of ft^3 stowage versus delta weight to the orbiter vehicle. This graph shows both AMD and ETA concepts compared on one chart. ETA-3 and ETA-4 show the most stowage volume, but at a much greater weight. AMD-1 seems to have the greatest potential on this comparison and the ETA concepts do not fare as well as any of the AMD concepts. This is based on a six person crew with SAWD CO^2 removal.

Figure 38 shows the ft^3 stowage versus orbiter duration on a comparison basis graph for all concepts. The baseline stowage/duration is included in these figures. Again, AMD-3 and AMD-4 shows the greater duration with AMD-1 not far behind. Again, the AMD concepts seem to offer much greater potential for increased duration with the least weight, cost, and impact to the baseline orbiter. See Section III for further summary and recommendations.

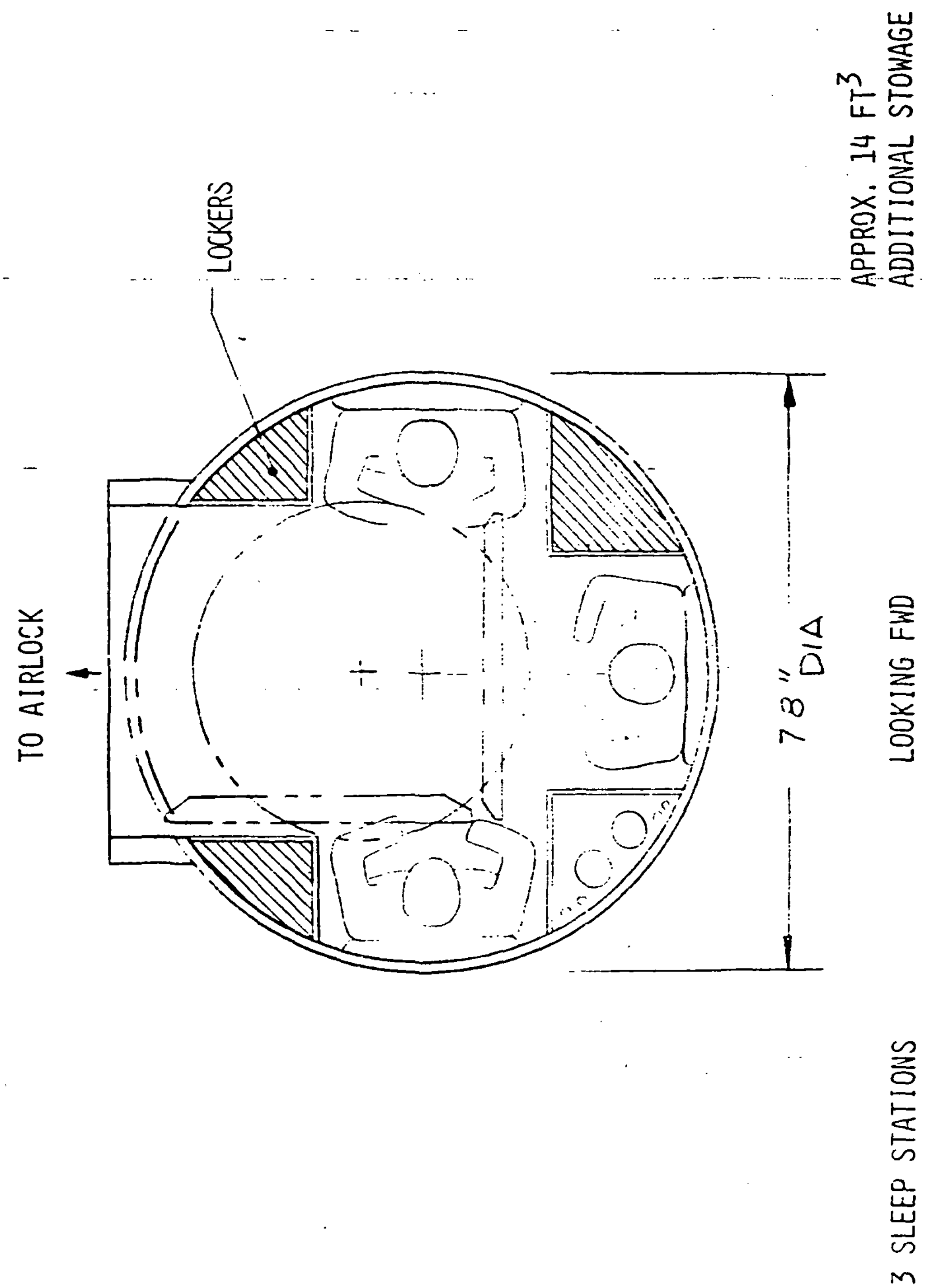


FIGURE 36 - EXPANDED TUNNEL ADAPTER CONCEPT ETA-3E

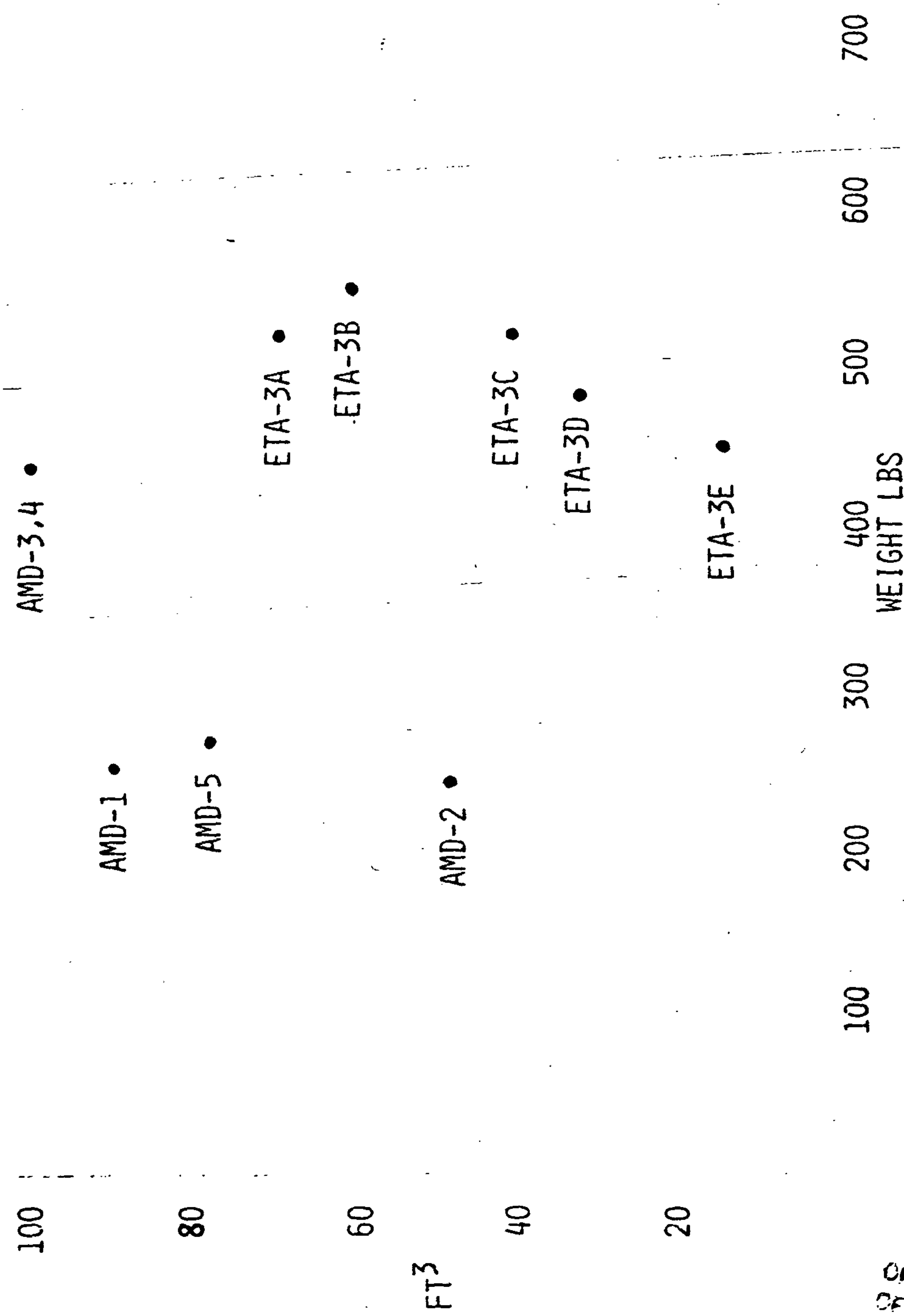


FIGURE 37 - CONCEPT COMPARISON OF STOWAGE VOLUME VS. Δ VEHICLE WEIGHT

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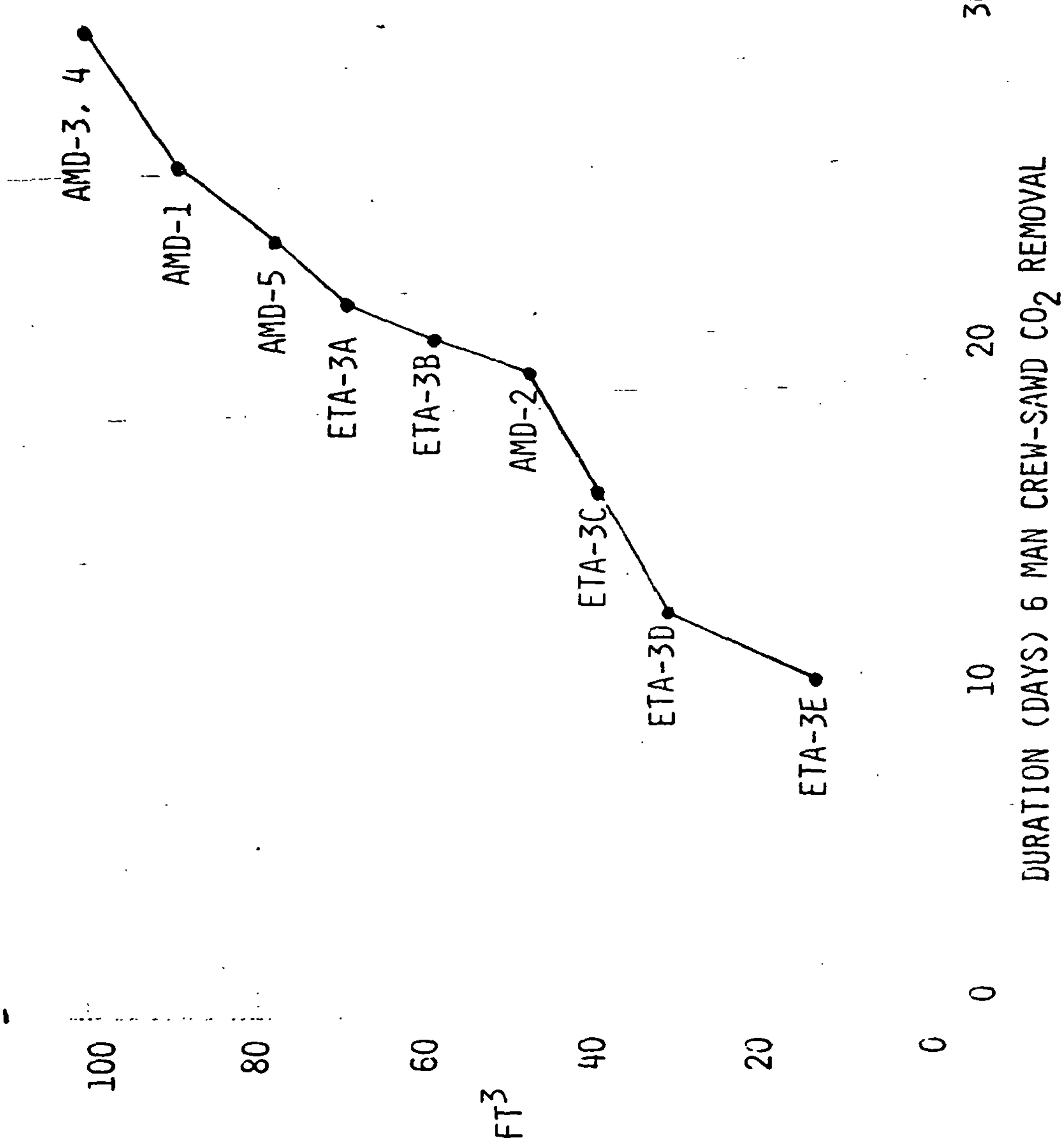

FIGURE 38 - CONCEPT COMPARISON OF STOWAGE VOLUME VS. ORBITER DURATION

VI. MID-DECK GENERAL ARRANGEMENT DRAWING

An interior arrangement drawing of the C/M mid-deck was completed as Task 4 of this contract. This drawing (SS79-00242) is drawn to one quarter scale on a "J" size vellum (36" x 24 zones, 4 sheets) and is shown in reduced form in Appendix C. The drawing shows the major elements located in the mid-deck area, by views, section cuts and inner moldlines. A list of the major assembly drawings will also be included on the face of the drawing along with an orientation view to show how to calculate from the crew module numbering reference system to the orbiter numbering reference system (and vice versa). The major elements shown on the drawing includes primary and secondary structure, airlock and hatches, avionic bays, moldlines, interior closeout panels, lockers, bunk outlines, galley outline and the waste management compartment.

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VII. SUMMARY AND RECOMMENDATIONS

This section will summarize briefly each of the four tasks in order of Task 1, Task 2, Task 4 and Task 3, and then give some recommendations for the Phase II of this study.

TASK 1

Habitability improvements for early flights that can be implemented with minimum impact, were the main concern of this task of the study. A number of concepts were generated that would save time on-orbit and on routine-daily living "chores" and improve the living conditions of the crew. A number of suggestions and recommendations were given by the mid-term briefing in written and picture form, and several were implemented by NASA/JSC. These included launching the water dispenser in the on-orbit position instead of in a locker. The sleep pallet concept that could be used in a horizontal or vertical position is being developed. The suction cup foot restraints are being reevaluated and several other suggestions are being evaluated at this time. All of these were minimum impact concepts that could be implemented for early flights.

TASK 2

Past studies and investigations that used volumetric terms and requirements for crew size versus mission duration were reviewed and common definitions of key habitability terms ~~was~~ were established. Also, a common value of volume versus duration for minimum and acceptable habitable conditions was generated in graph form. All of these terms and values can be used as a baseline reference for future studies and investigations.

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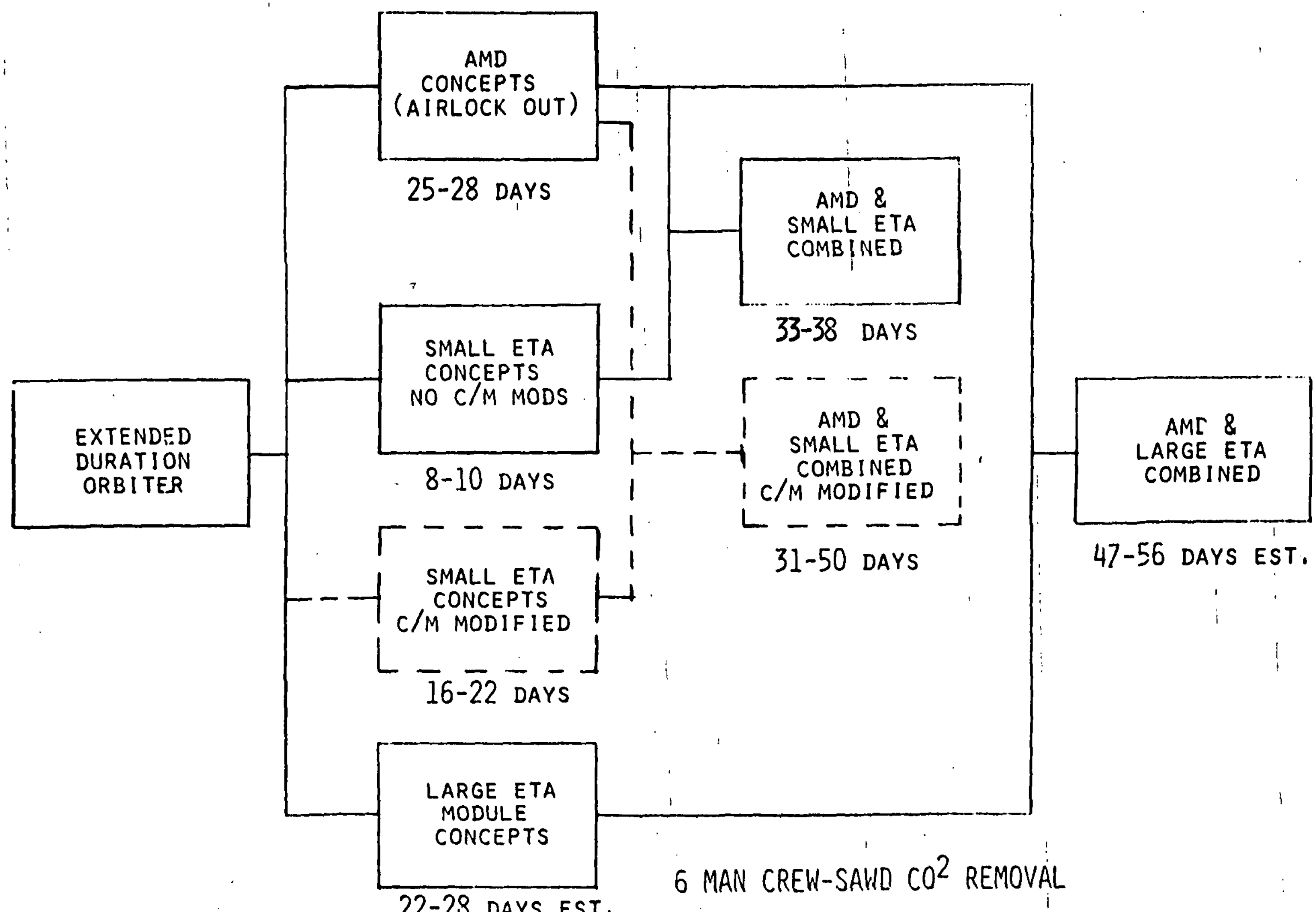
TASK 4

An accurately dimensioned drawing of the orbiter mid-deck, locating all of the known major elements was produced. This drawing can be used as a baseline for assessment of future changes of habitability, improvement and for Phase II of this study and all future changes to the orbiter mid-deck.

TASK 3

It was established that orbiter duration and crew size can be increased with minimum modification and impact to the crew module. Preliminary concepts of the aft mid-deck (AMD), external versions of expanded tunnel adapters (ETA) and interior concepts of ETA-3 was produced, and comparison charts showing the various factors of volume, weight, duration, volume, size, impact to orbiter and number of sleep stations were generated. The aft mid-deck (AMD) concepts show the greatest potential for a significant increase in stowage volume for the least amount of weight and impact (change) to the orbiter. The ETA concepts show another alternative way to increase volume beyond the AMD concepts, if even greater duration is needed, but at a higher penalty in weight and impact to the vehicle, with not as great an increase in volume for stowage or sleep stations.

Extending the orbiter duration beyond approximately thirty days will probably require the combining of AMD and ETA concepts as shown in Figure 39. The approximate number of days duration with a six person crew and SAWD (solid amine water desorbed) CO^2 removal, is shown under the boxes for comparison. The need or requirement for a long-term duration mission has not been established yet, but this study has shown several ways to dramatically increase the duration of the orbiter without a major impact.



6 MAN CREW-SAWD CO^2 REMOVAL

FIGURE 39 - SUMMARY OF EXTENDED DURATION CAPABILITY

The stowage volume requirement is the first "stepping stone" to increased duration with the CO^2 removal system the next level. The solid amine ECLSS replacement appears to be a worthwhile change over the LiOH system presently used, since the LiOH uses up an increasing amount of stowage as duration and/or crew size goes up,and further aggravates the stowage problem.

RECOMMENDATIONS FOR PHASE II

Any dramatic increase in stowage volume will cause an encroachment in payload volume, weight and possibly center of gravity. Other impacts to the vehicle that are affected when duration is increased, such as ECLSS, electrical power, oxygen, nitrogen, water, EVA requirements, etc. should be addressed in subsequent studies. Also, impacts to the payload, detailed stress analysis, cost estimates, detailed weight and center of gravity should be investigated at the appropriate level in future studies to provide additional data for programmatic evaluation.

As outlined in the previous paragraph, the relationship of extended orbiter duration with all the crew support subsystems and the "total picture" impact data, as duration is extended, is not well defined and needs to be investigated. The interaction with the spacelab and potential concepts (SOC, power module, etc.), as well as mission requirements for long duration, are also not well defined.

The promising habitability concepts from this Phase I study needs to be refined and defined in more detail and new concepts for improved habitability and increased mission duration/crew size enhancement still needs further investigation.

APPENDIX A

AFT MID-DECK CONCEPT DRAWINGS

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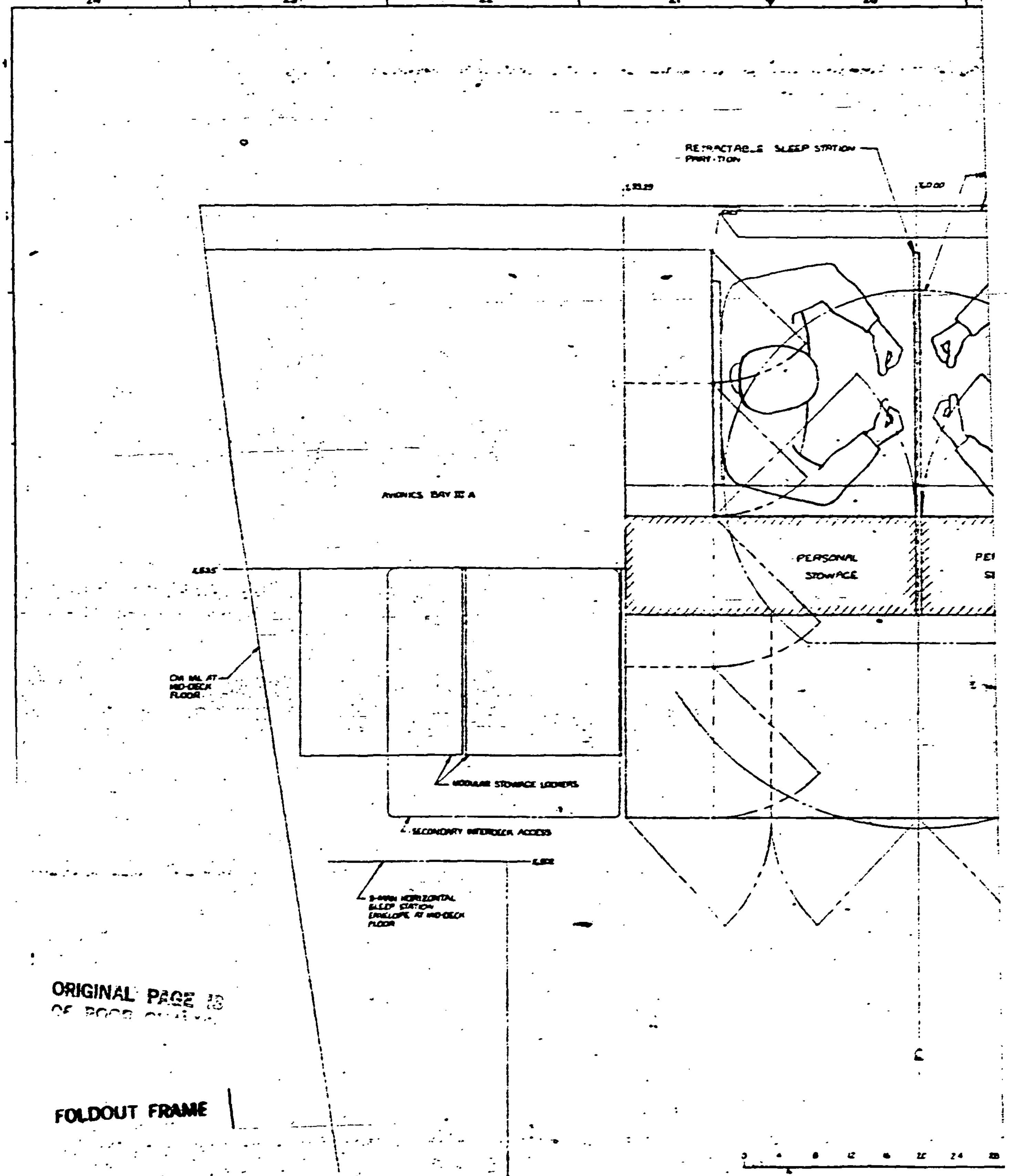

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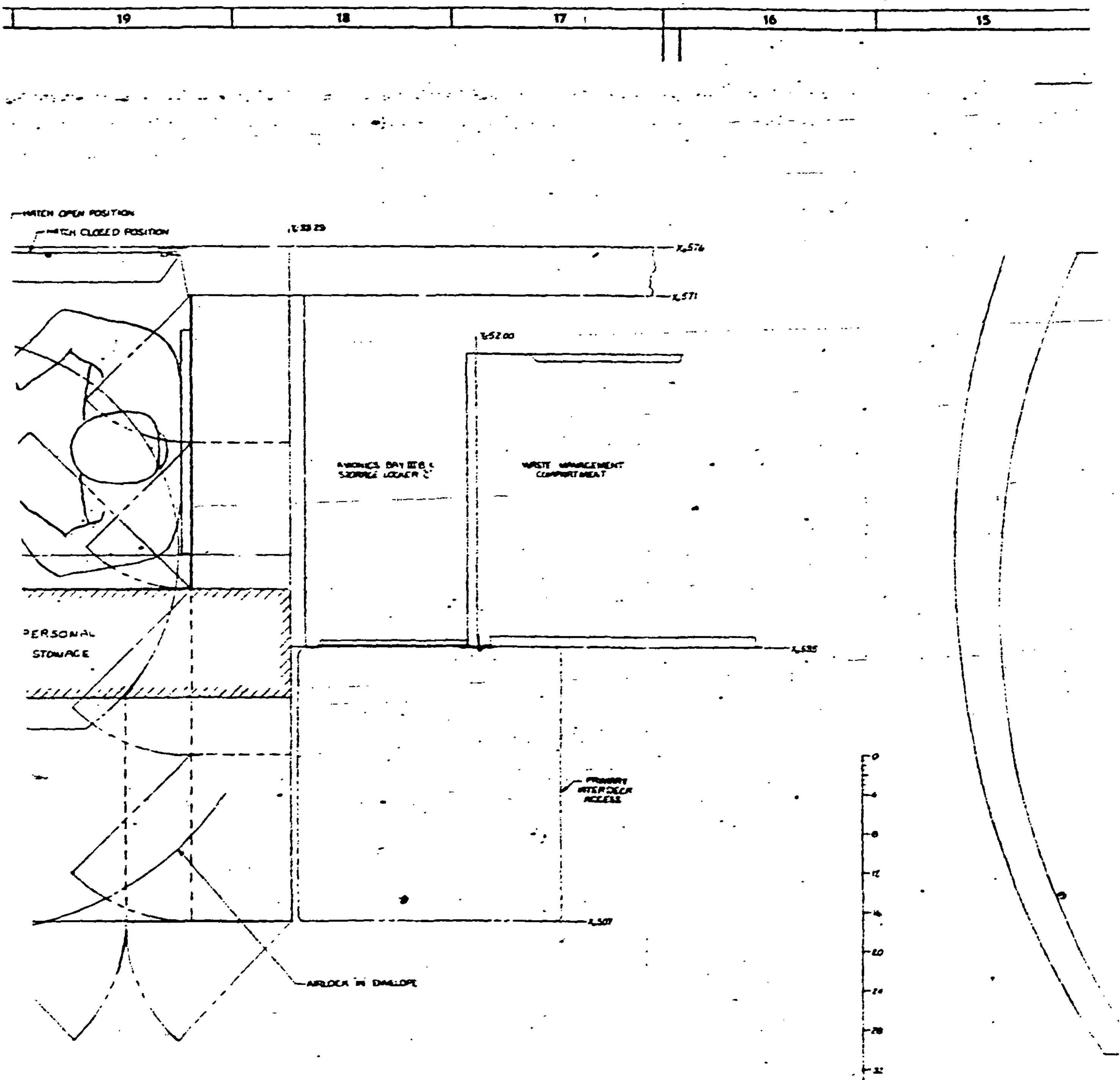

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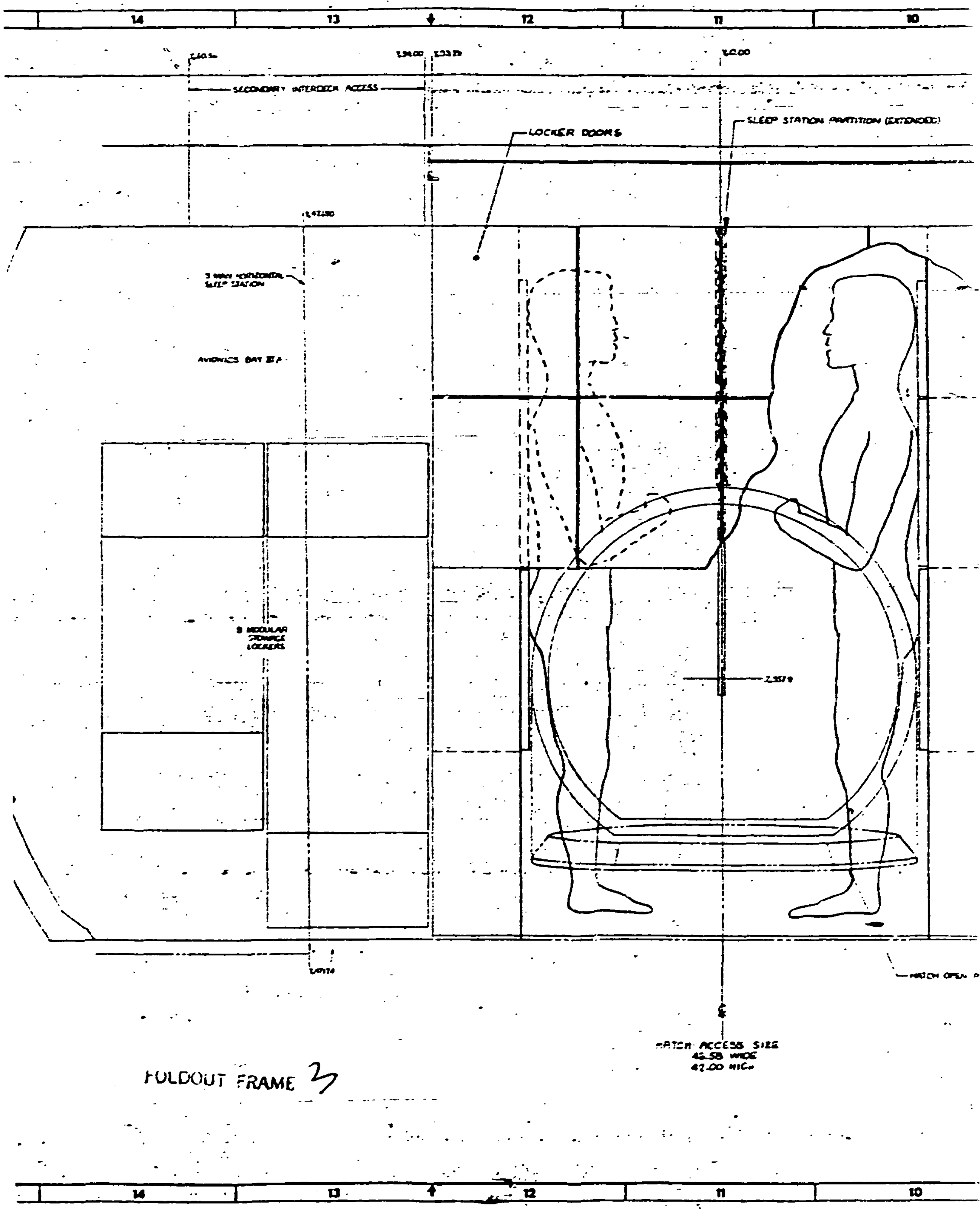

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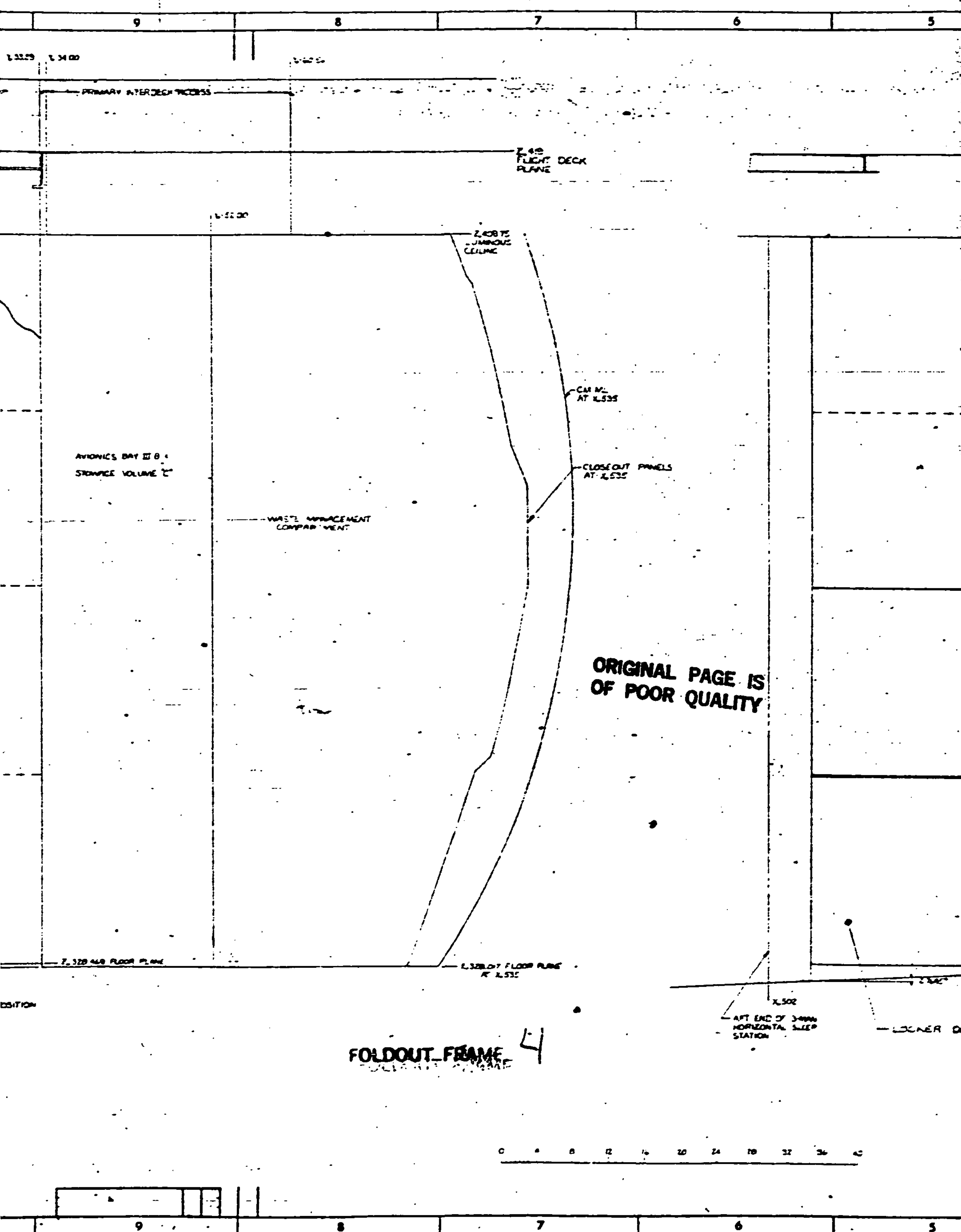

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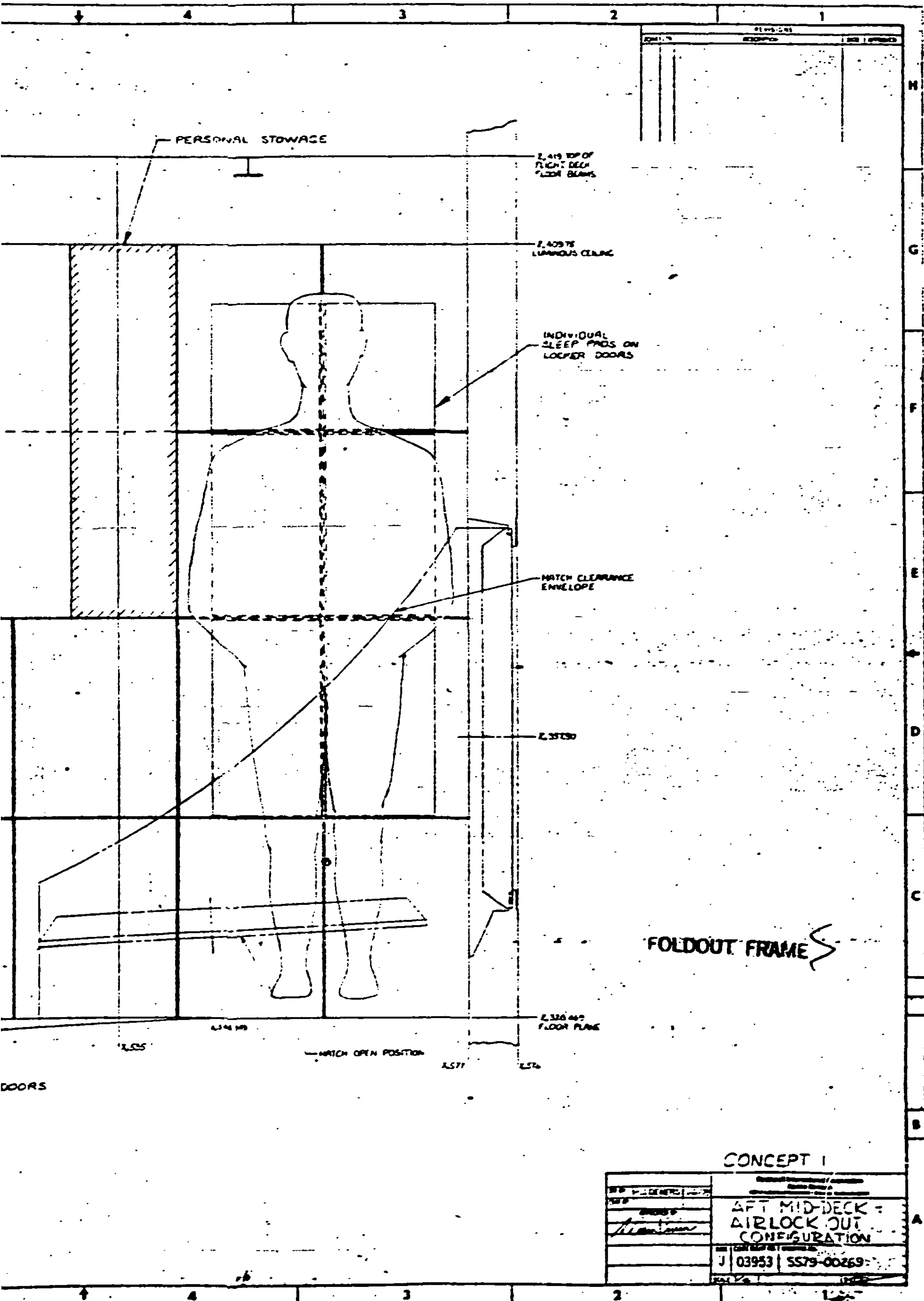
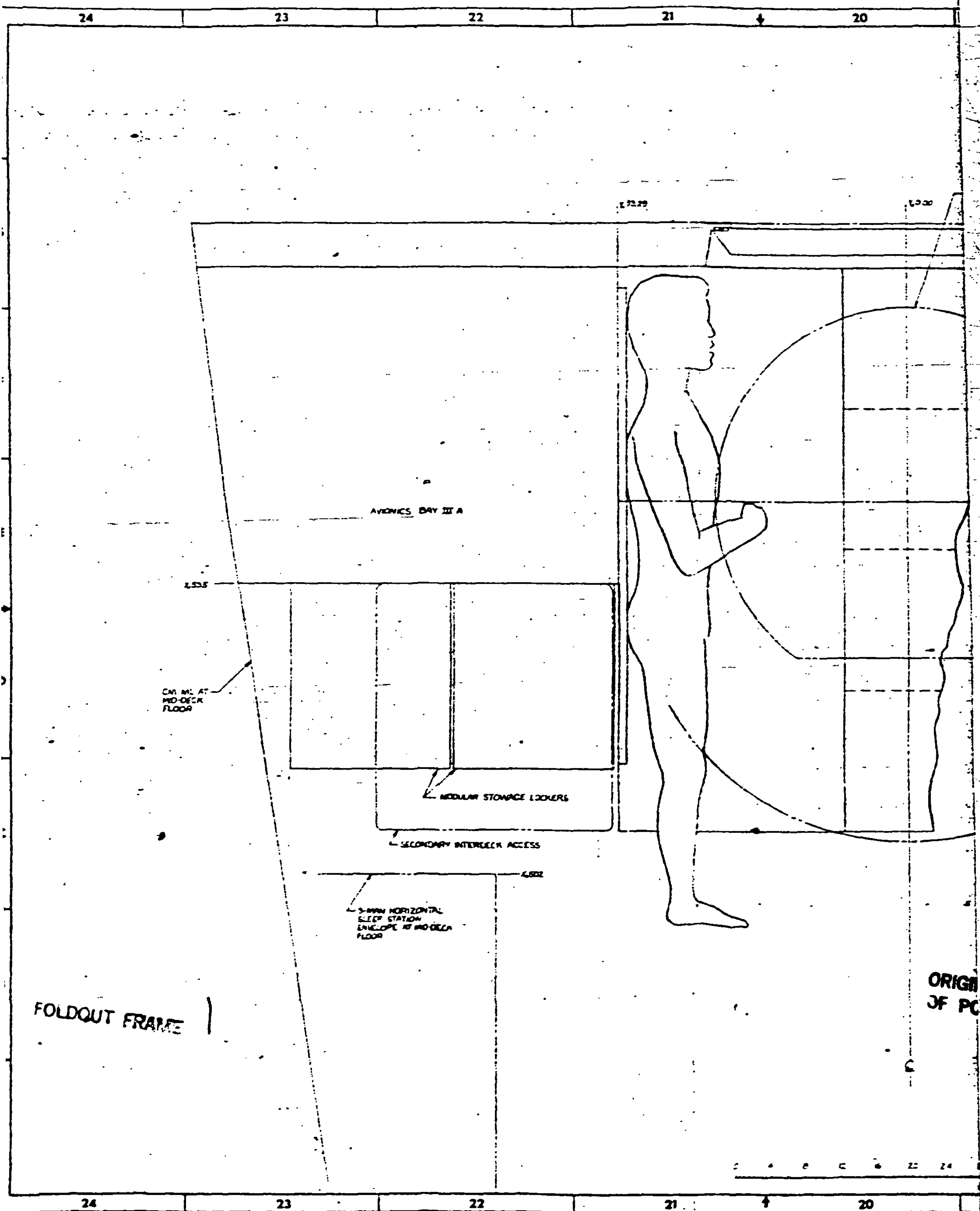


A2 S0D 79-0321


24
23
22
21
20
AVIONICS BAY III A
CM ML AT
MID-DECK
FLOOR
MODULAR STOWAGE LOCKERS
SECONDARY INTERDECK ACCESS
3-MAN HORIZONTAL
SLEEP STATION
ENVELOPE AT MID-DECK
FLOOR
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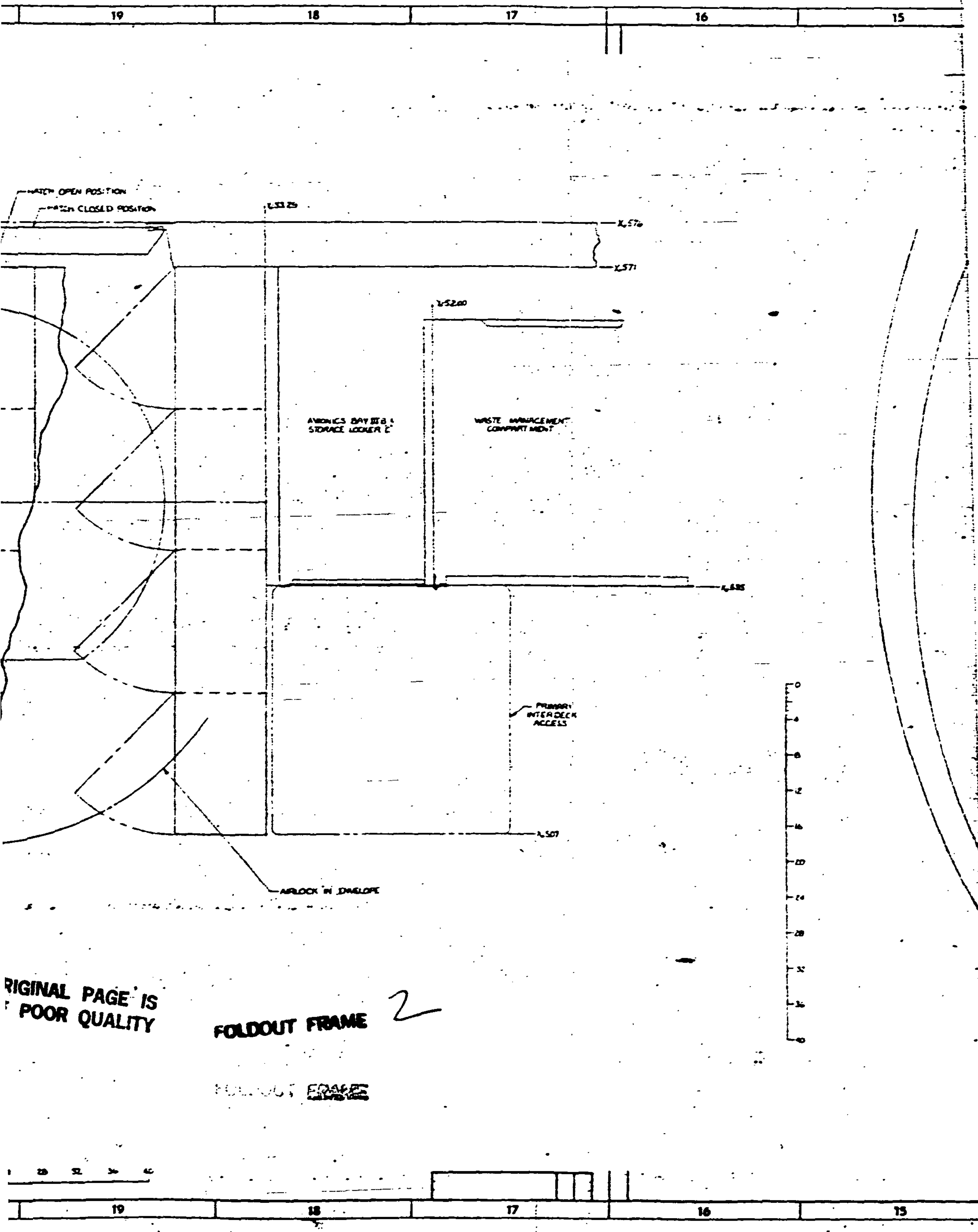
OF PO



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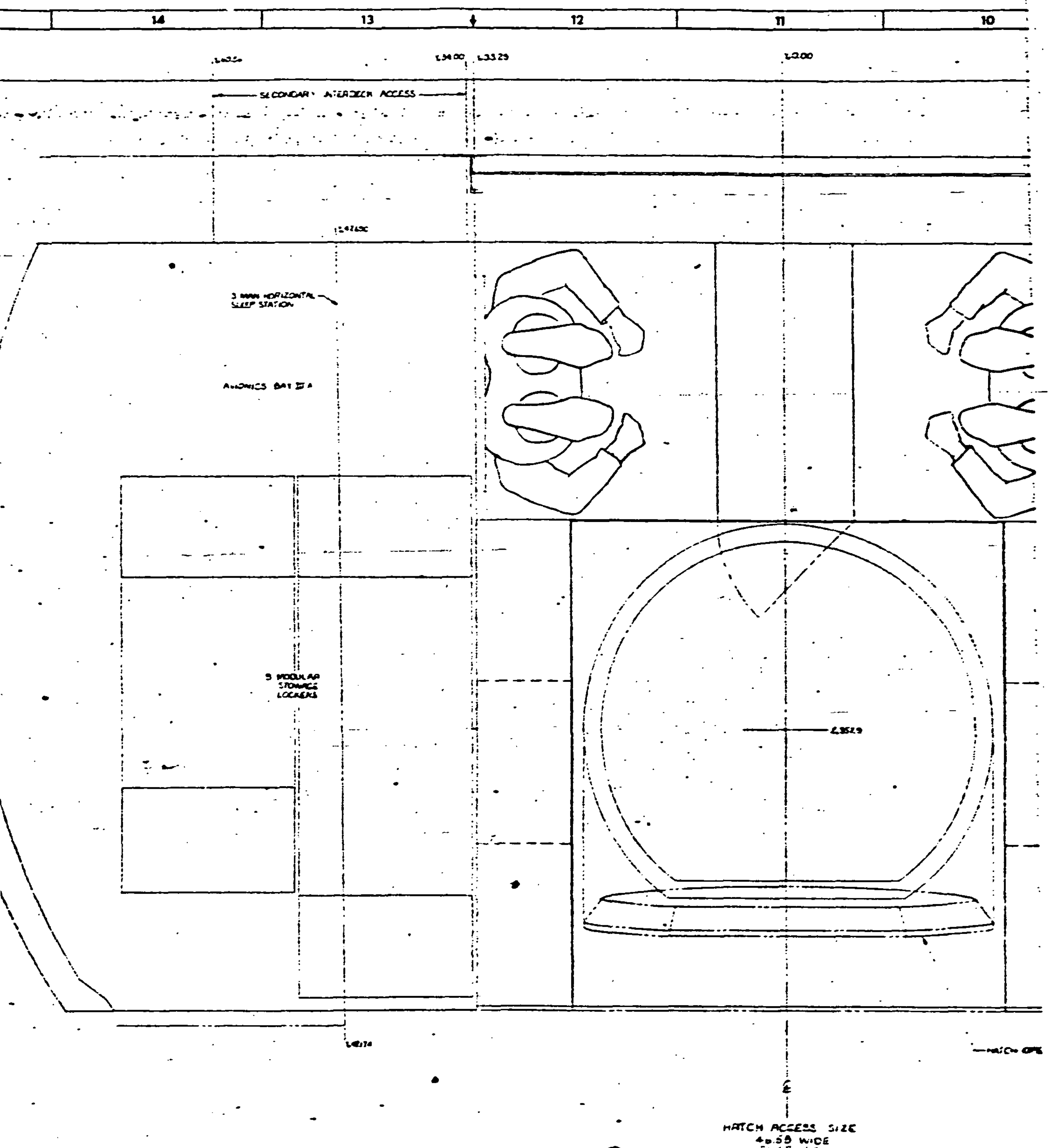

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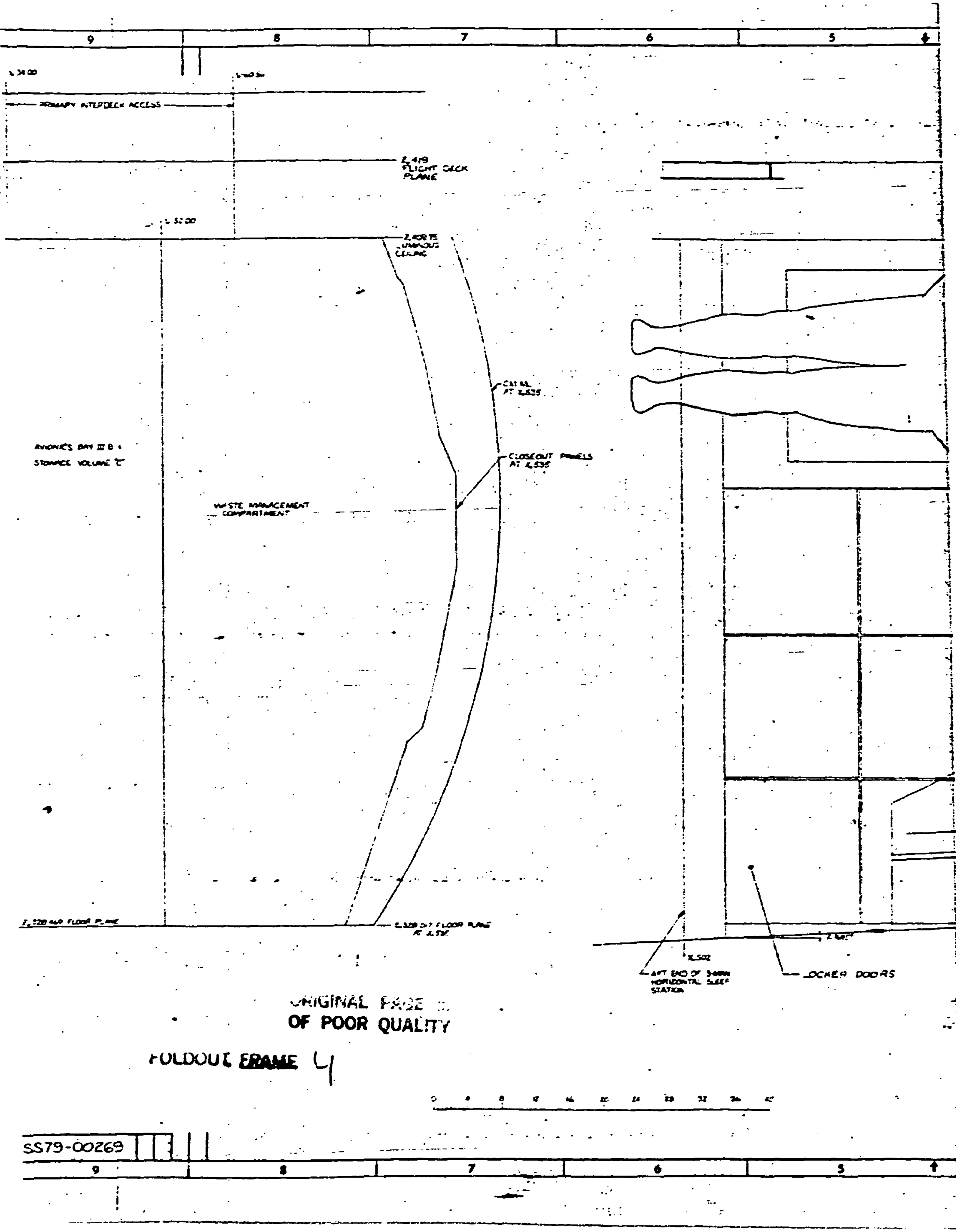

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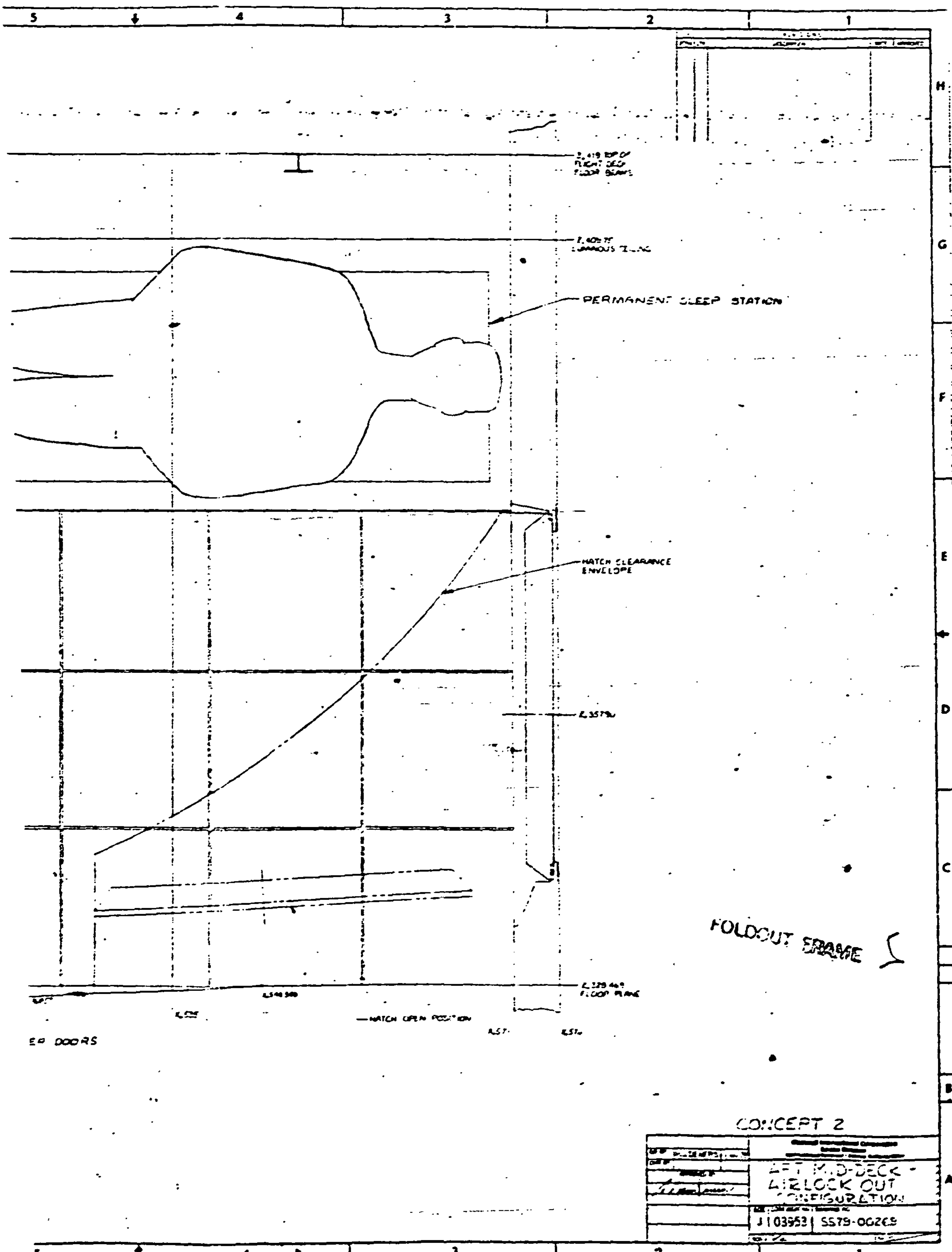

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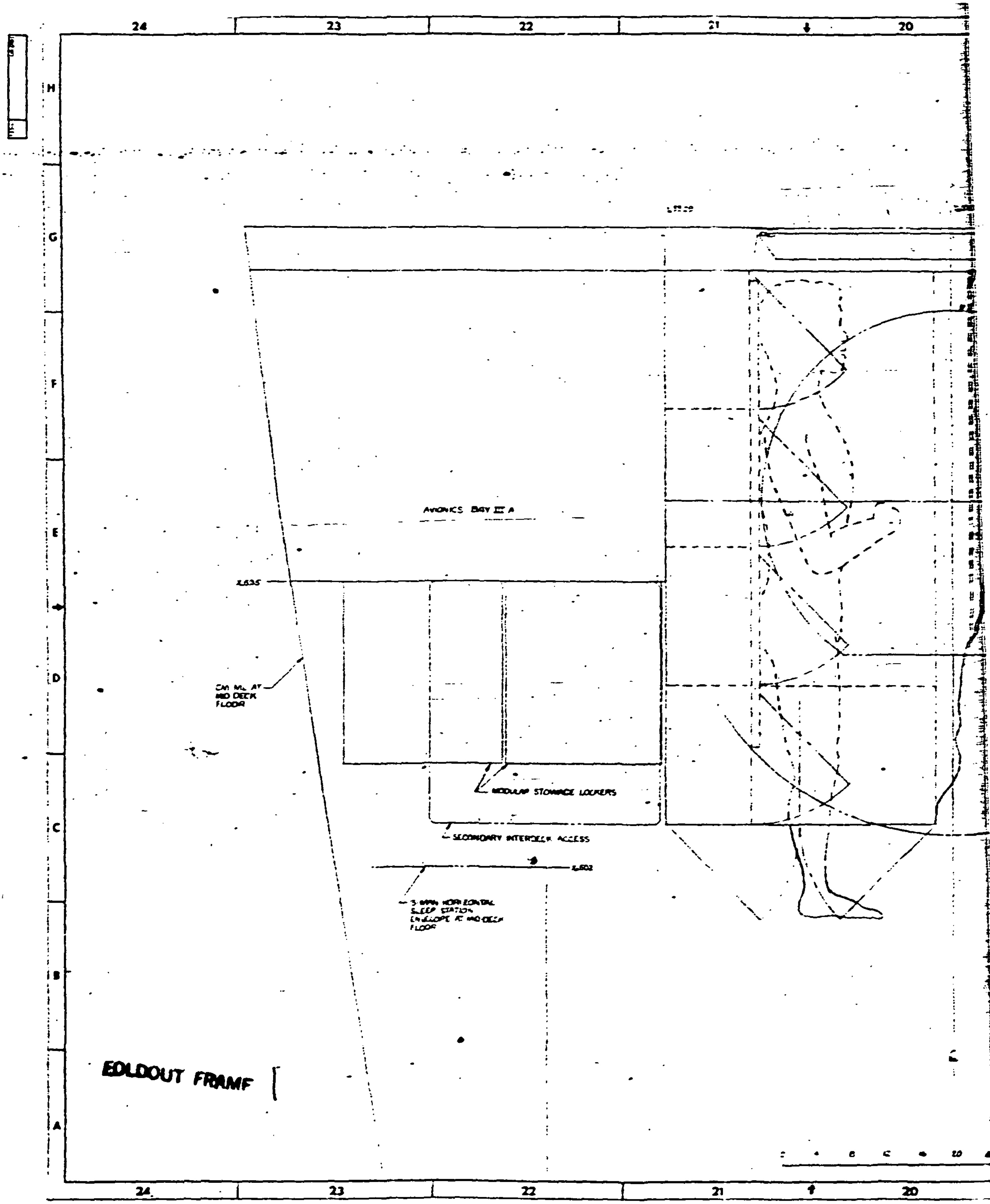

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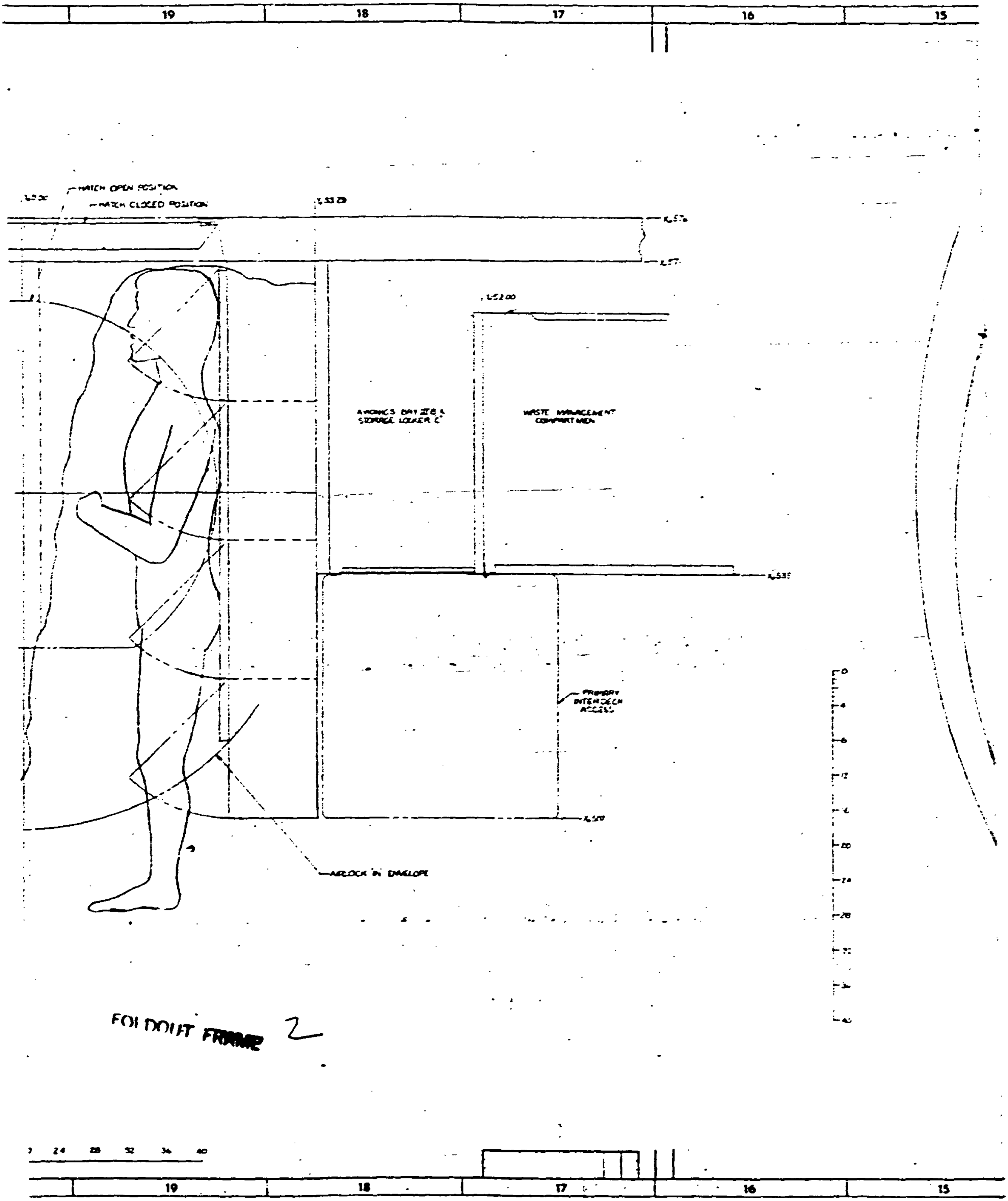

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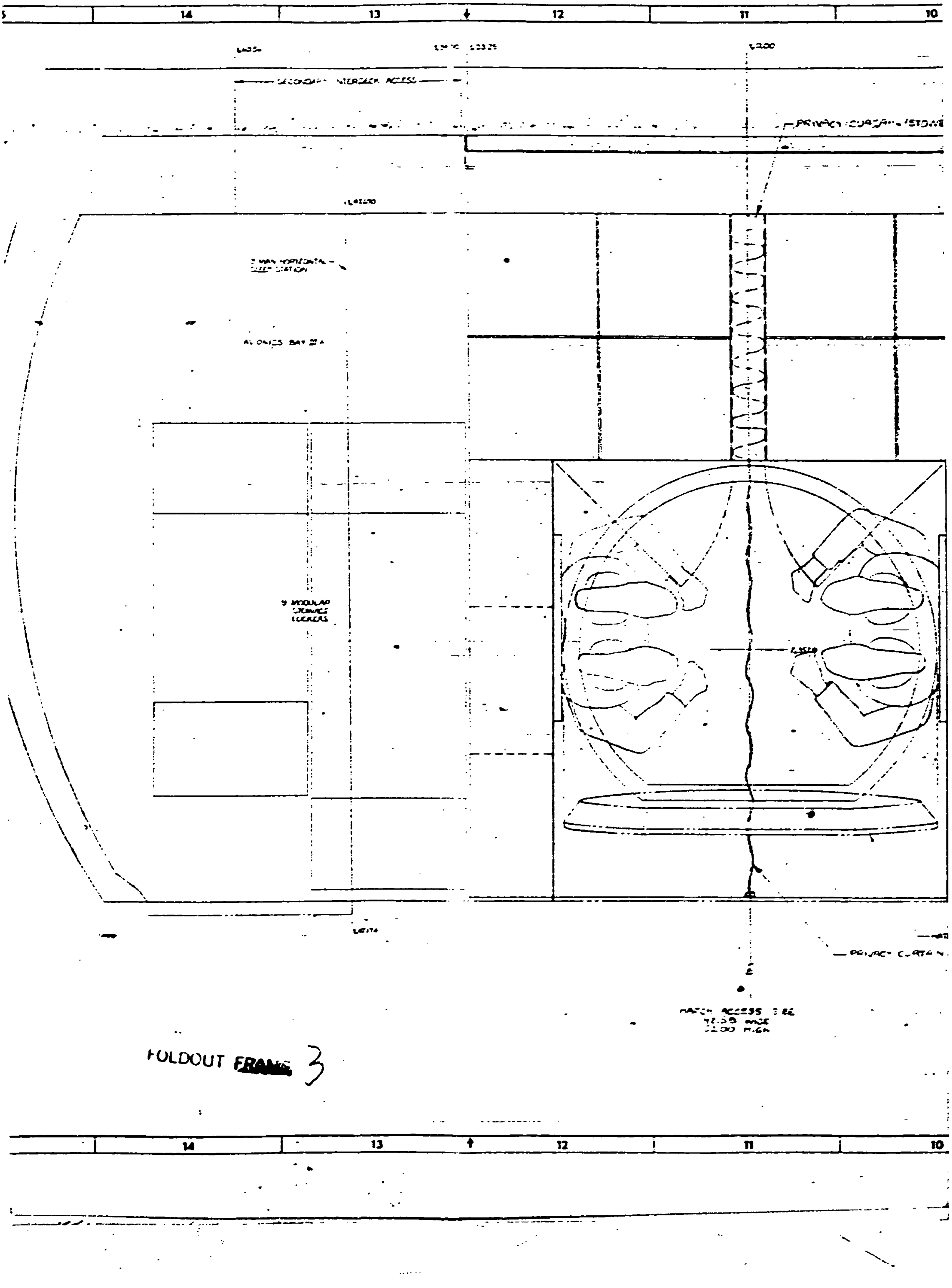

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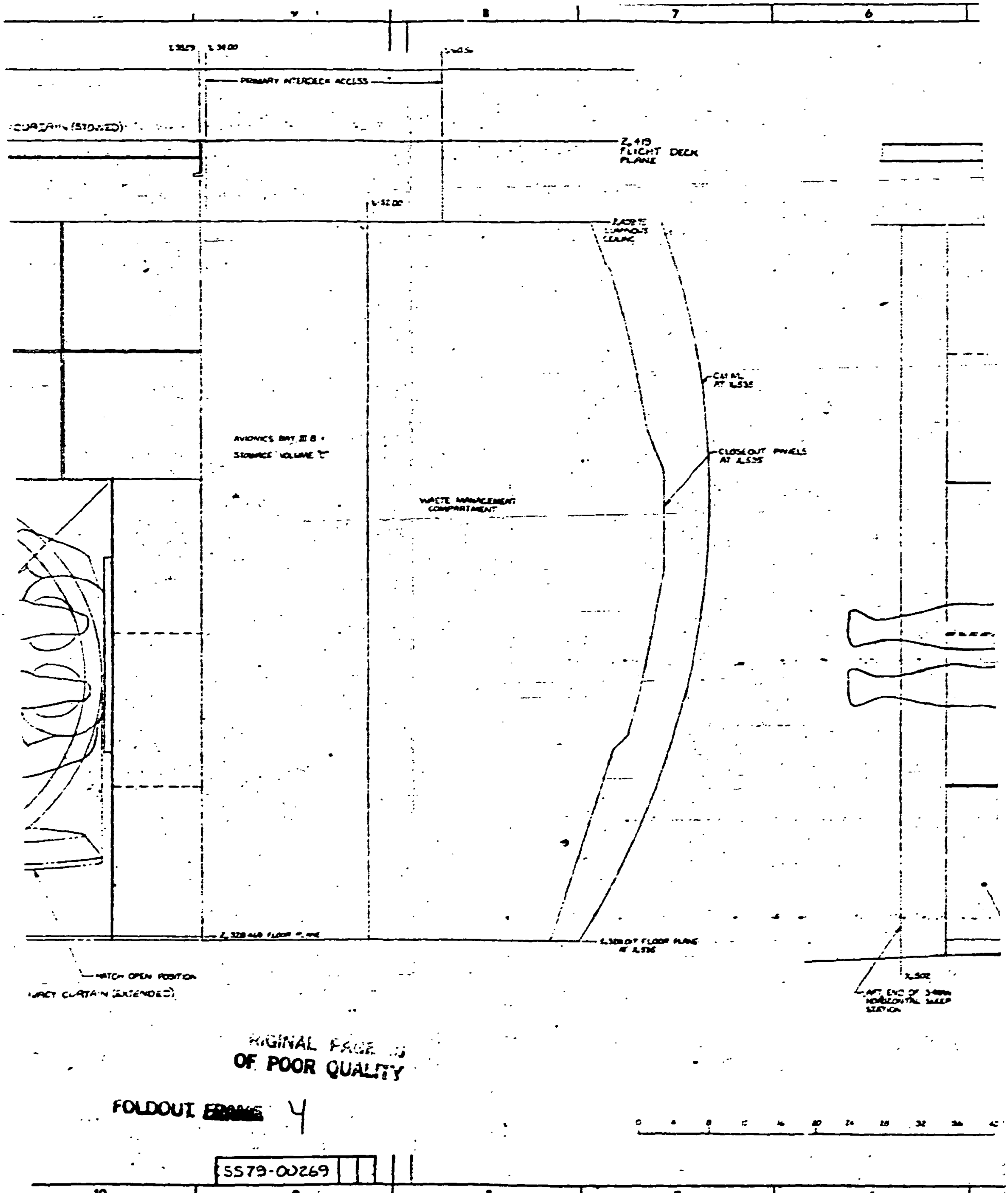

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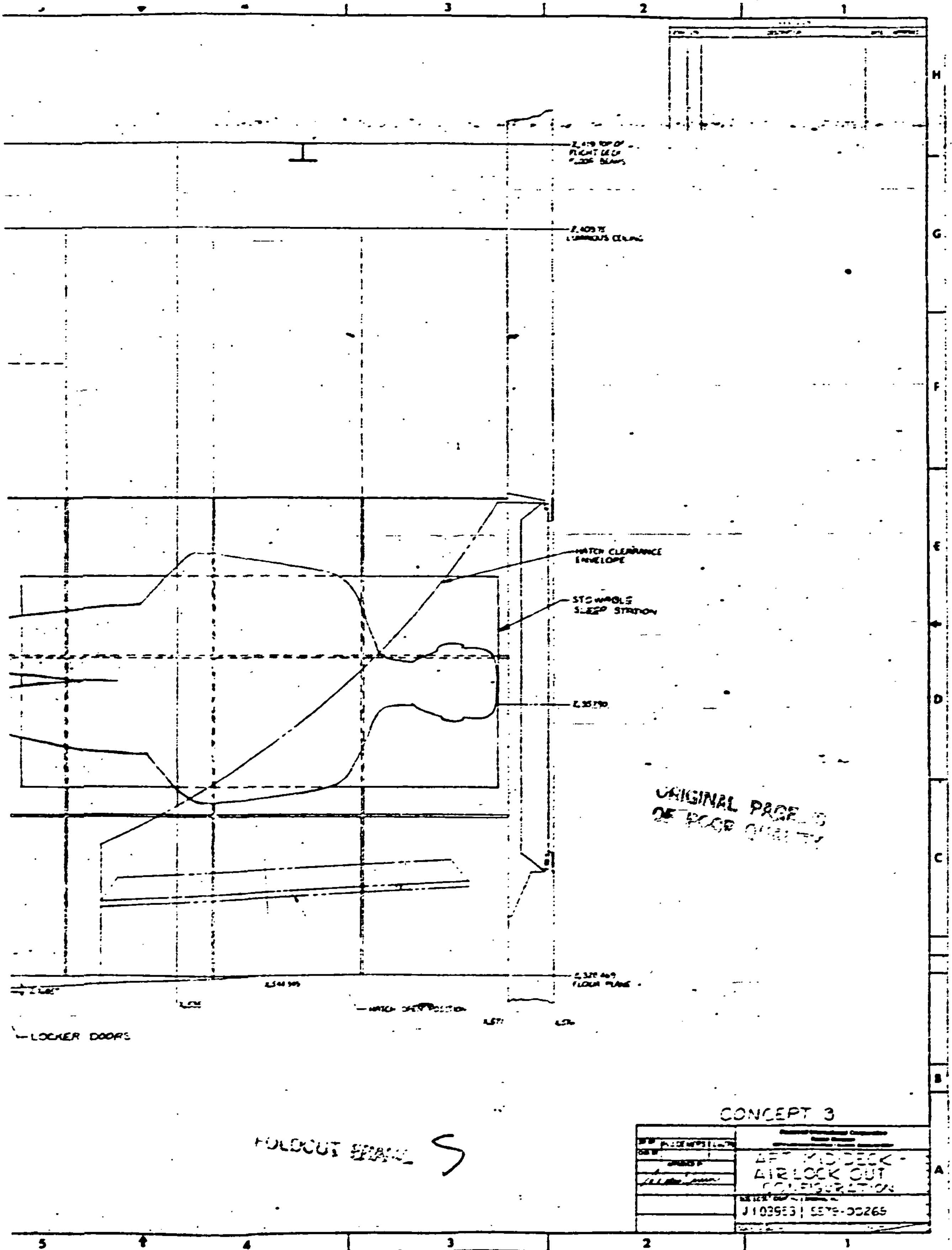
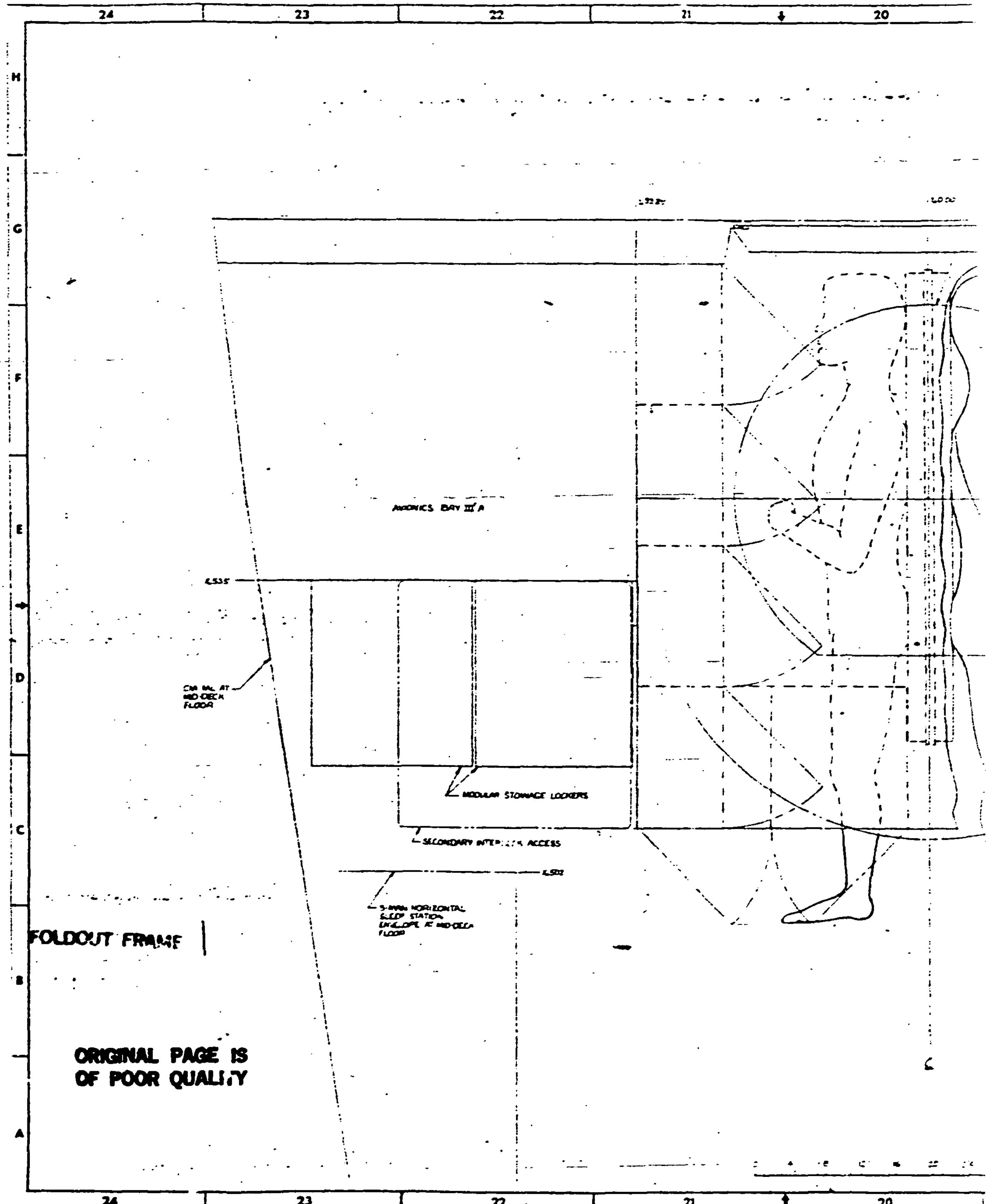


A4 SOD 79-0321



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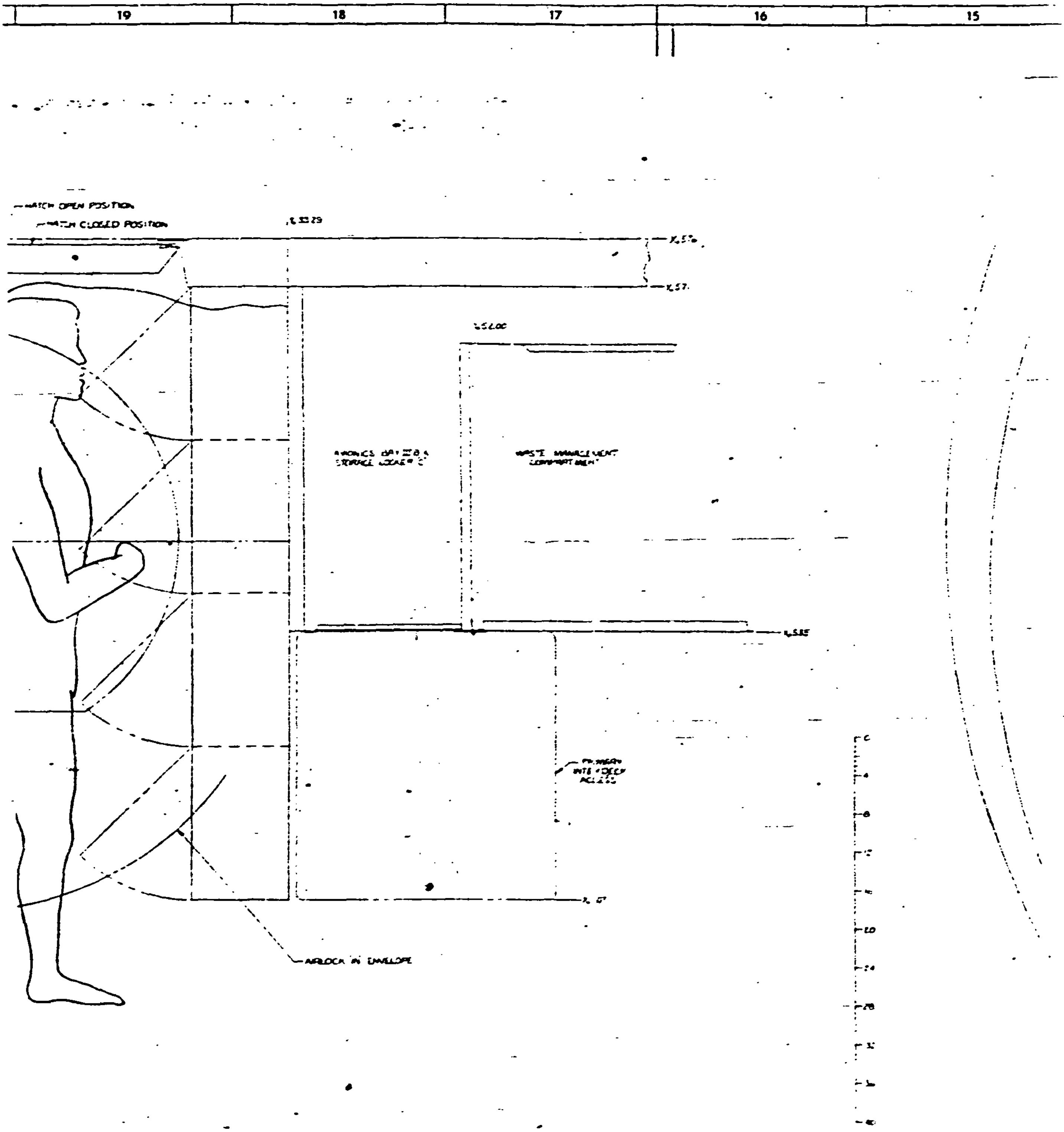

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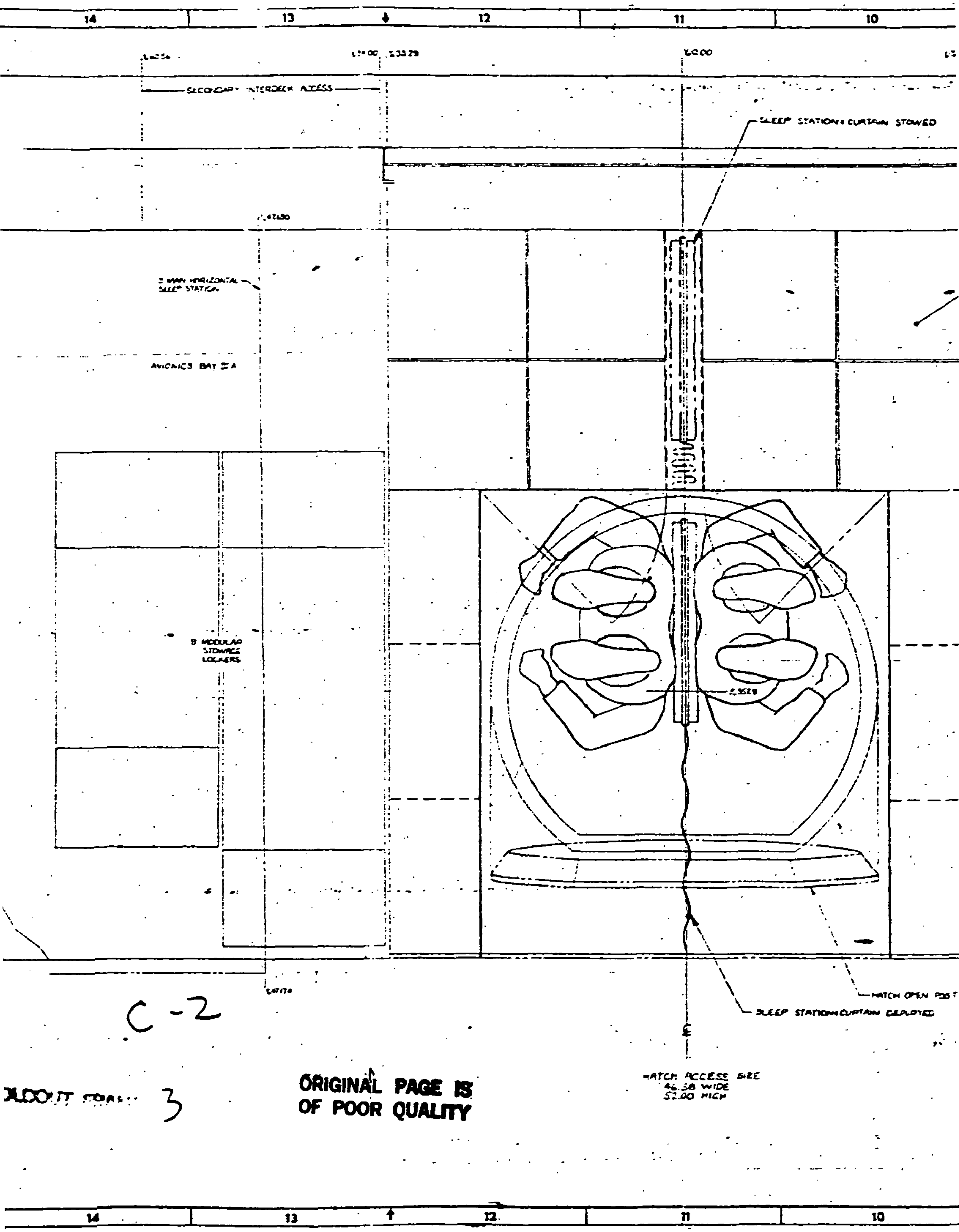
19 18 17 16 15



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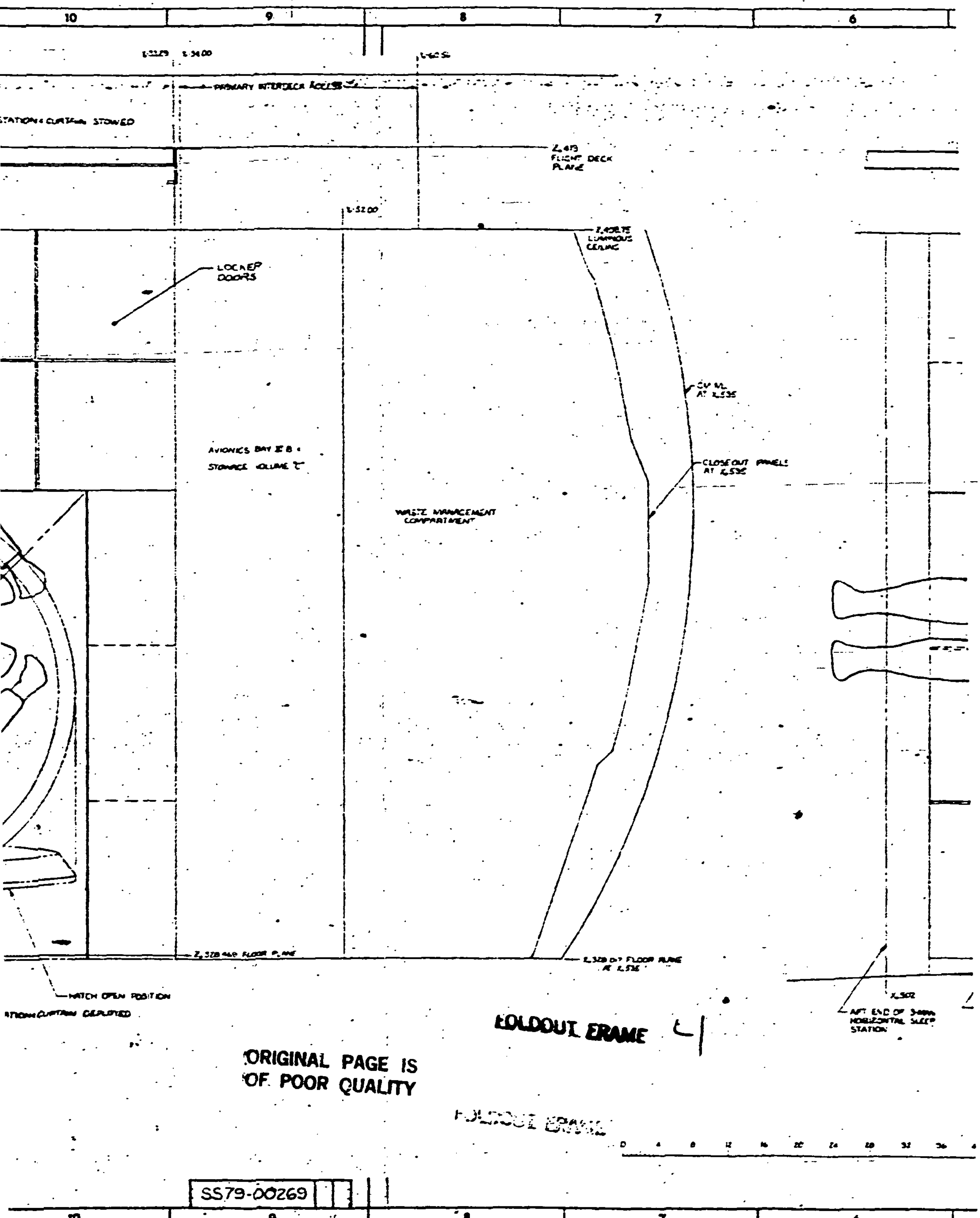

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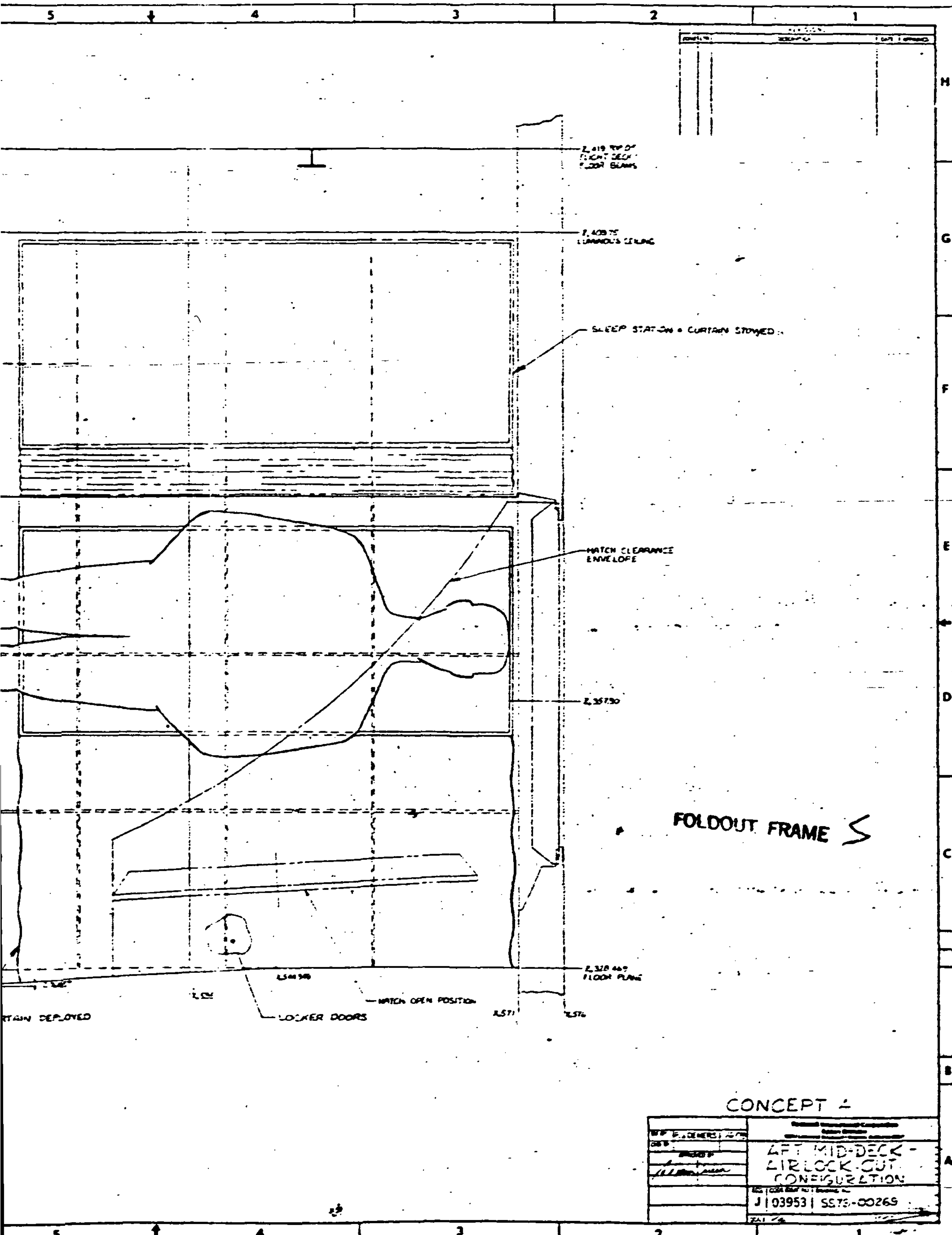
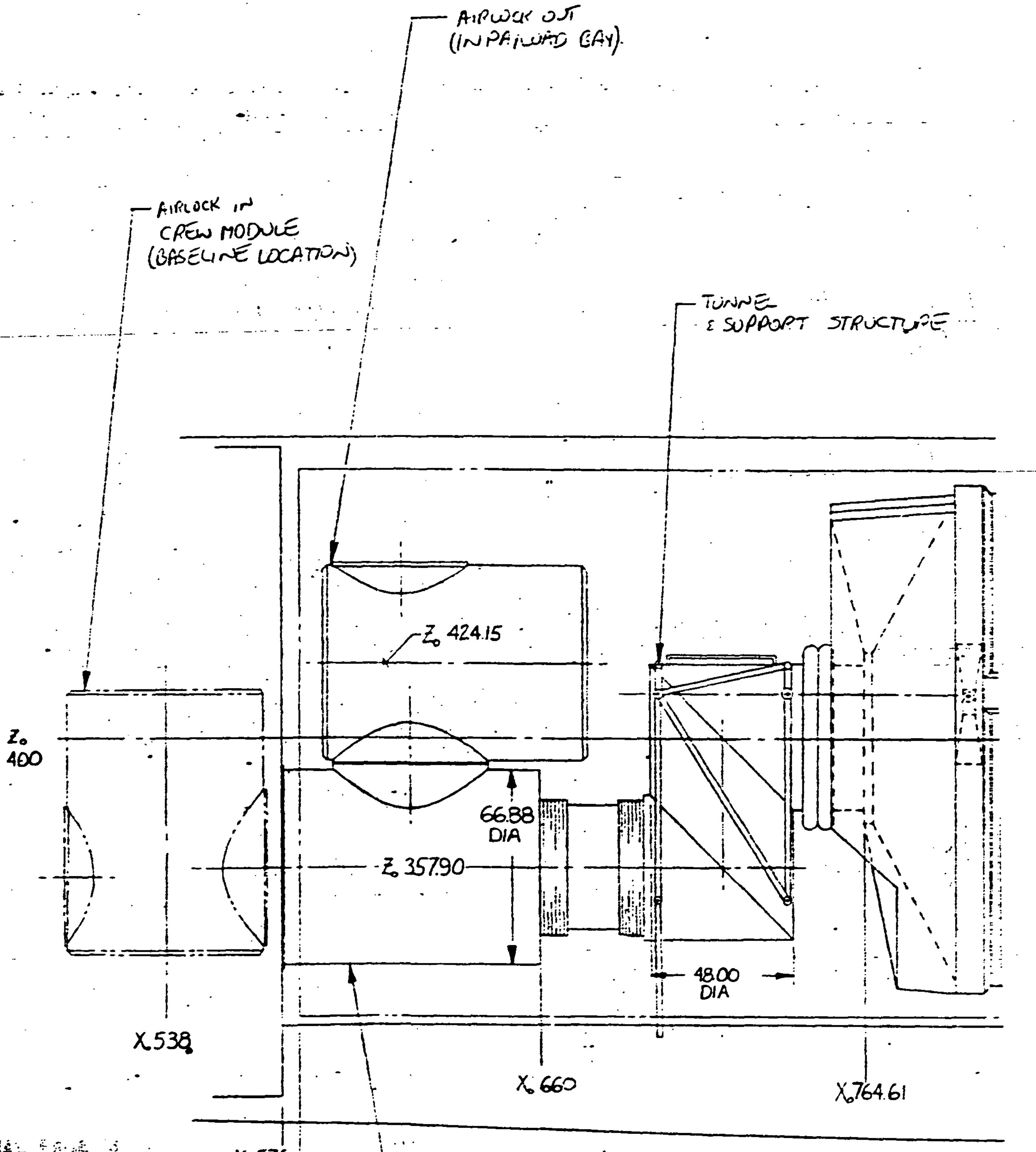


LUMINOUS CEILING
SLEEP STATION & CURTAIN STOWED
HATCH CLEARANCE ENVELOPE
FLOOR PLANE
HATCH OPEN POSITION
LOCKER DOORS
FOLDOUT FRAME 5
CONCEPT 4
AFT MID-DECK - AIRLOCK-CUT CONFIGURATION
J 03953 SS79-00269

APPENDIX B

EXPANDED TUNNEL ADAPTER CONCEPT DRAWINGS



ETA-1

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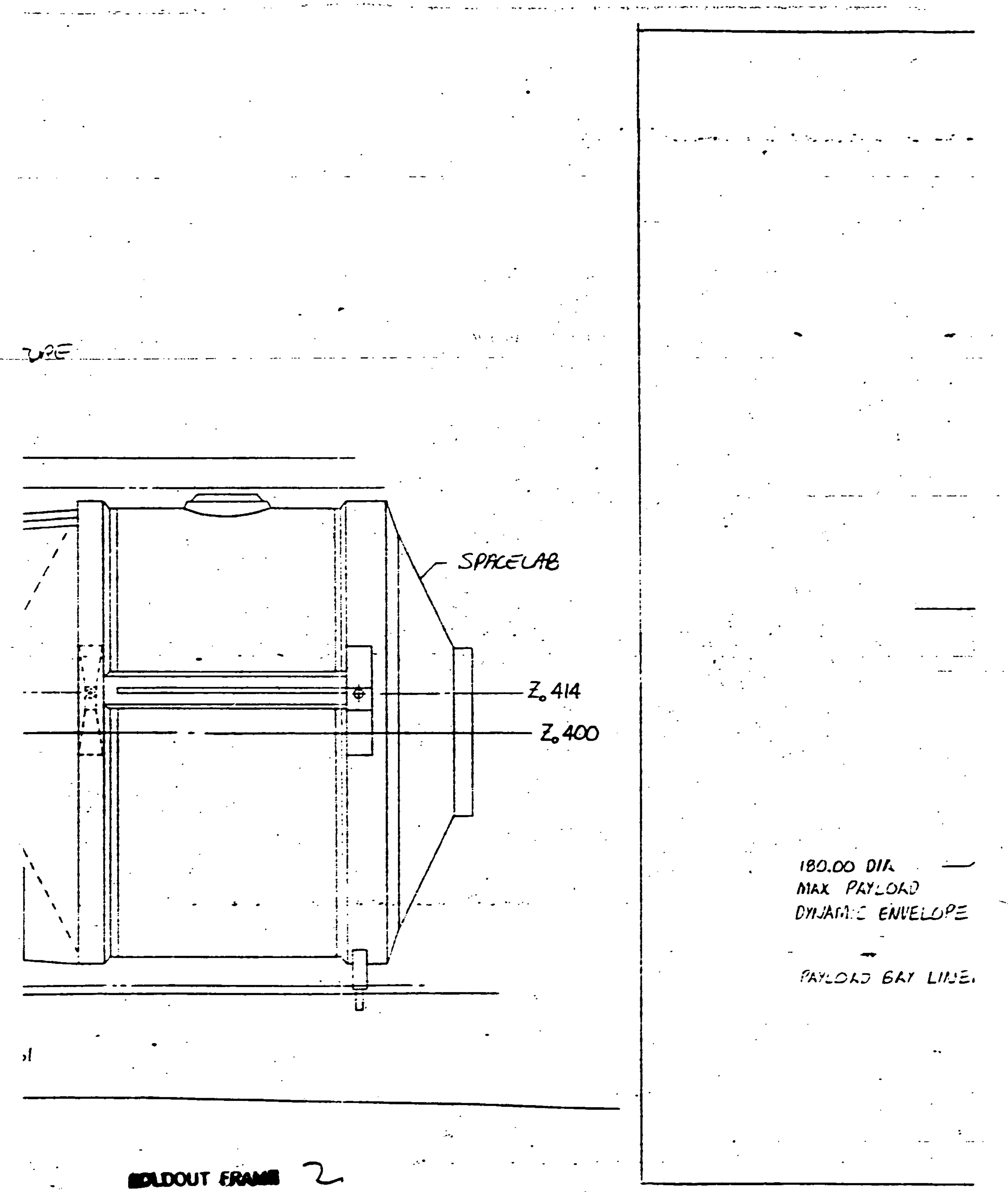

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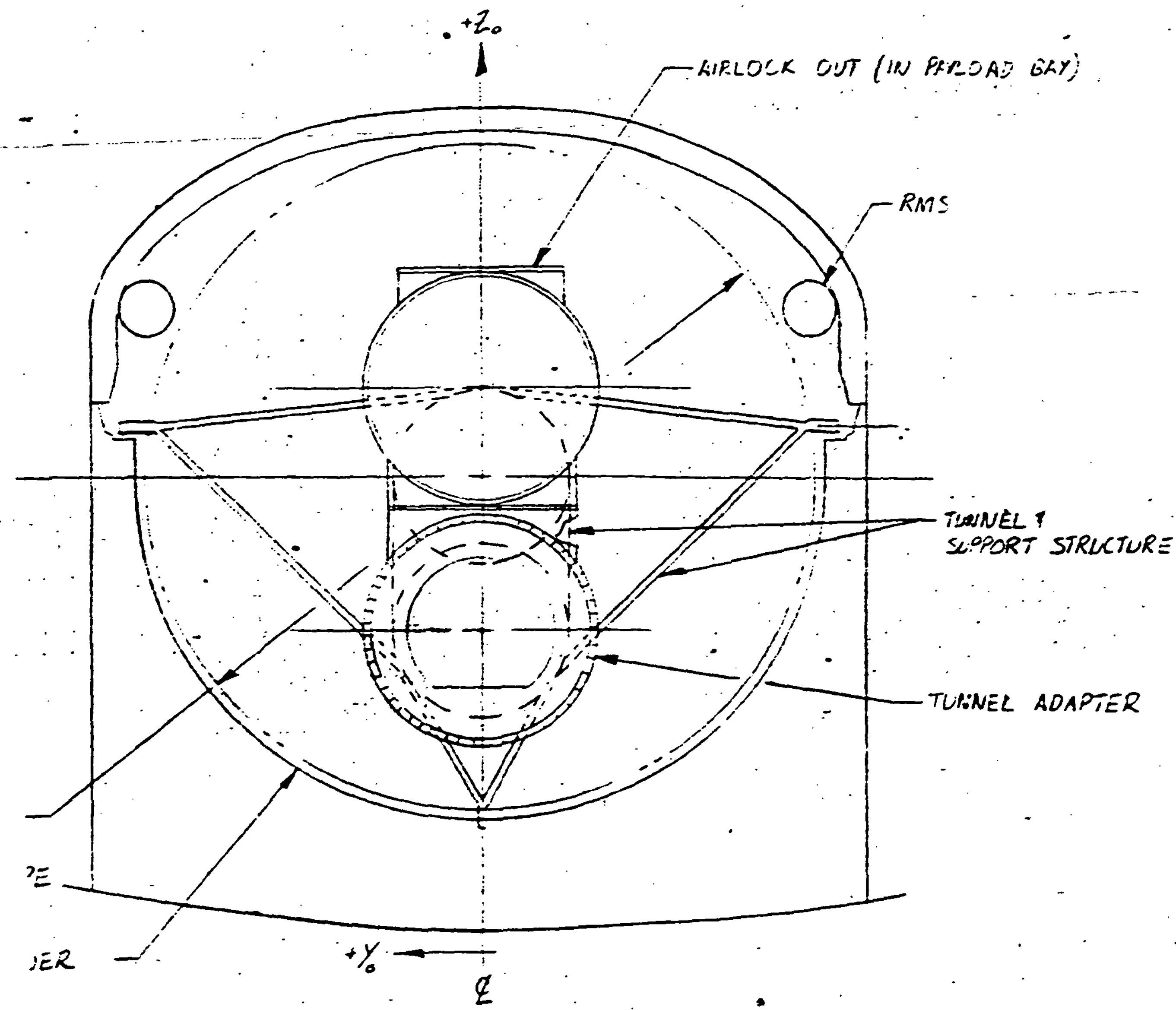

SECTION B-B
VIEW LOOKING AFT

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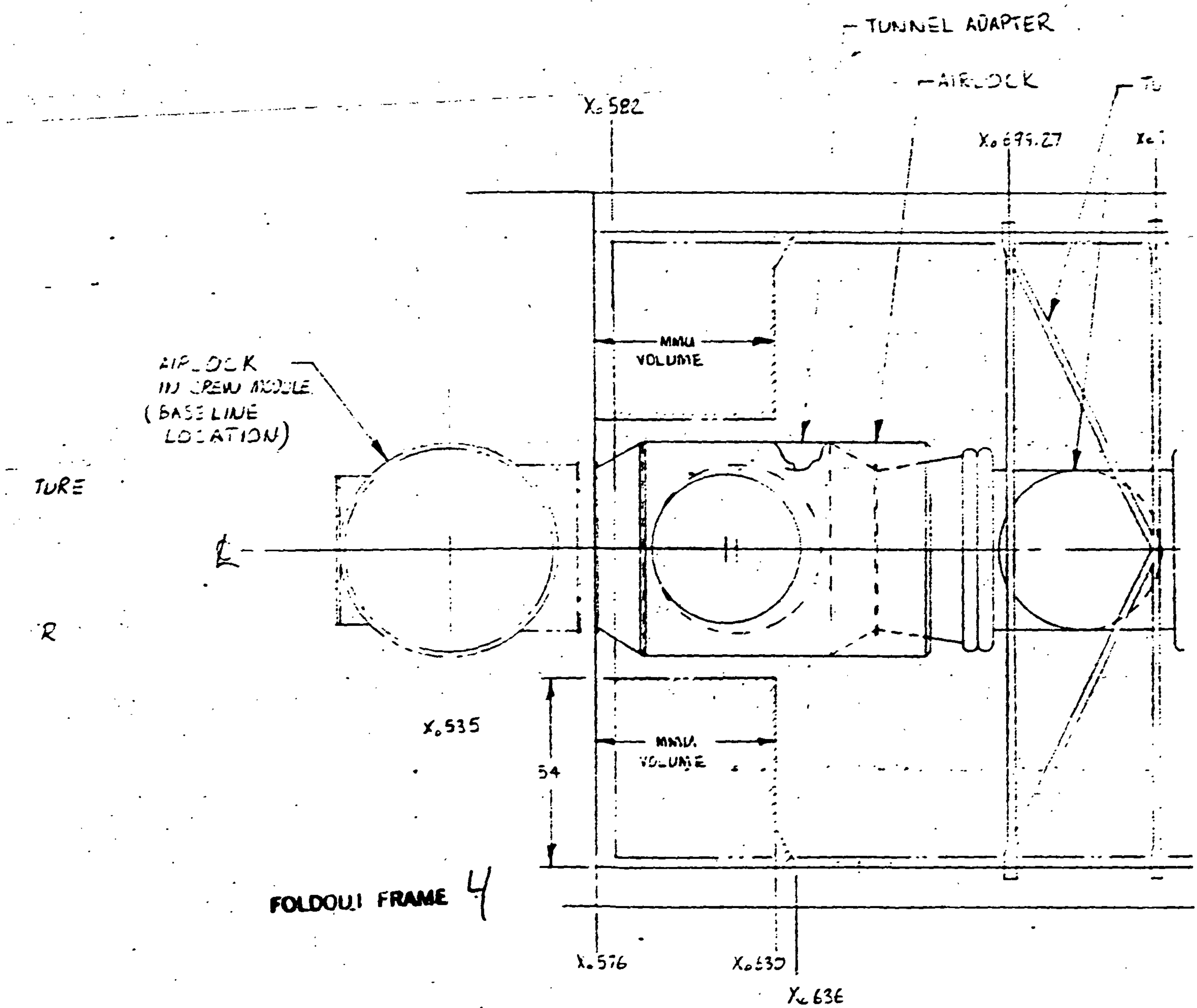

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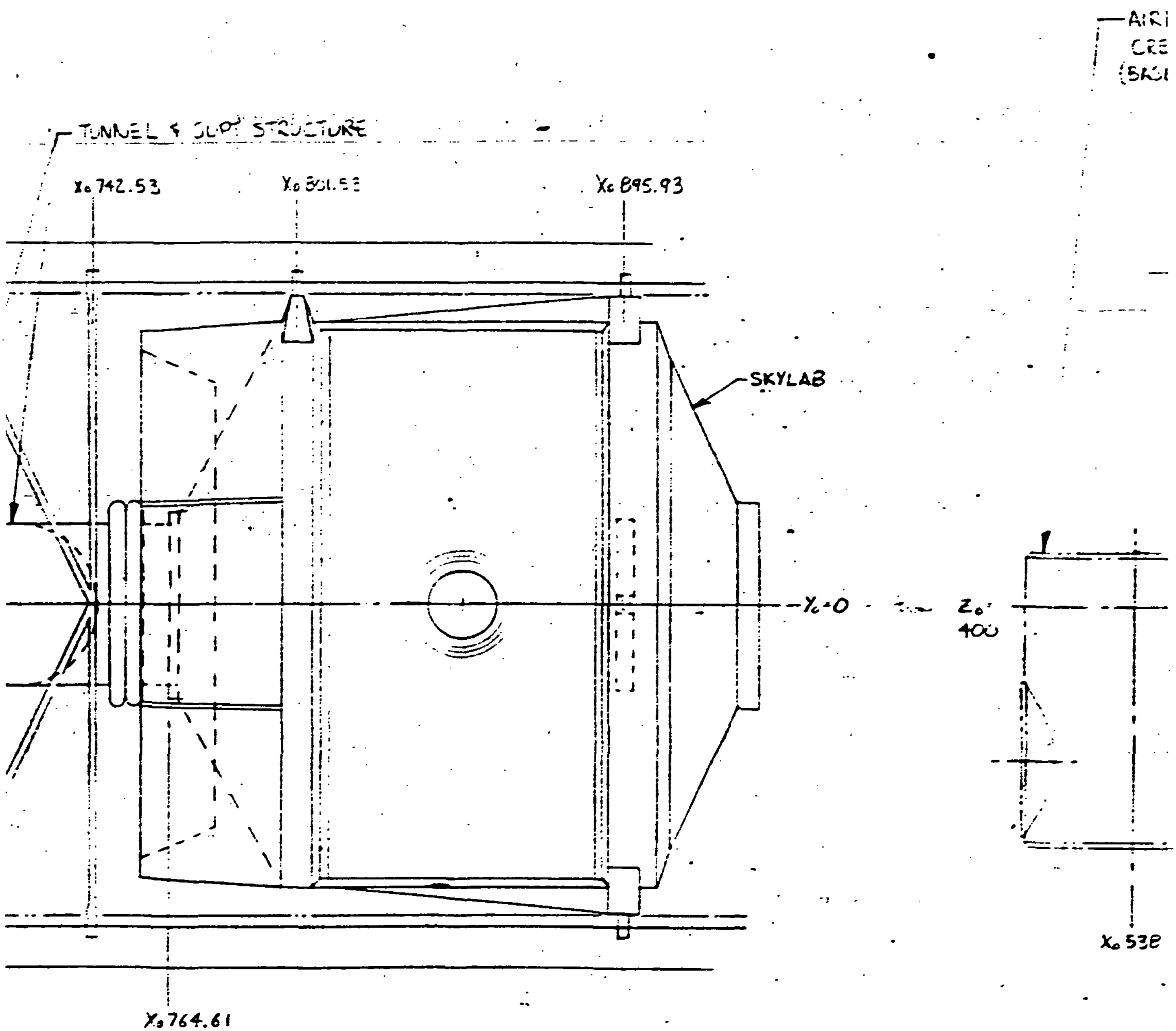
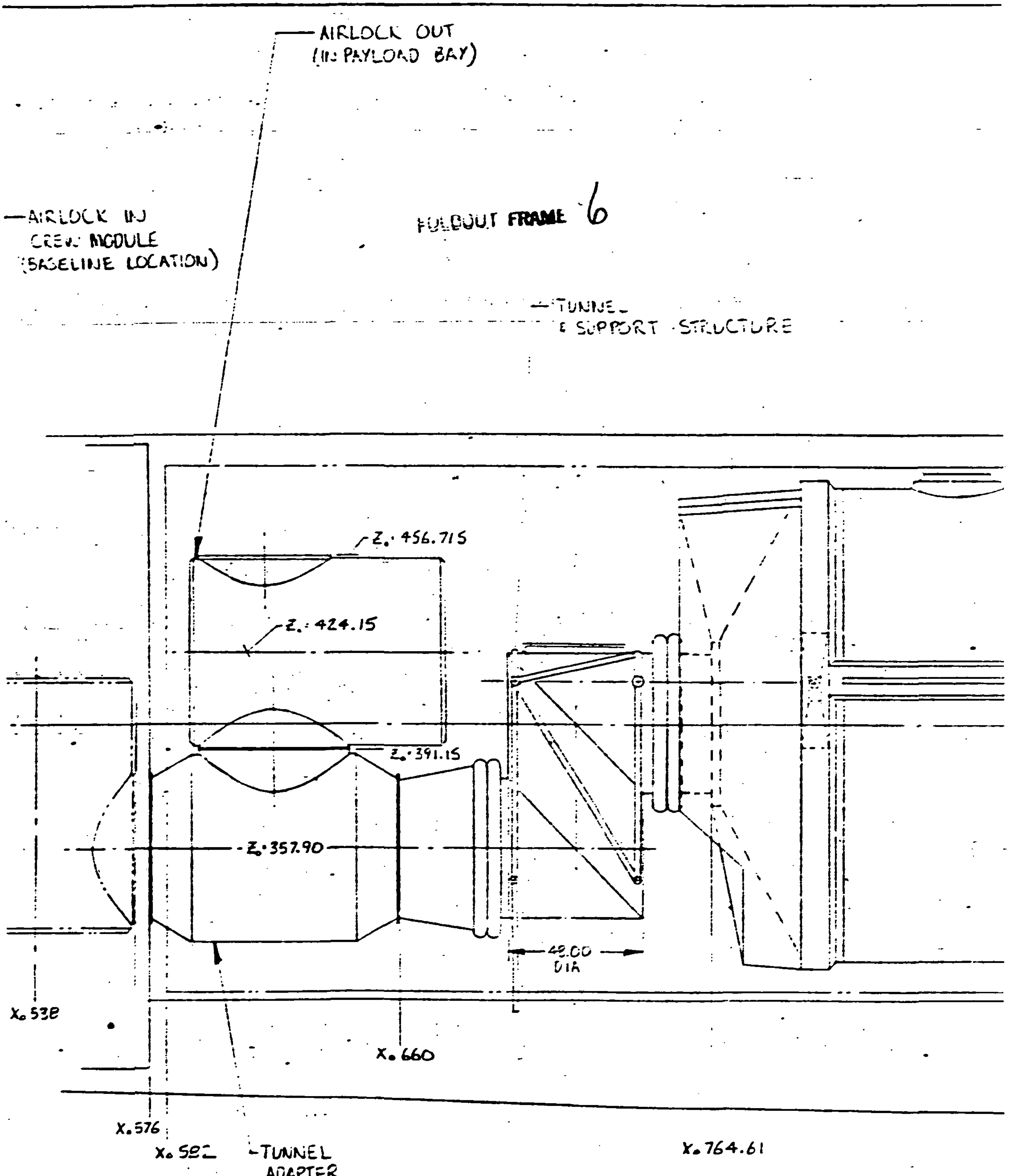


BASE LINE

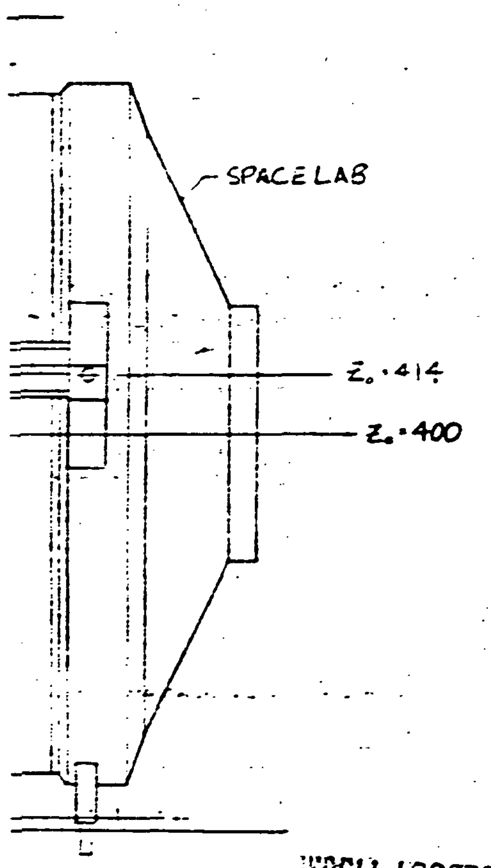
FOLDOUT FRAME 5

FOLDOUT FRAME 6



VOLUME GROSS WTL: 126 CU. FT. WEIGHT: 714 LBS

GROSS STOWAGE: 0 CU FT.



T. HEALY

1/2

TUNNEL ADAP
— ORBITER

FOLDOUT FRAME 7

1/20	T HEALY	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION	
TUNNEL ADAPTOR INSTL L/O — ORBITER BASELINE			SS79-00271

EXPANDED TUNNEL ADAPTER

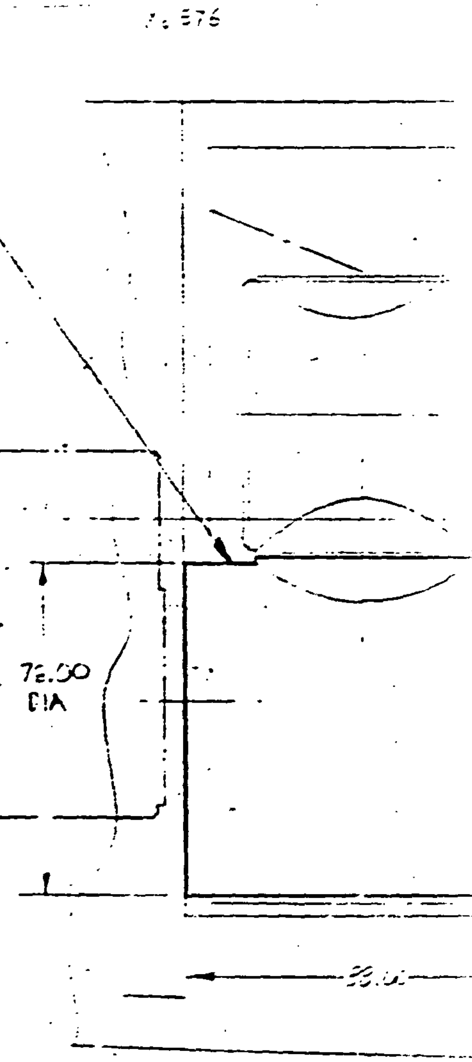
VOLUMES:

GROSS INTL (INCL BELLOWS): 275 FT^3

INTL STOWAGE IN ETA: 105 FT^3

SUPPLEMENTARY STOWAGE IN BELLOWS: 44 FT^3

WEIGHTS:	AIRLOCK OUT	AIRLOCK IN
MAX ON SH'D:	2450 LBS	2550 LBS
LESS AIRLOCK	1036 LBS	1036 LBS
ETA (INCL ALLOWANCE FOR BELLOWS)	1099 LBS	1099 LBS
AVAILABLE STOWAGE + LAUNCH & ENTRY (INCL SUPTS.)	315 LBS	415 LBS

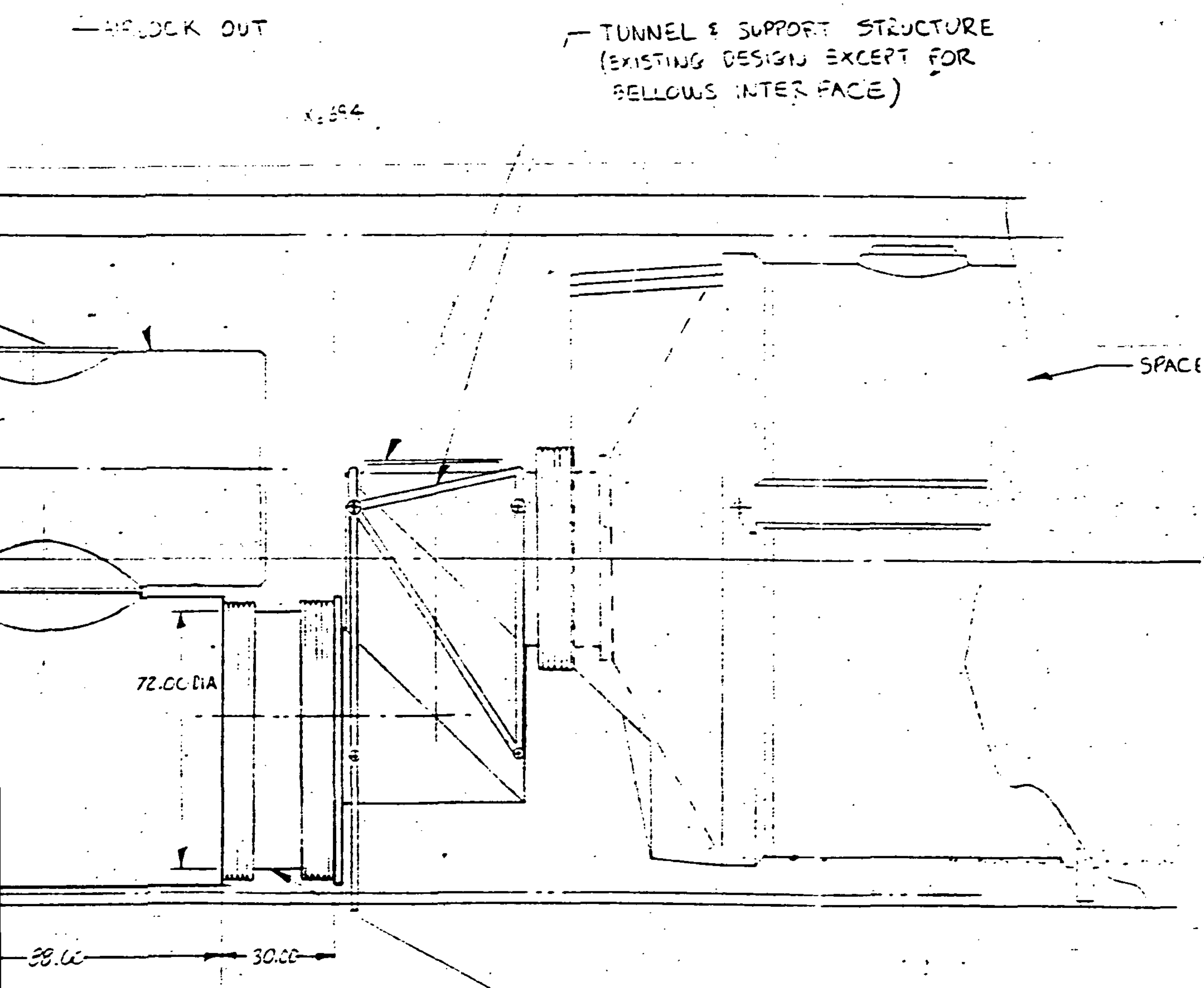


AIRLOCK IN

FOLDOUT FRAME

SMALL
ALTER
LA

FOLDOUT FRA[redacted] 2



OVERSIZE BELLOWS SEC

NOTE: WILL REQ NEW TO

EXCEEDS SIZE OF BE

ETA-4

SMALL EXPANDED TUNNEL ADAPTER

ALTERNATE NO. 2

LARGE DIA BELLOWS

(BELLOWS VOLUME AVAILABLE FOR ON-ORBIT STOWAGE)

CELAB

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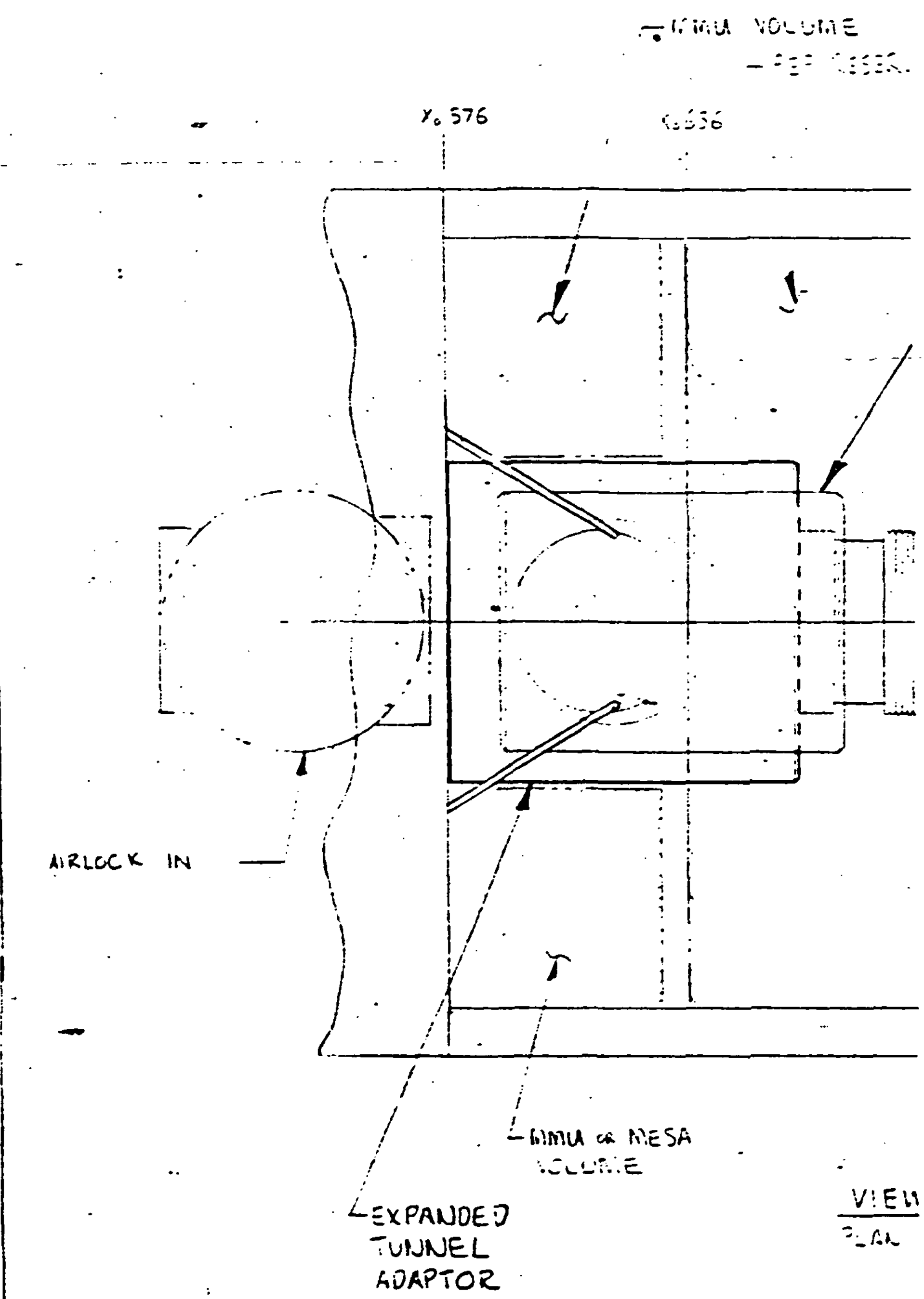
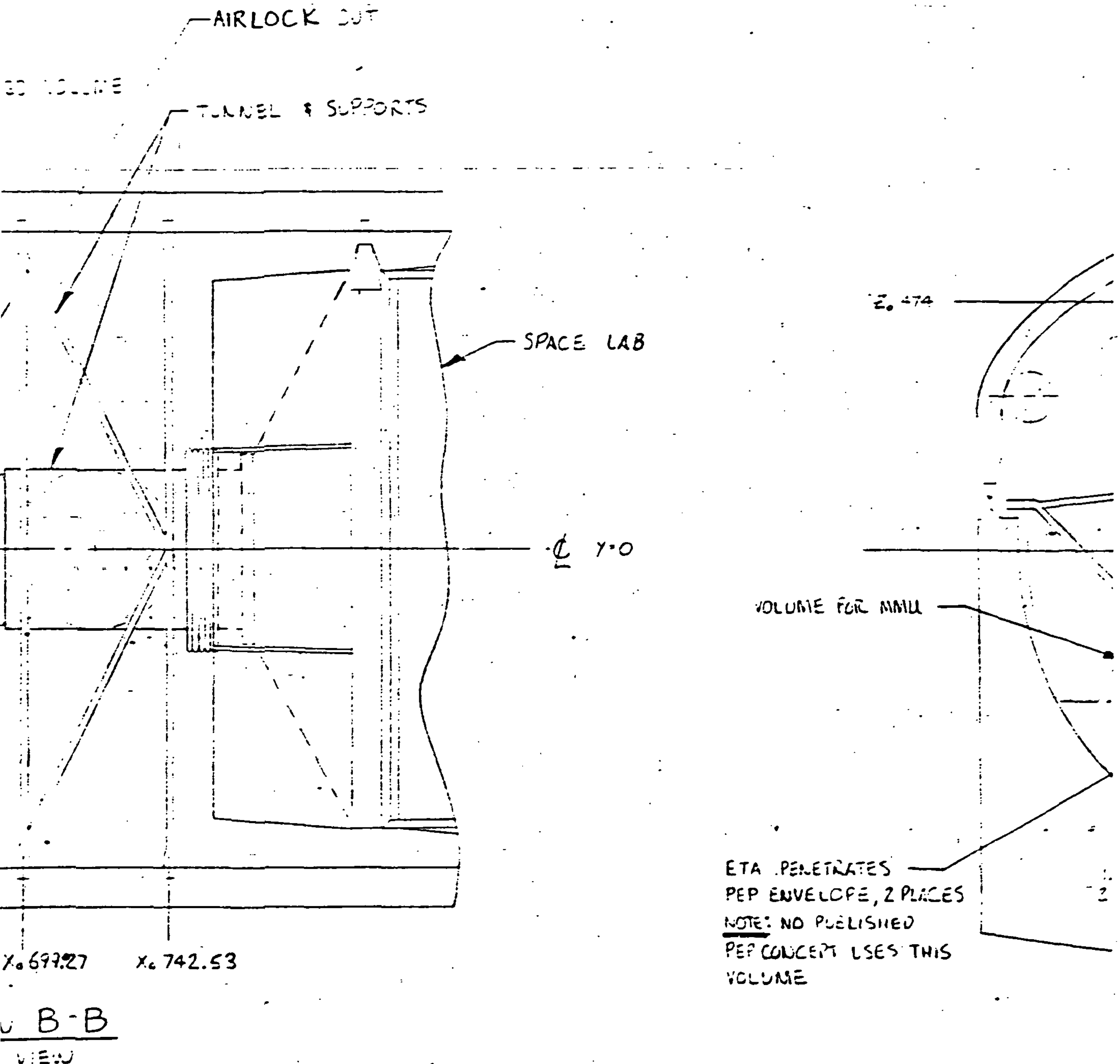
ECTION
TOOLING —
AVAILABLE





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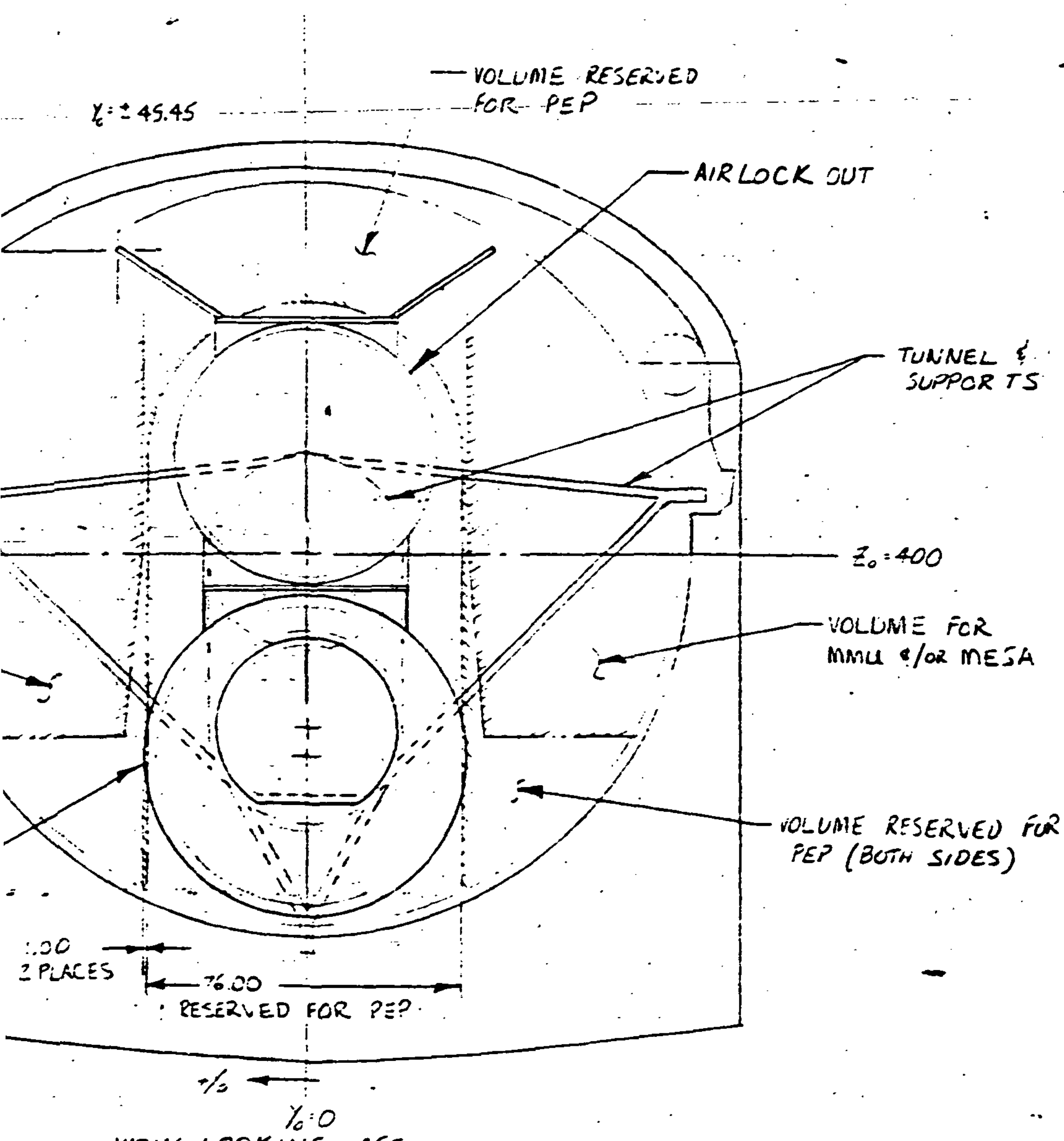

VIEW LOOKING AFT

SECTION A-A

EXPANDE:
VOLUME:
GROSS INT
GROSS STC
WEIGHTS:
MAX ON B'H'D
LESS
AIRLOCK
ETA STRUCT
AVAILABLE
STOWAGE
(INCL SUPT STRUCT

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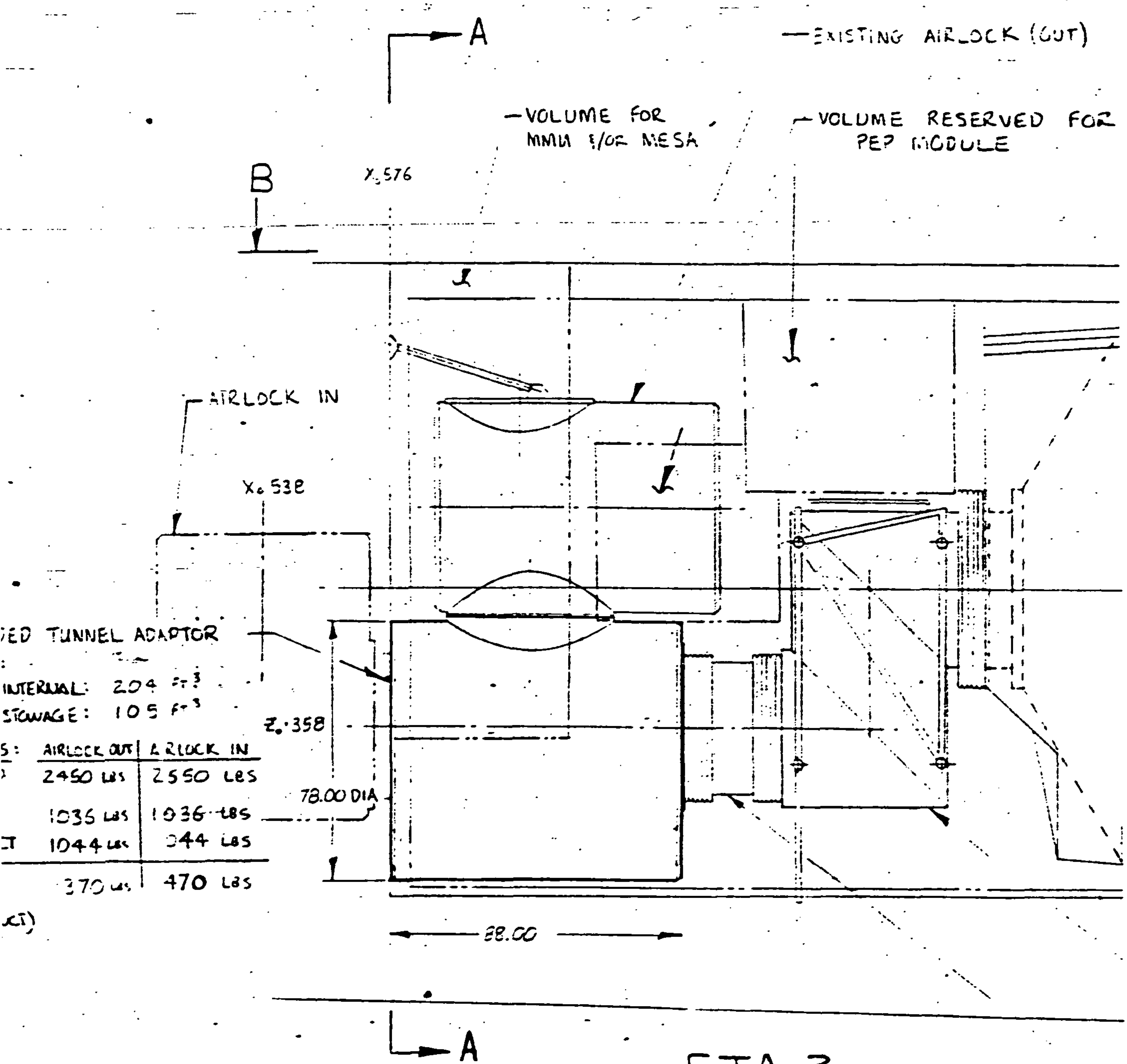

ETA-3

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SMALL EXPANDED TUNNEL ADAPTER

SCALE 1/20

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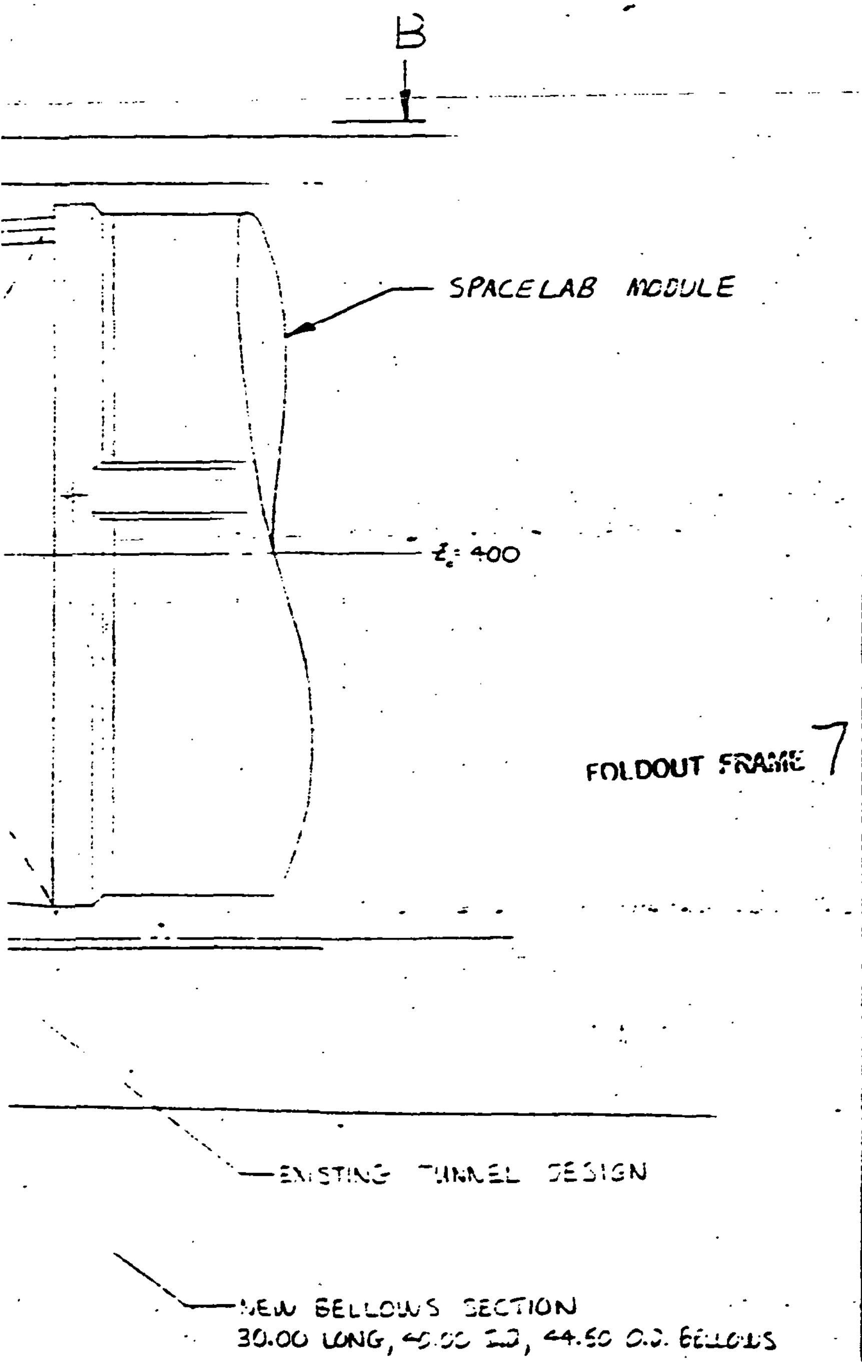

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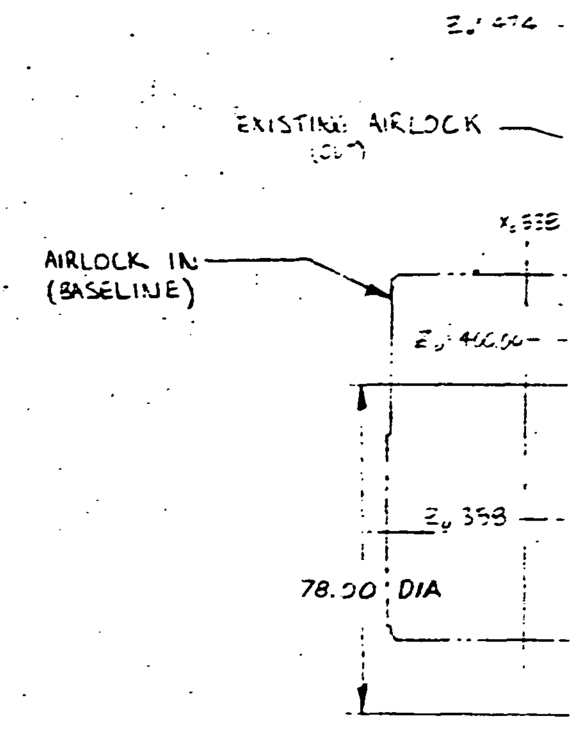


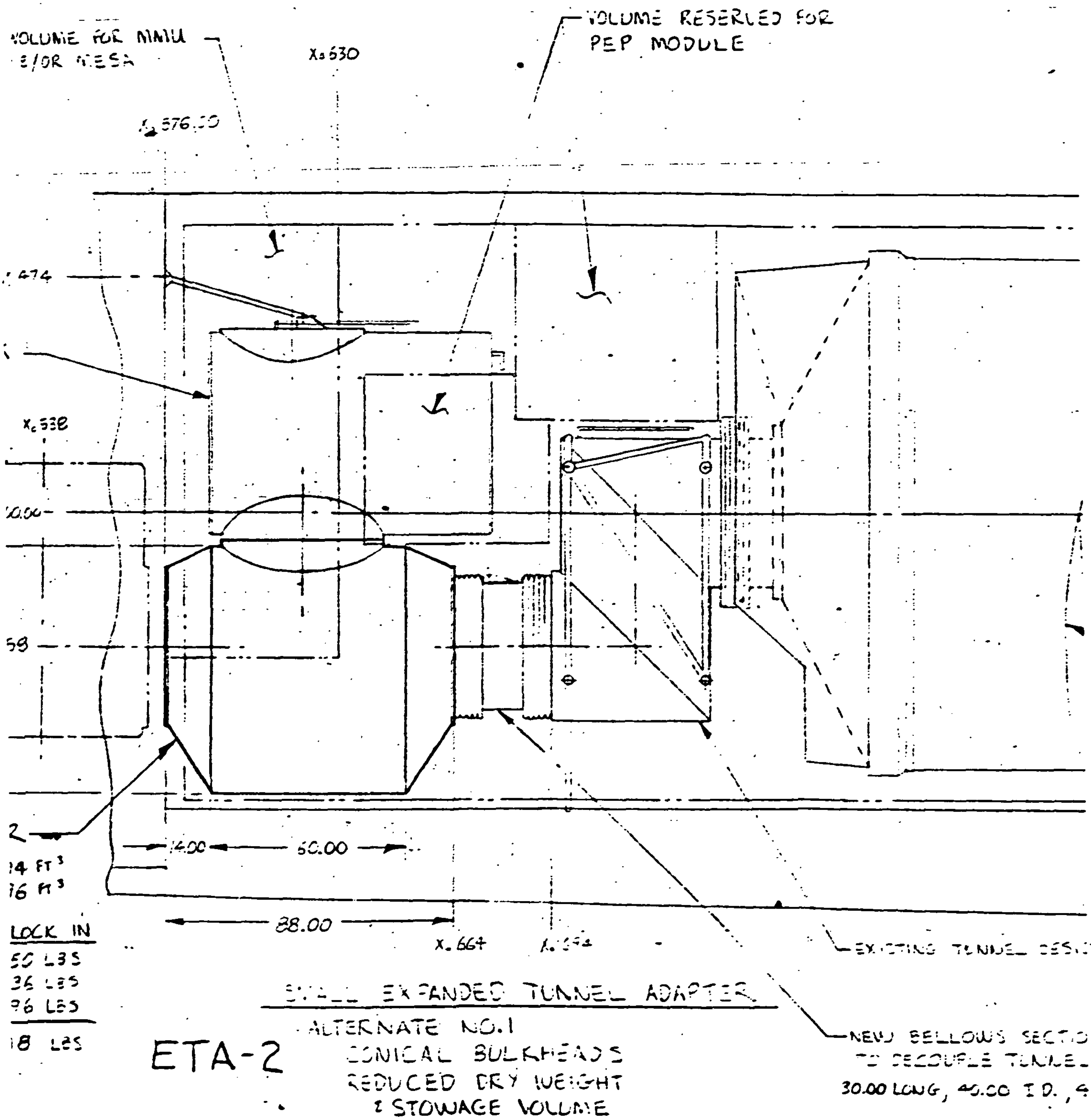
EXPANDED TUNNEL ADAPTOR

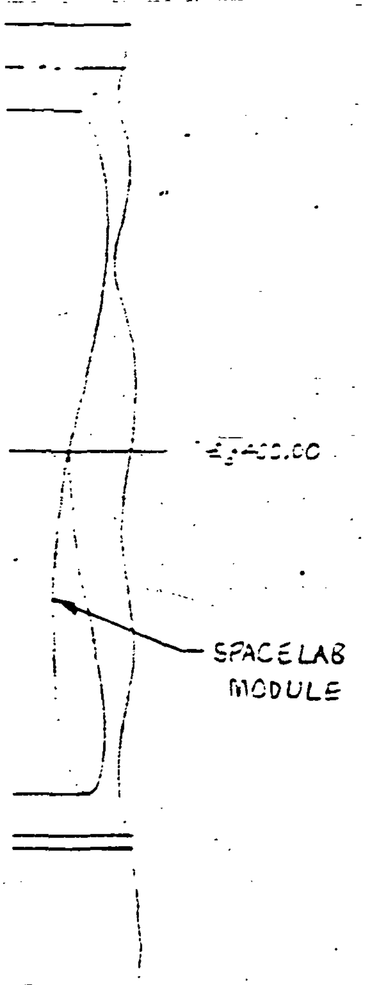
VOLUME GROSS INTL: 194 FT³

GROSS STOWAGE: 96 FT³

	WEIGHTS	AIRLOCK OUT	AIRLOCK
	MAX ON BHD	2450 LBS	2550 LBS
LESS	AIRLOCK	1036 LBS	1036 LBS
	ETA STRUCT	796 LBS	796 LBS
	AVAILABLE STOWAGE (INCL SUPT STRUCT)	618 LBS	718 LBS

FOLDOUT FRAME 8





FOLDOUT FRAME 9

5: AIRLOCK IN = AIRLOCK IN
AIRLOCK OUT = AIRLOCK OUT

4. NO SIGNIFICANT IMPACTS
PEP
TUNNEL

3. NO IMPACT ON: ORBIT
AIRLO
SPACE
MMU
MESA

2. THESE CONFIGURATIONS
ADAPTOR LAYOUTS & TUNN
NO FLIGHT HARDWARE EX
AT THIS DATE.

1. THIS LAYOUT PRESENTS
FOR AN EXPANDED TUN
IS WITHIN ORBITER 3

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NOTES:

DESIGN

ECTION
UNEL FROM CREW CABIN
D., 44.50 O.D BELLOWS

EXPANDED
SMALL MIN.

ᴐCK IN = AIRLOCK IN CREW MODULE (ORBITER BASELINE)
ᴐCK OUT = AIRLOCK OUT IN PAYLOAD BAY

SIGNIFICANT IMPACTS ON:
'EP
TUNNEL

FOLDOUT FRAME 10

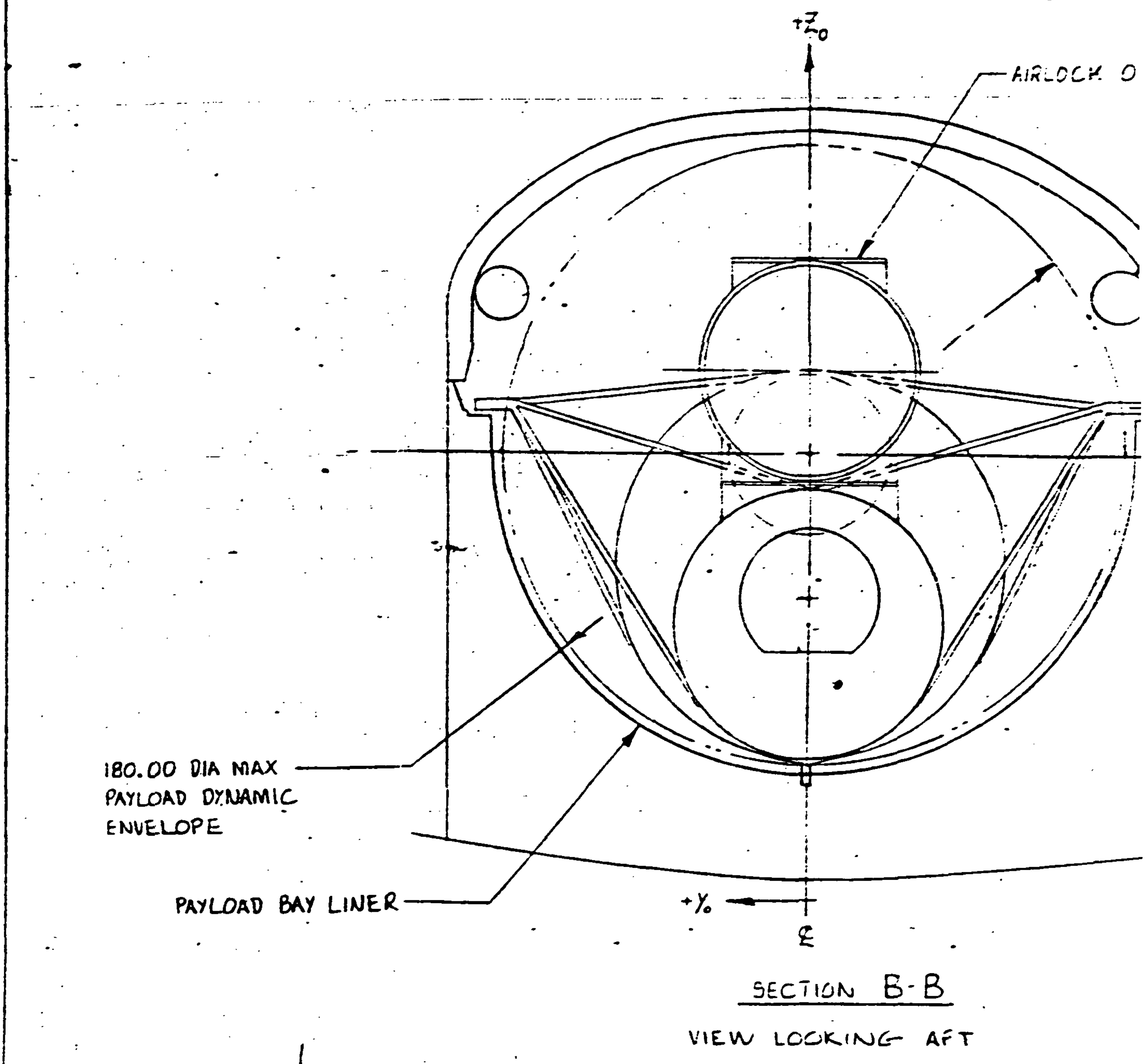
IMPACT ON: ORBITER
AIRLOCK
SPACE LAB
MMU
MESA

SE CONFIGURATIONS IMPACT BASELINE TUNNEL
PTOR LAYOUTS & TUNNEL BELLOWS DESIGN ONLY.
FLIGHT HARDWARE EXISTS FOR THESE ITEMS
THIS DATE.

IS LAYOUT PRESENTS DESIGN CONCEPTS
R AN EXPANDED TUNNEL ADAPTER THAT
WITHIN ORBITER BASELINE CAPABILITIES.

1/20	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION	
EXPANDED TUNNEL ADAPTER - SMALL, MIN, MOD CONFIGURATIONS		SS79-00270

B3



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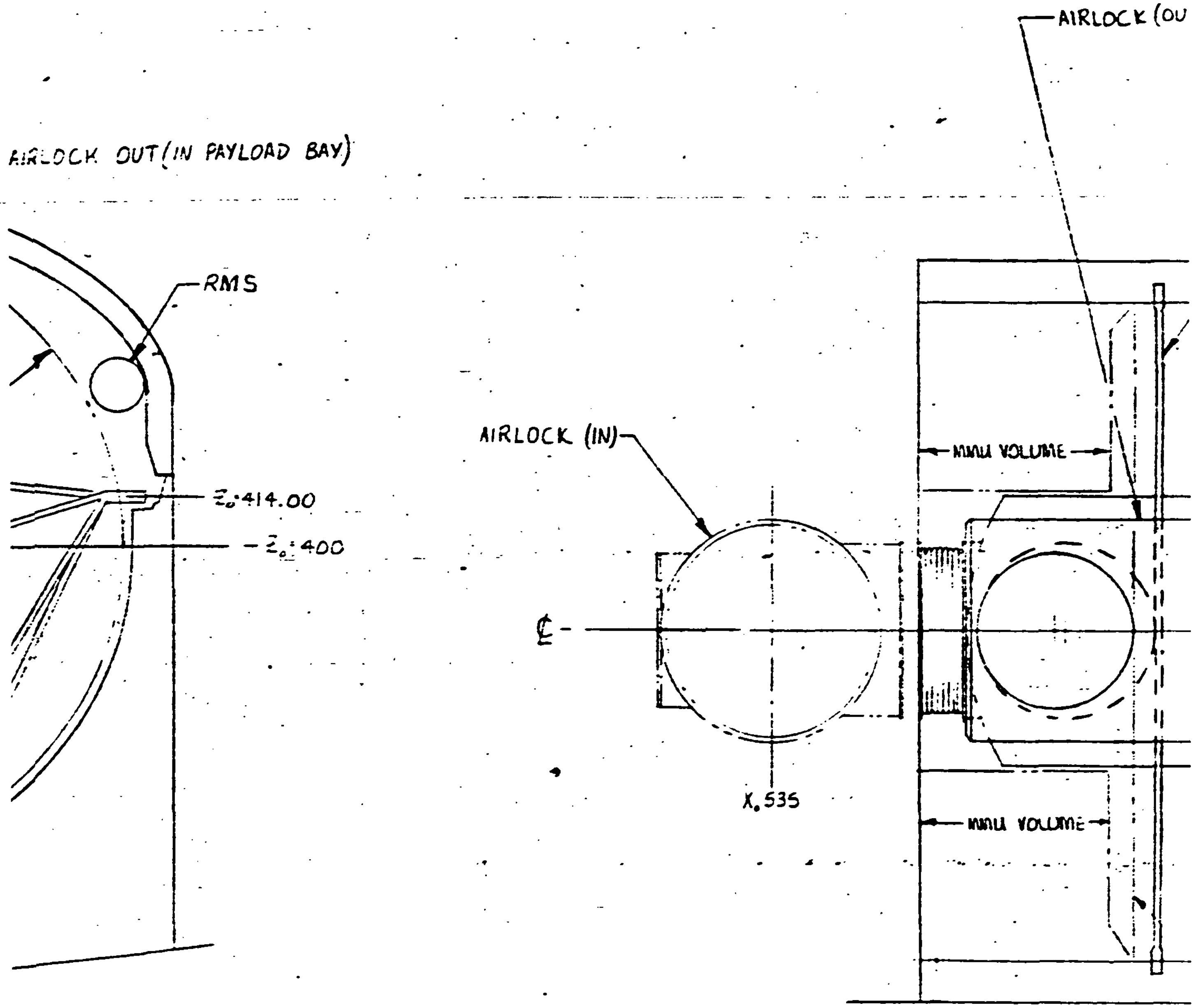

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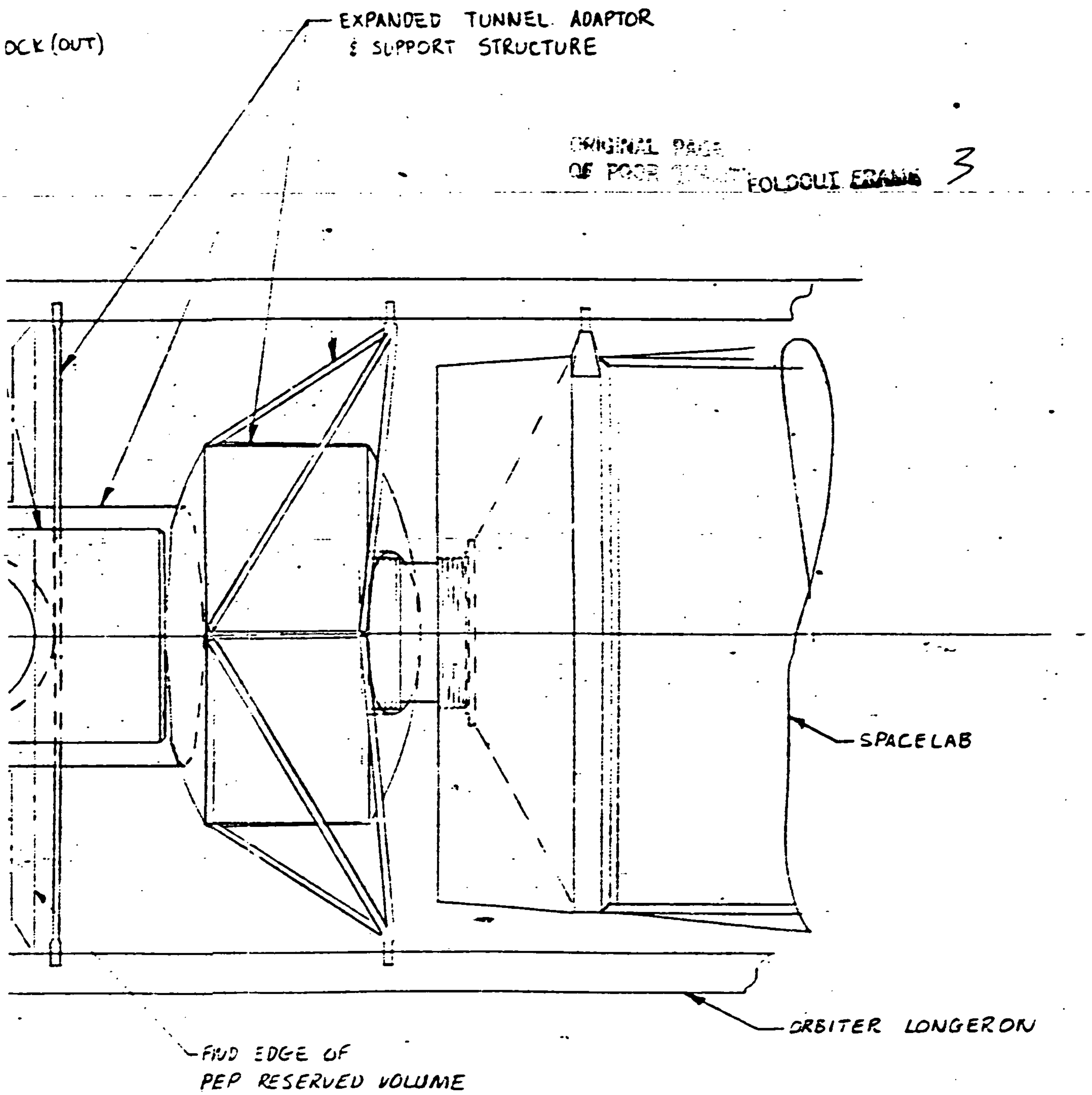
FOLDOUT FRAME 3



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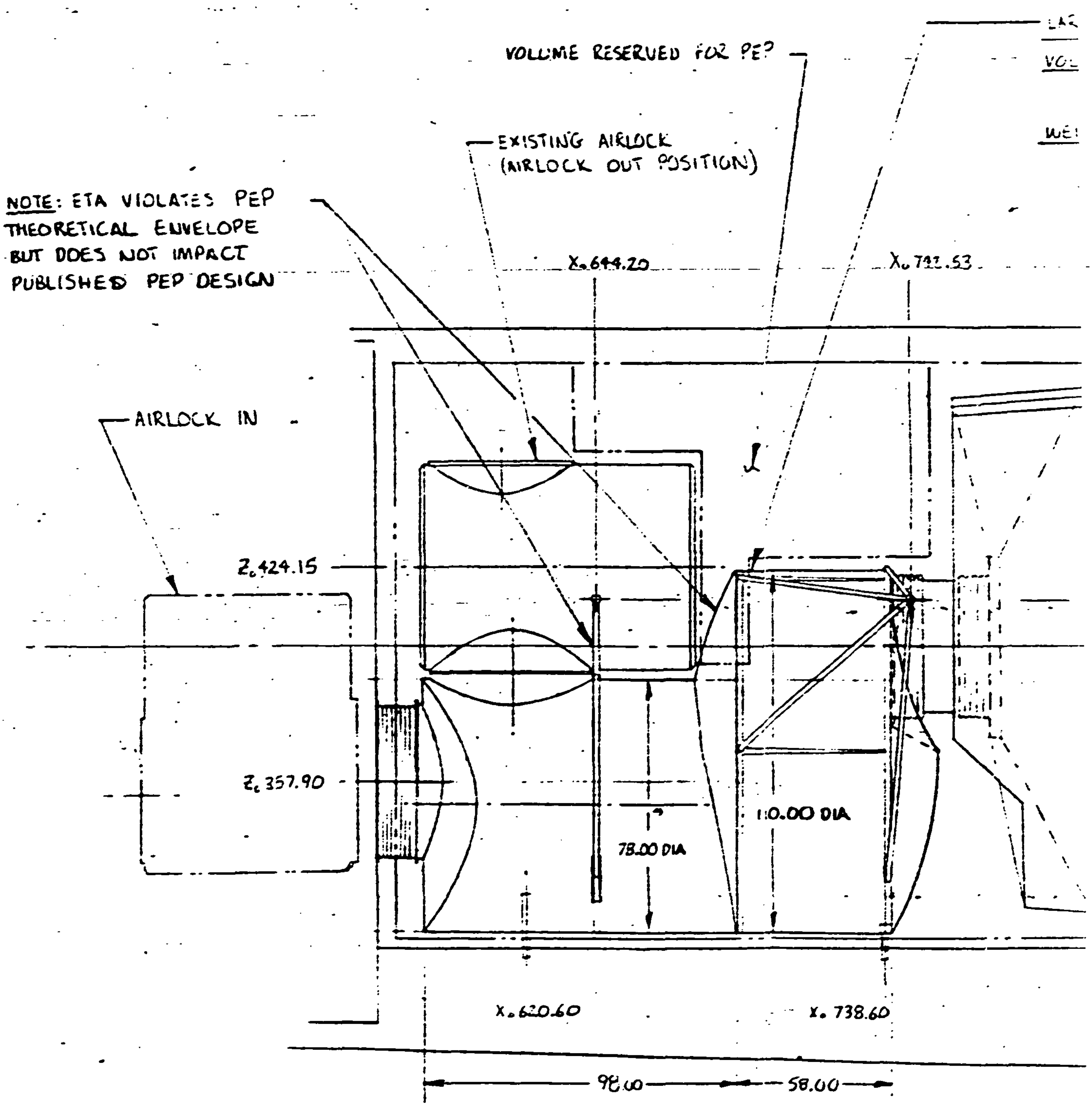

FOLDOUT FRAME 4

ETA-5

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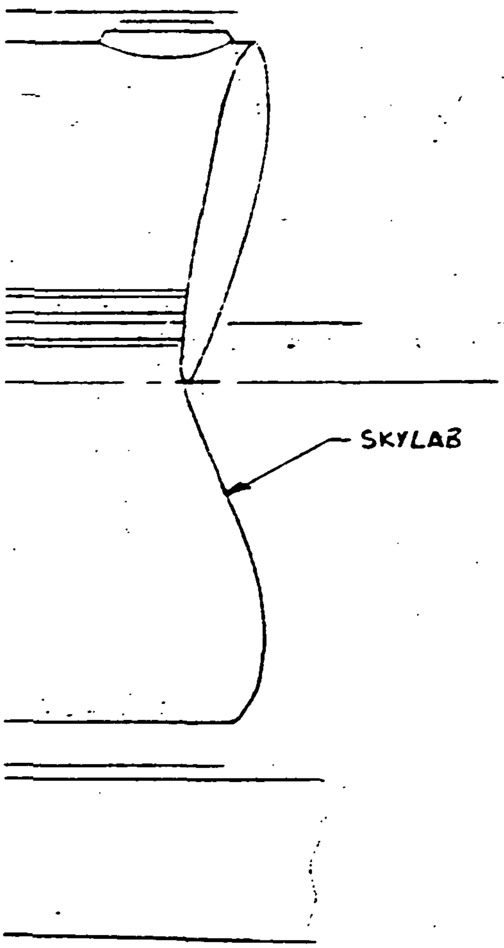
XTENDED TUNNEL ADAPTER

: GROSS INTERNAL : 590 FT^3
GROSS STOWAGE : 375 FT^3

: AIRLOCK :	1036 LBS
ETA STRUCT :	1702 LBS
	2738 LBS
STOWAGE + SUPTS	2740 LBS
TOTAL	5523 LBS *

E: MUST BE COORDINATED WITH REMAINDER OF CARGO MANIFEST PER JSC 07700 VOL XIV



FOLDOUT FRAME 5

NOTES:

2. THIS CONCEPT REQUIRES CO-O... PROGRAM. MODULE VIOLATES PE... ENVELOPE, BUT DOES NOT INTE... FINAL REPORT DESIGN.

1. THIS CONCEPT REPLACES THE ADAPTER & TUNNEL.

1/20	T. HEALY / 11-20-76	ROCKWELL INTERN... SPACE DIVISION

EXPANDED TUNNEL ADA...
LARGE MODULAR ...

FOLDOUT FRAME 6

2. THIS CONCEPT REQUIRES CO-ORDINATION WITH PEP* PROGRAM. MODULE VIOLATES PEP RESERVED VOLUME ENVELOPE, BUT DOES NOT INTERFER WITH PEP FINAL REPORT DESIGN.

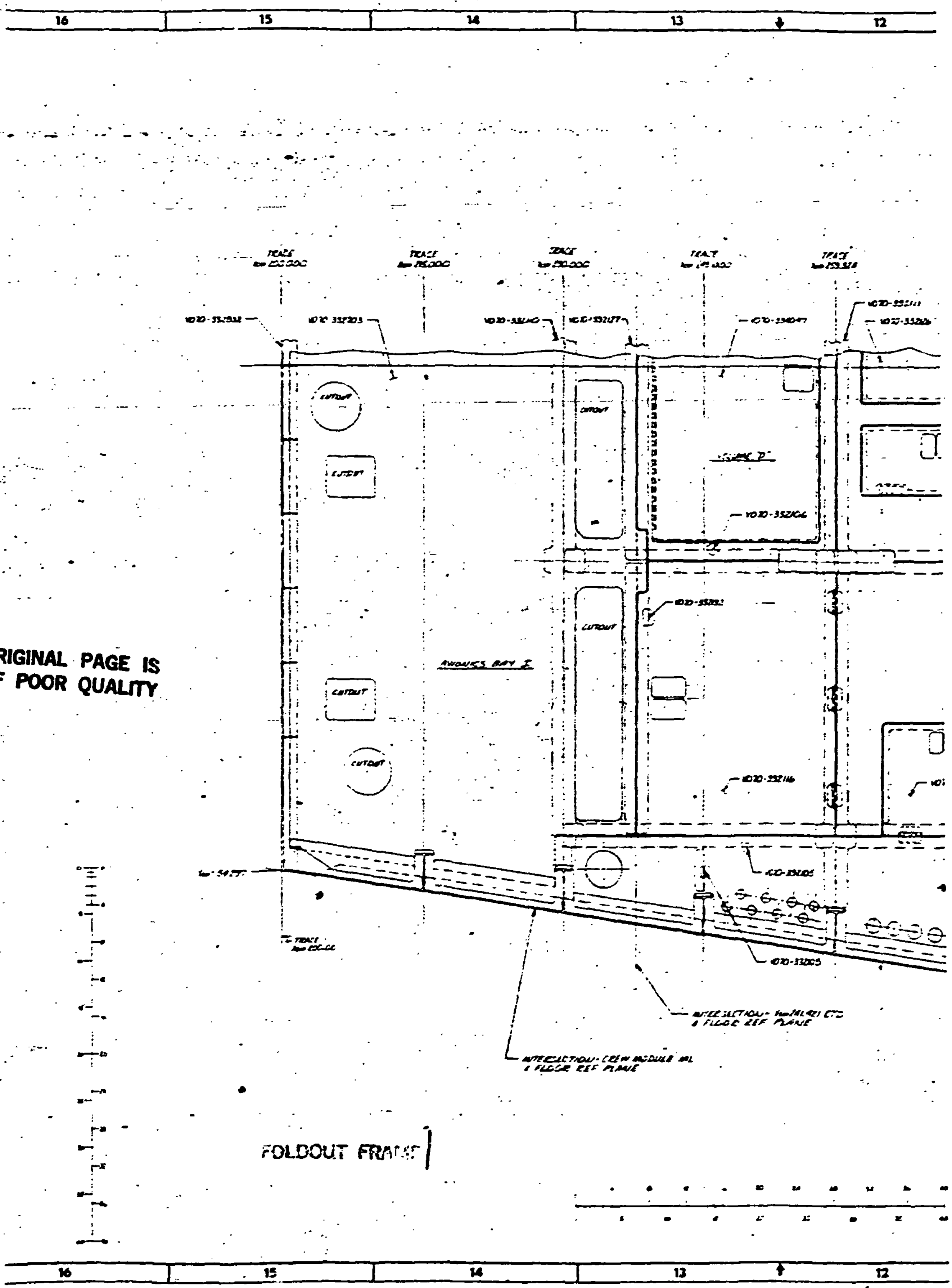
1. THIS CONCEPT REPLACES THE BASELINE TUNNEL ADAPTER & TUNNEL.

NOTES:

1/20	T. HEALY 11-20-79	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION	
EXPANDED TUNNEL ADAPTER - LARGE MODULAR CONFIGURATION			SS79-00275

APPENDIX C

MID-DECK GENERAL ARRANGEMENT DRAWINGS



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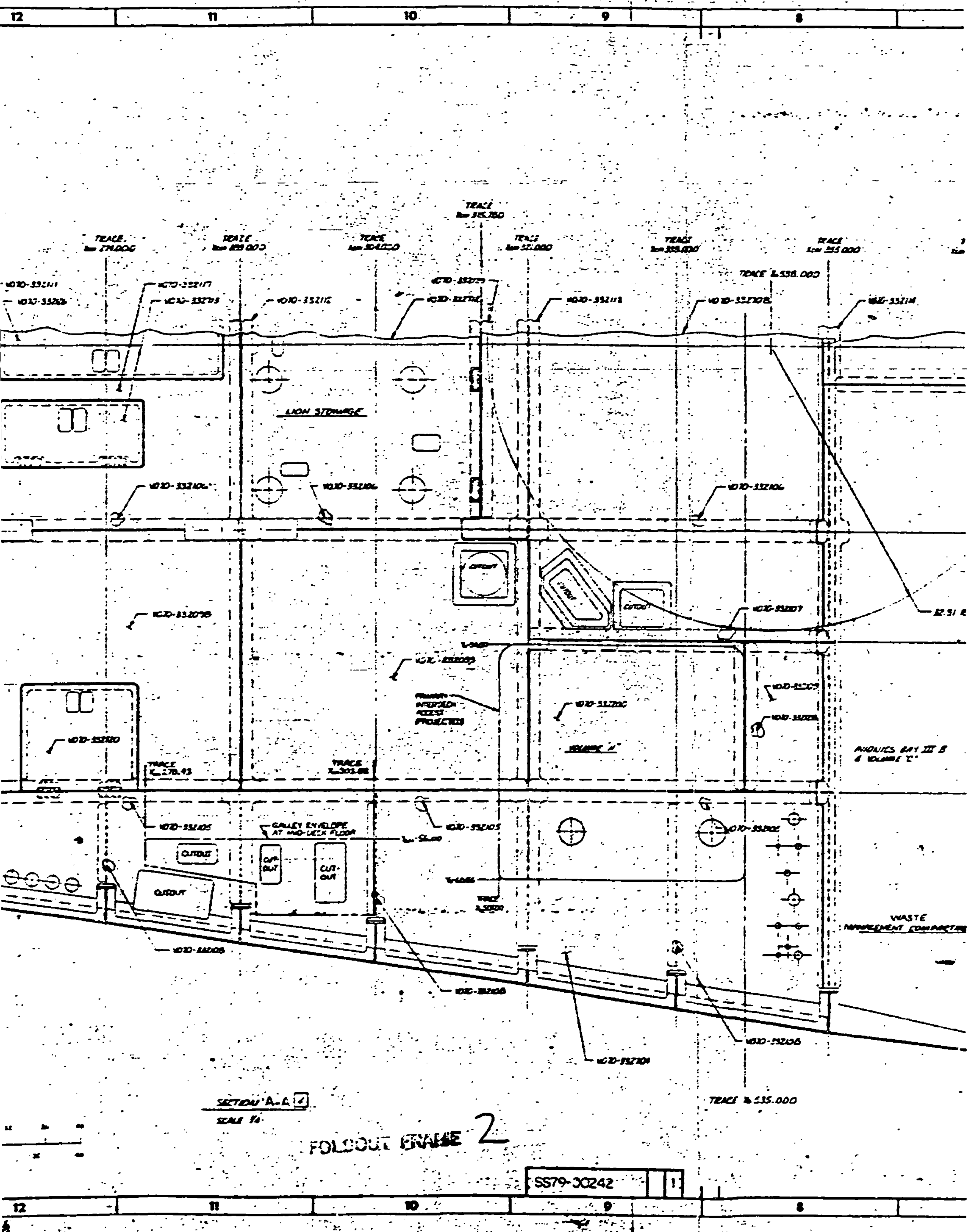

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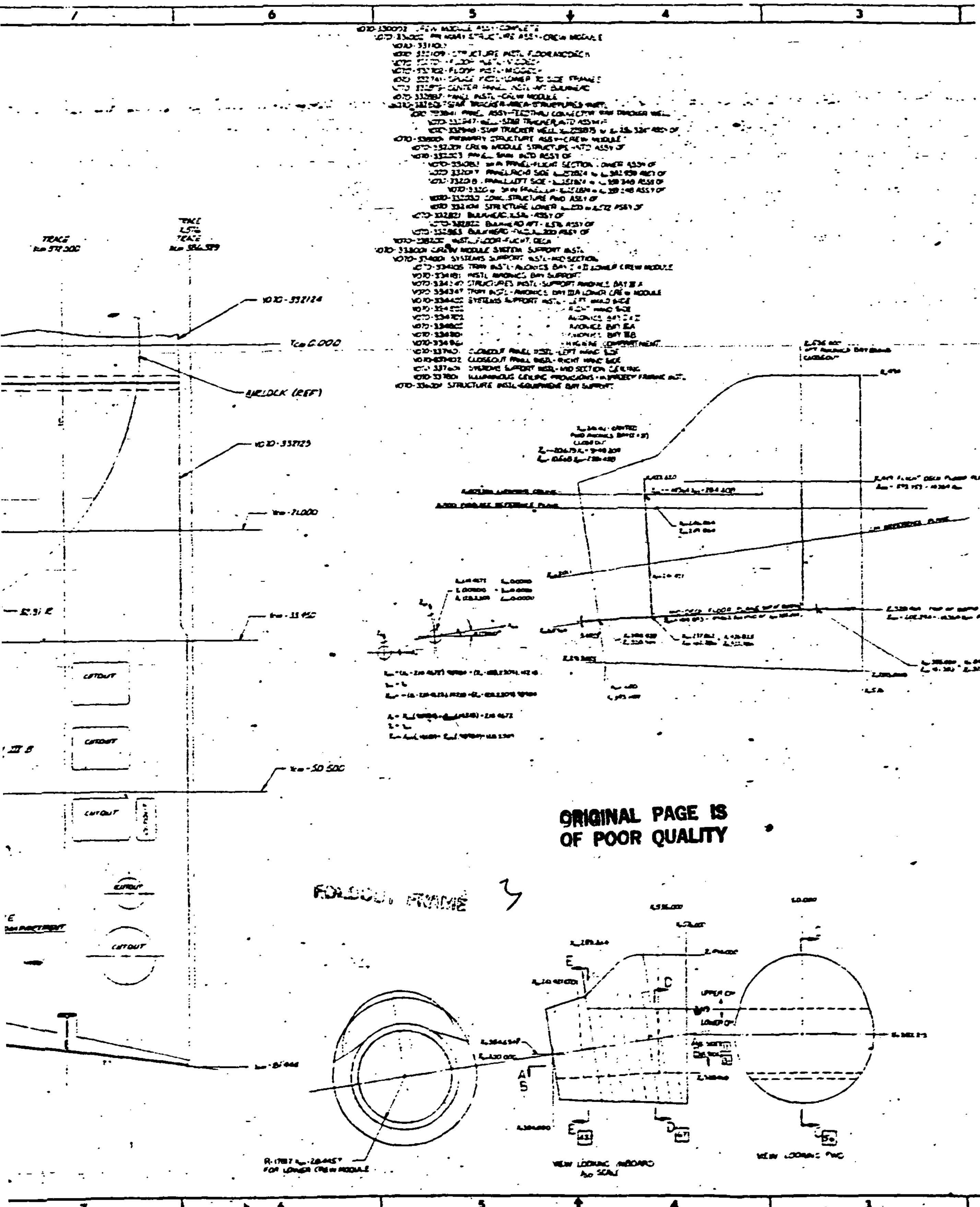

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FOLDOUT FRAME 3

FOLDOUT FRAME 4

GENERAL NOTES

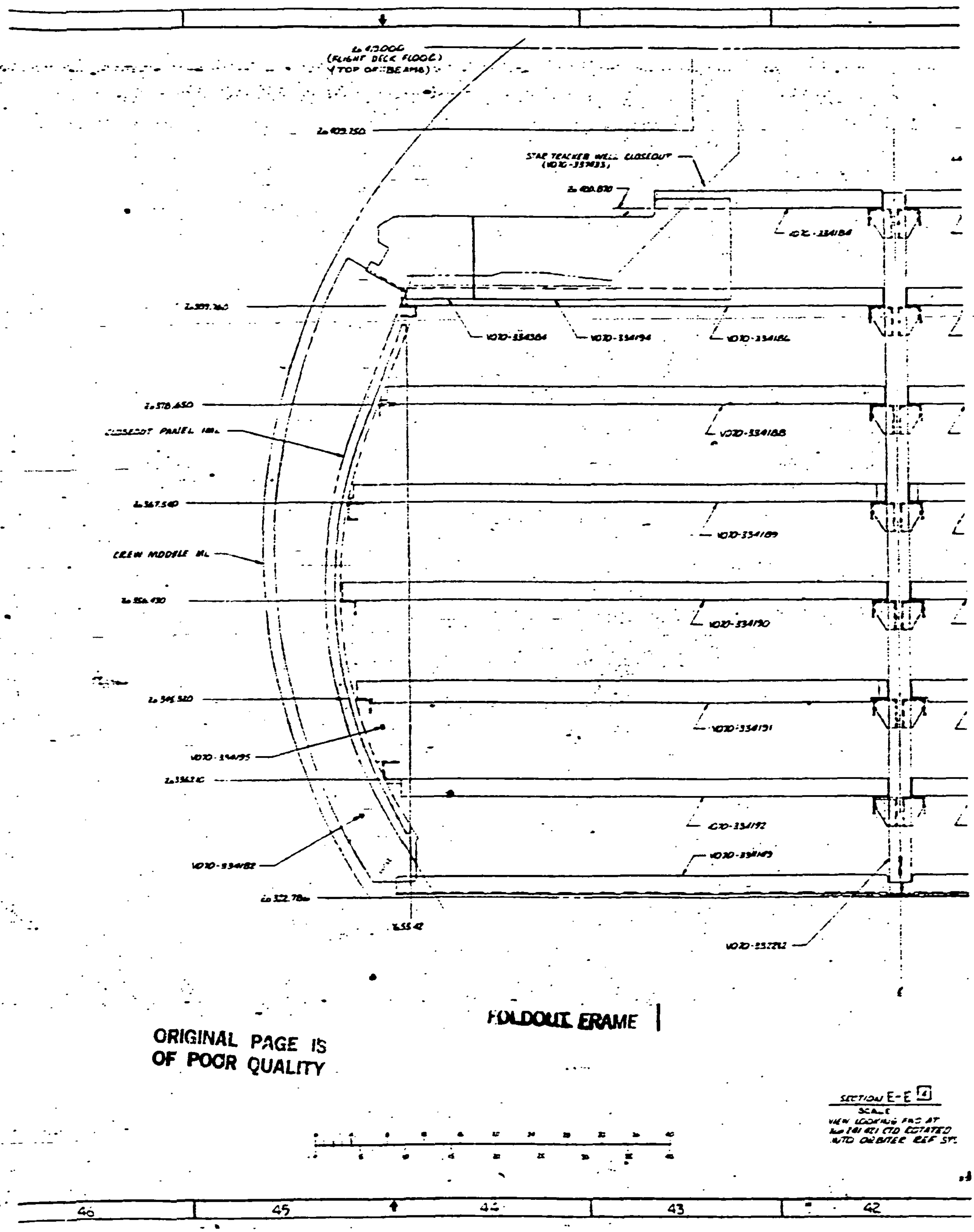
(1) 1. INDICATED FLOOR PANELS ARE FOR FLIGHT TEST ONLY. OPERATIONAL CONFIGURATION NOT RELEASED AT THIS TIME.

(2) 2. INDICATES EXISTING CREW SEAT ATTACH PROVISIONS. (3) INDICATES PROPOSED RELOCATION OF CREW SEAT ATTACH PROVISIONS.

3. THIS DRAWING REFLECTS THE OV-102 OPERATIONAL CONFIGURATION EXCEPT WHERE NOTED AS OF OCT. 1, 1979

R. EEMER	GENERAL ARRANGEMENT CREW MODULE MID DECK
	J 03953 SS79-00242

SOD 79-0321



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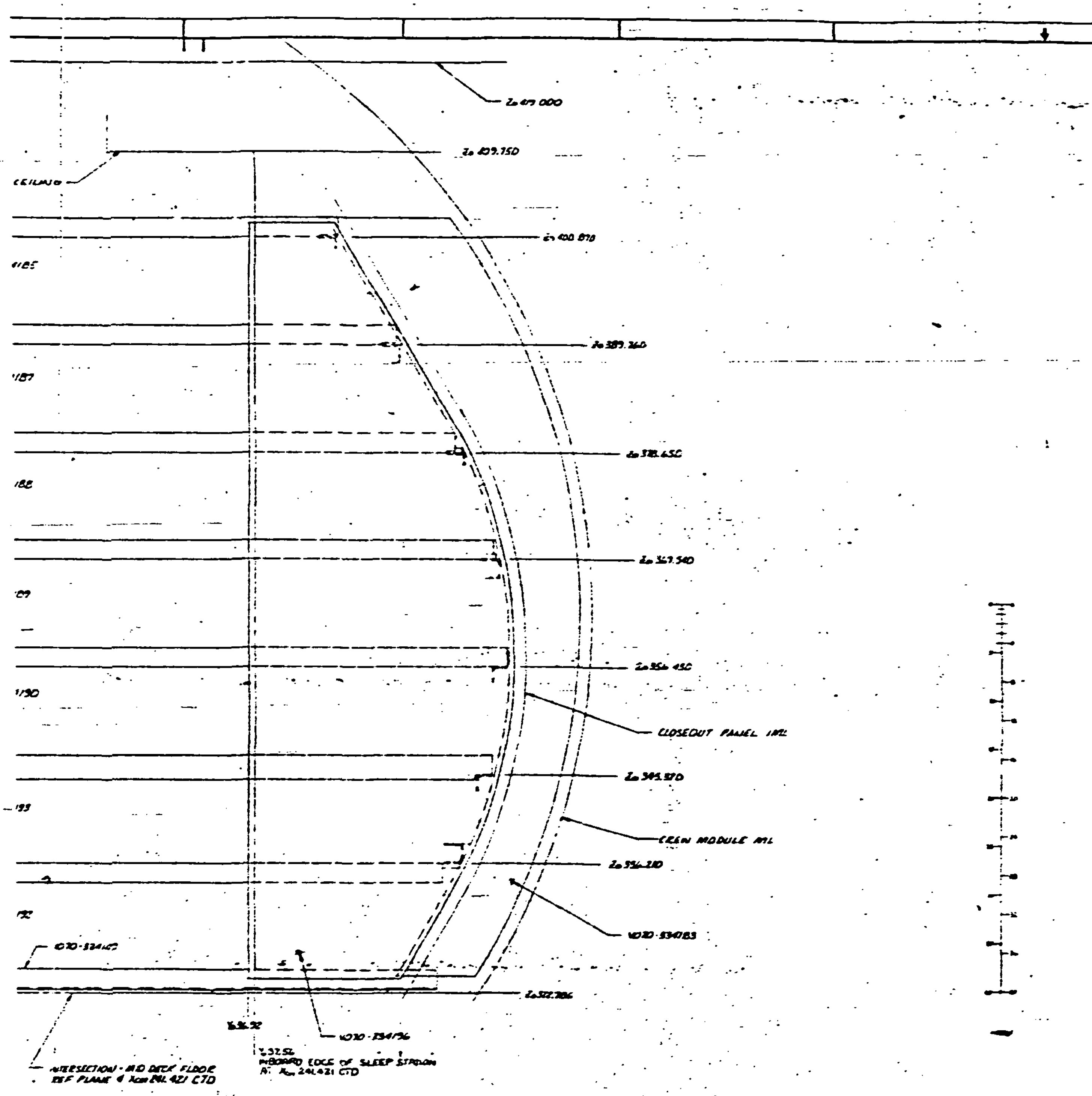
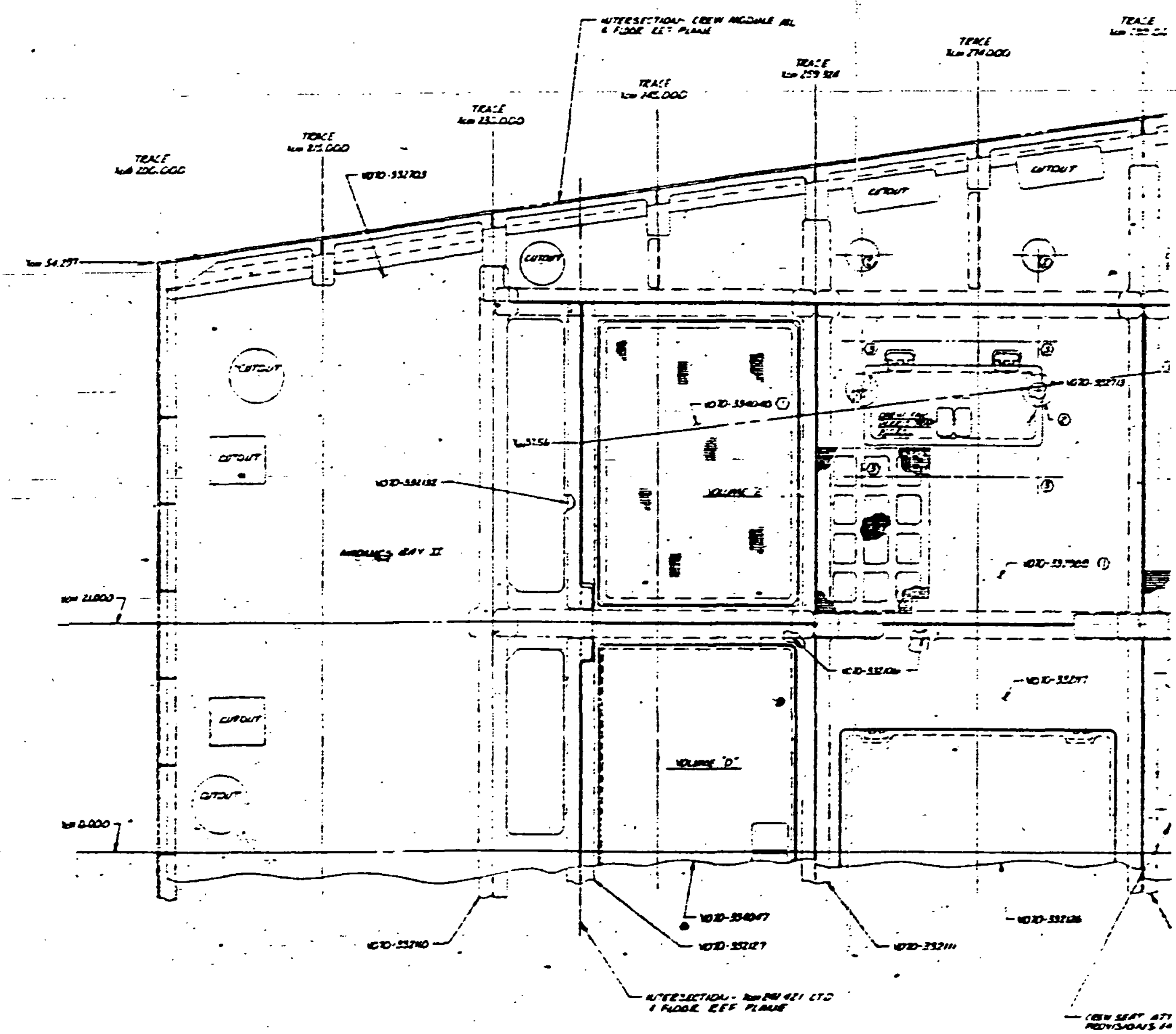


FOLDOUT FRAME 2

79-00242 23

41 40 39 38 37



FOLDOUT FRAME 3

SS79-00242 | 2

36 | 35 | 34 | 33 | 32

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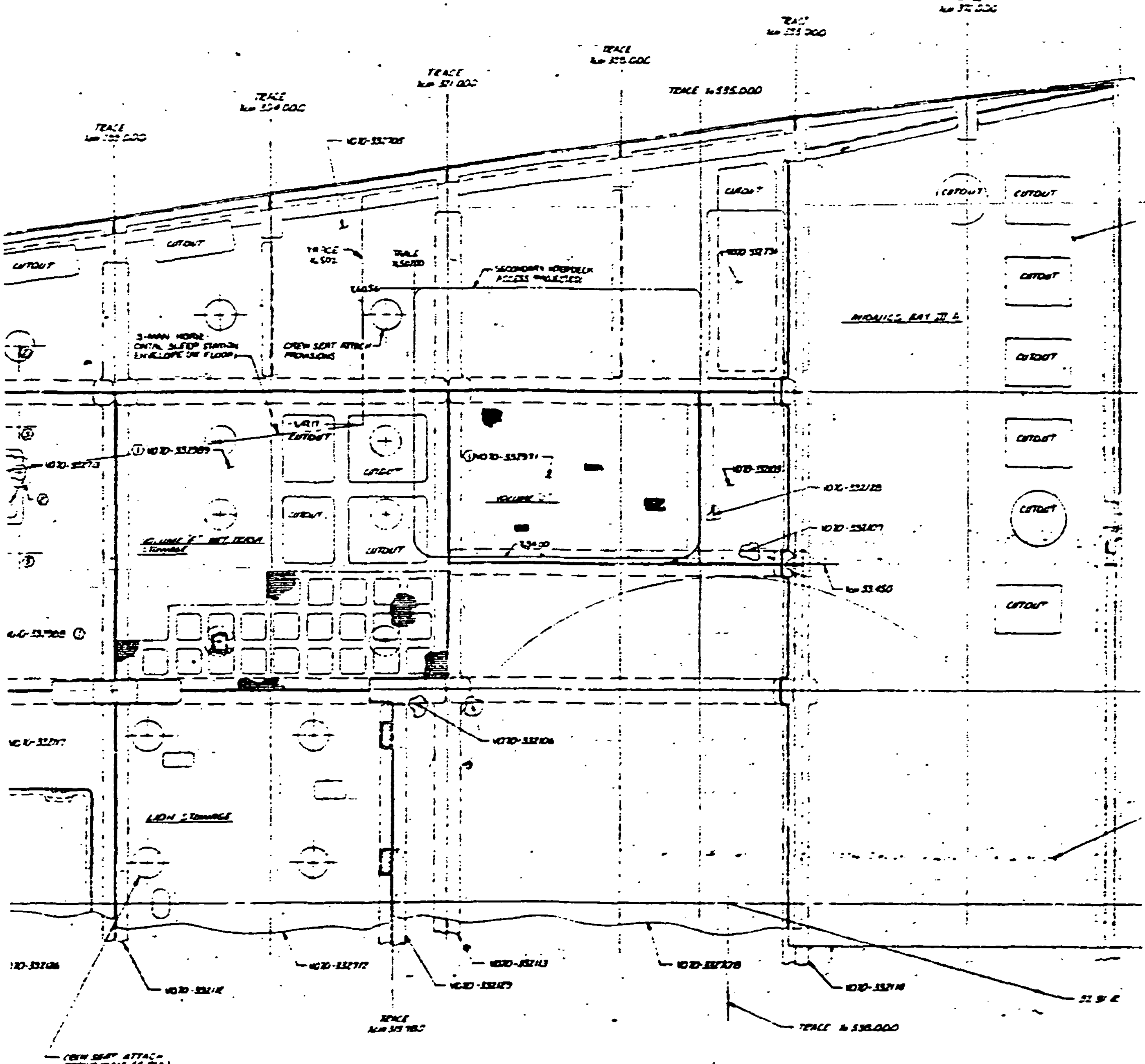
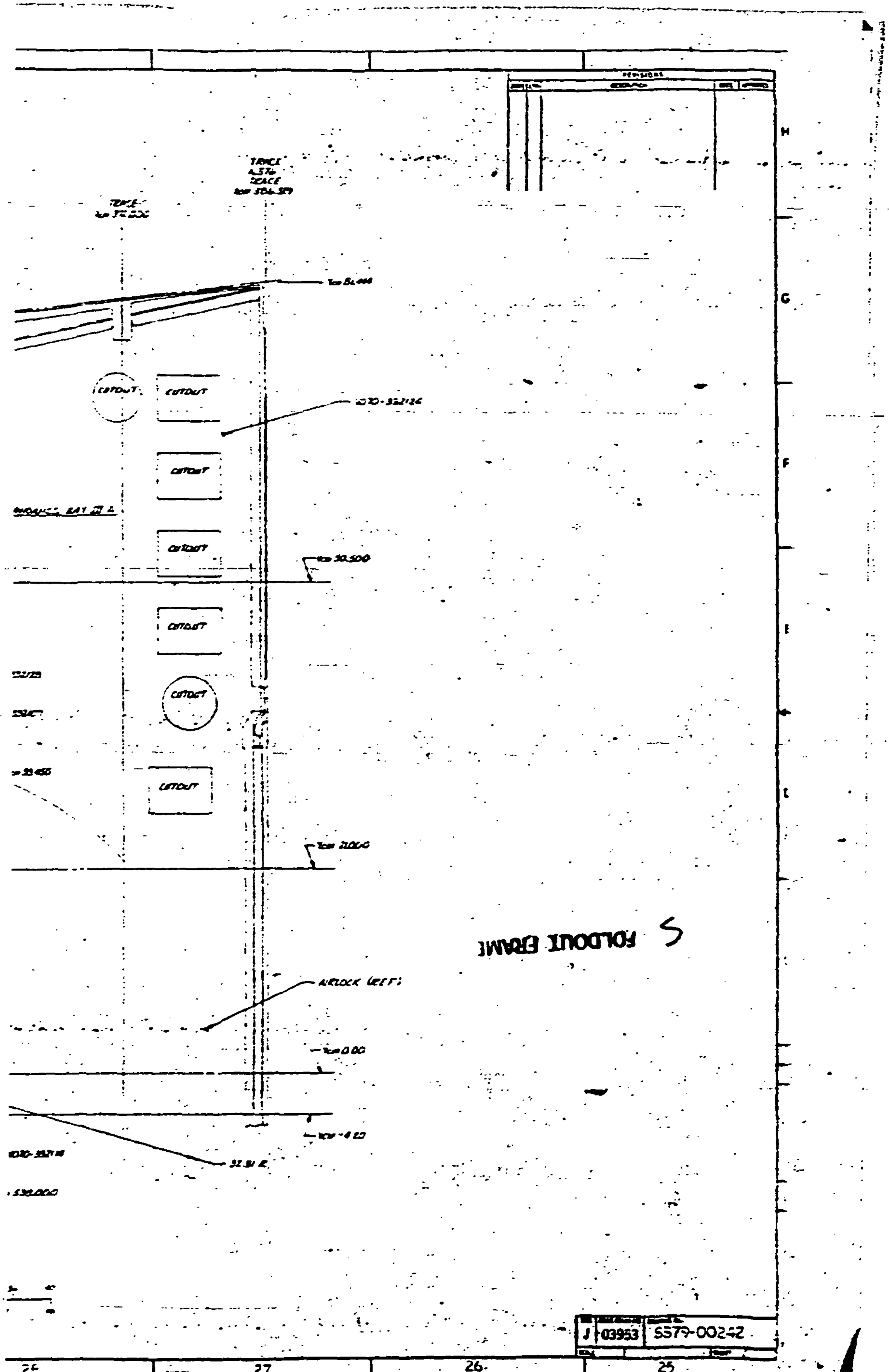


FOLDOUT FRAME 4

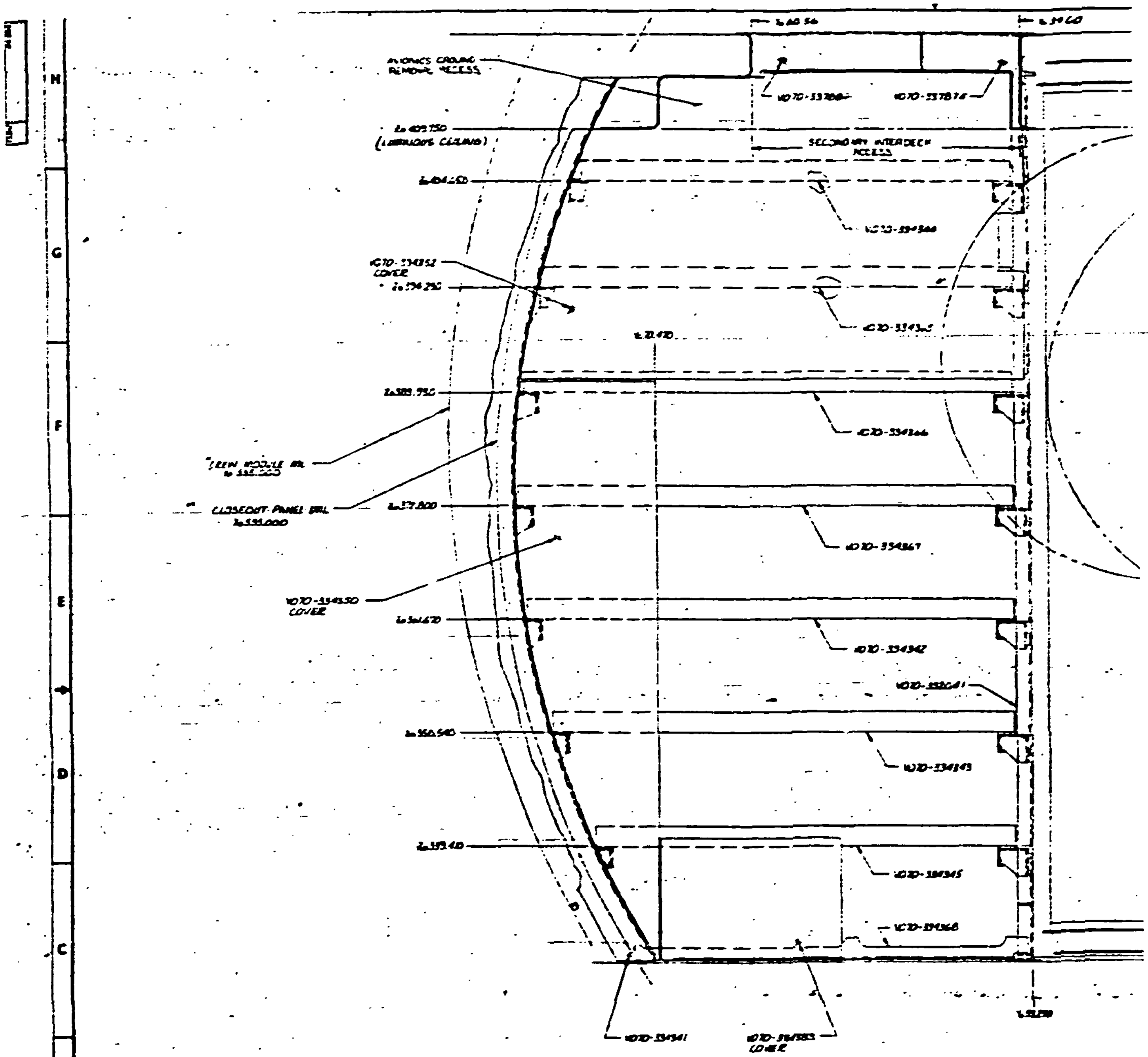
SECTION B-B

SCALE 4



C3

S00 79-0321



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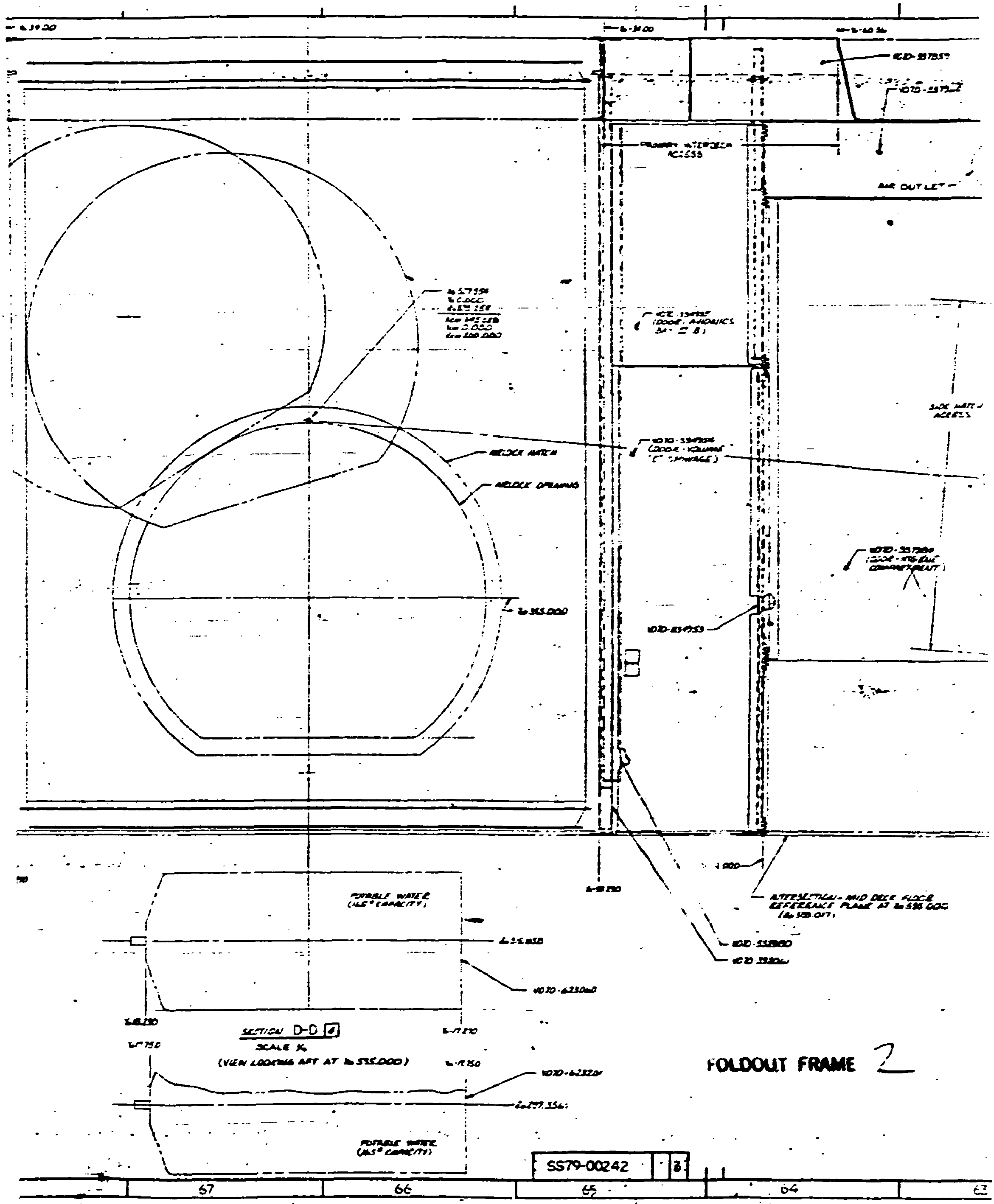

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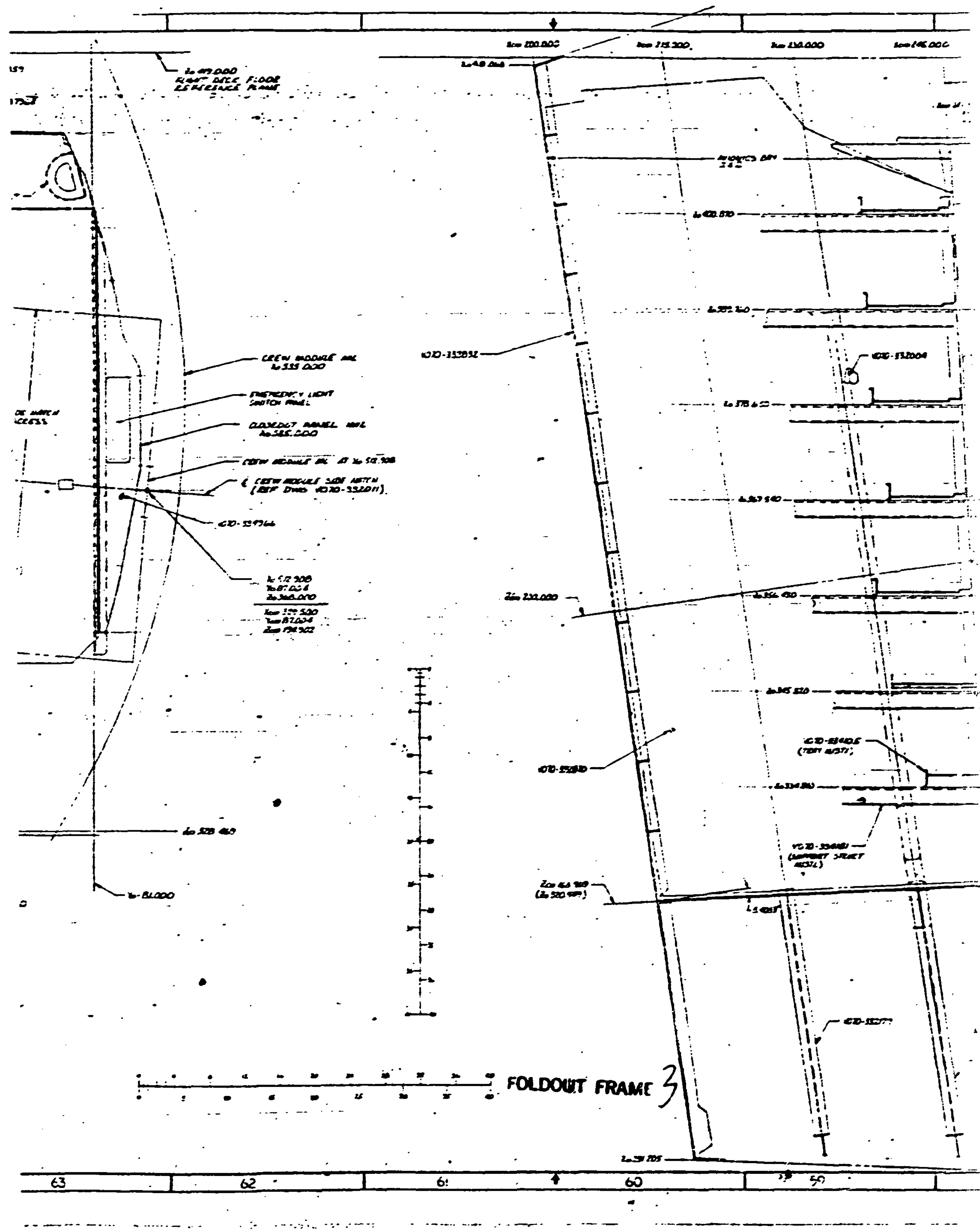
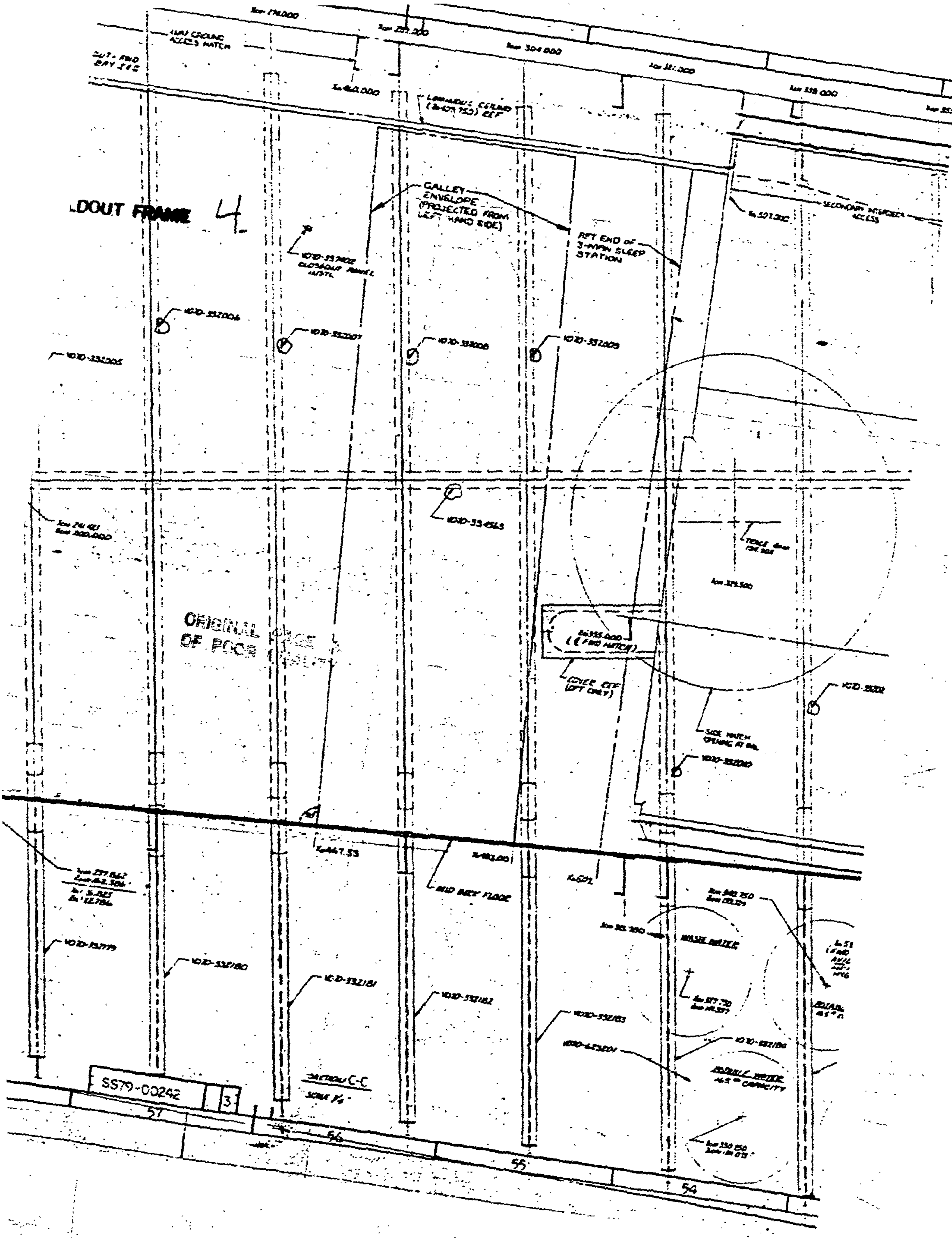
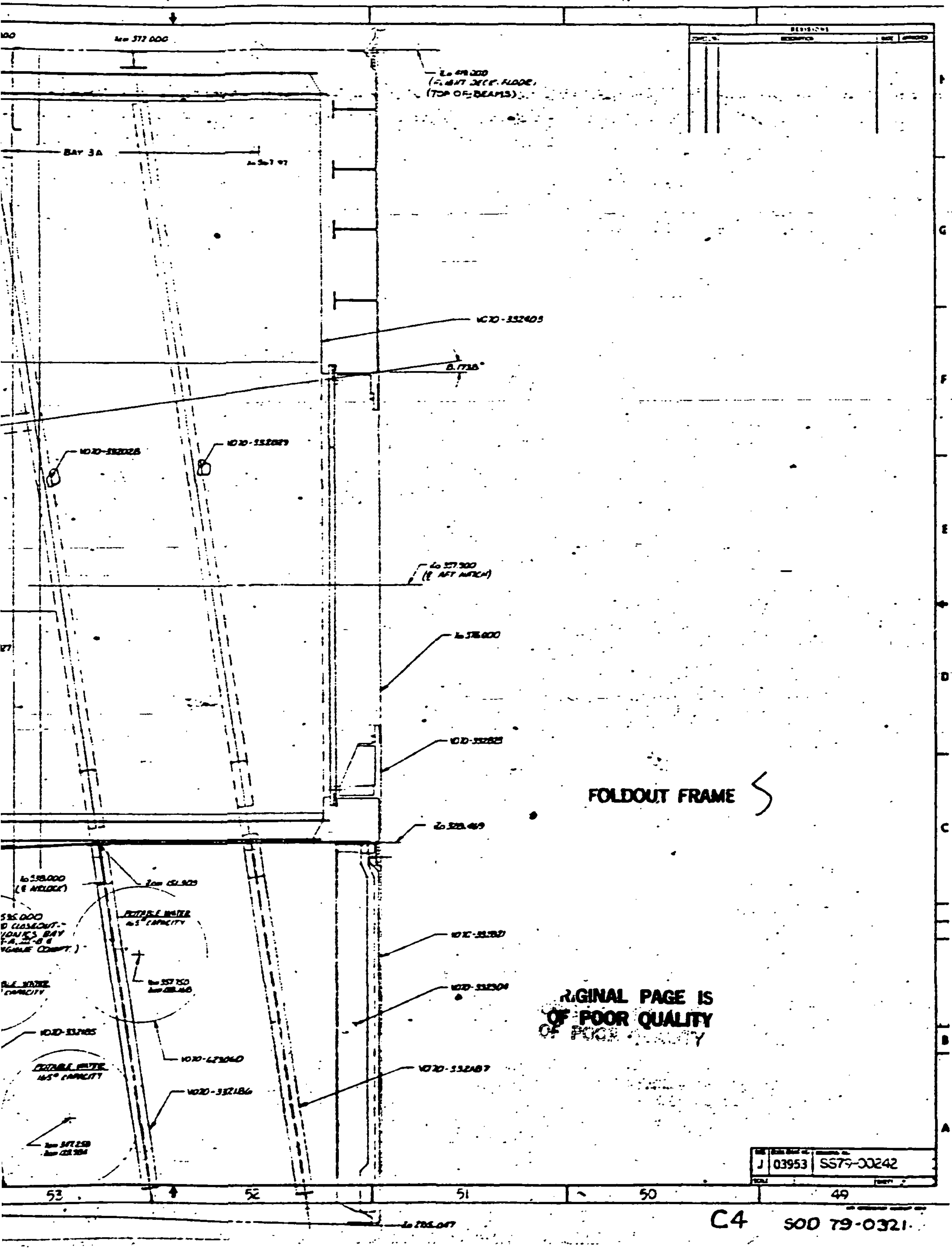


FLIGHT DECK FLOOR REFERENCE PLANE
CREW MODULE ARC
EMERGENCY LIGHT SWITCH PANEL
CLOSEOUT PANEL
CREW MODULE SIDE HATCH
(REF DWG V070-332011)
AVIONICS BAY
FOLDOUT FRAME 3
63
62
60

.LDOUT FRAME 4





FOLDOUT FRAME 5

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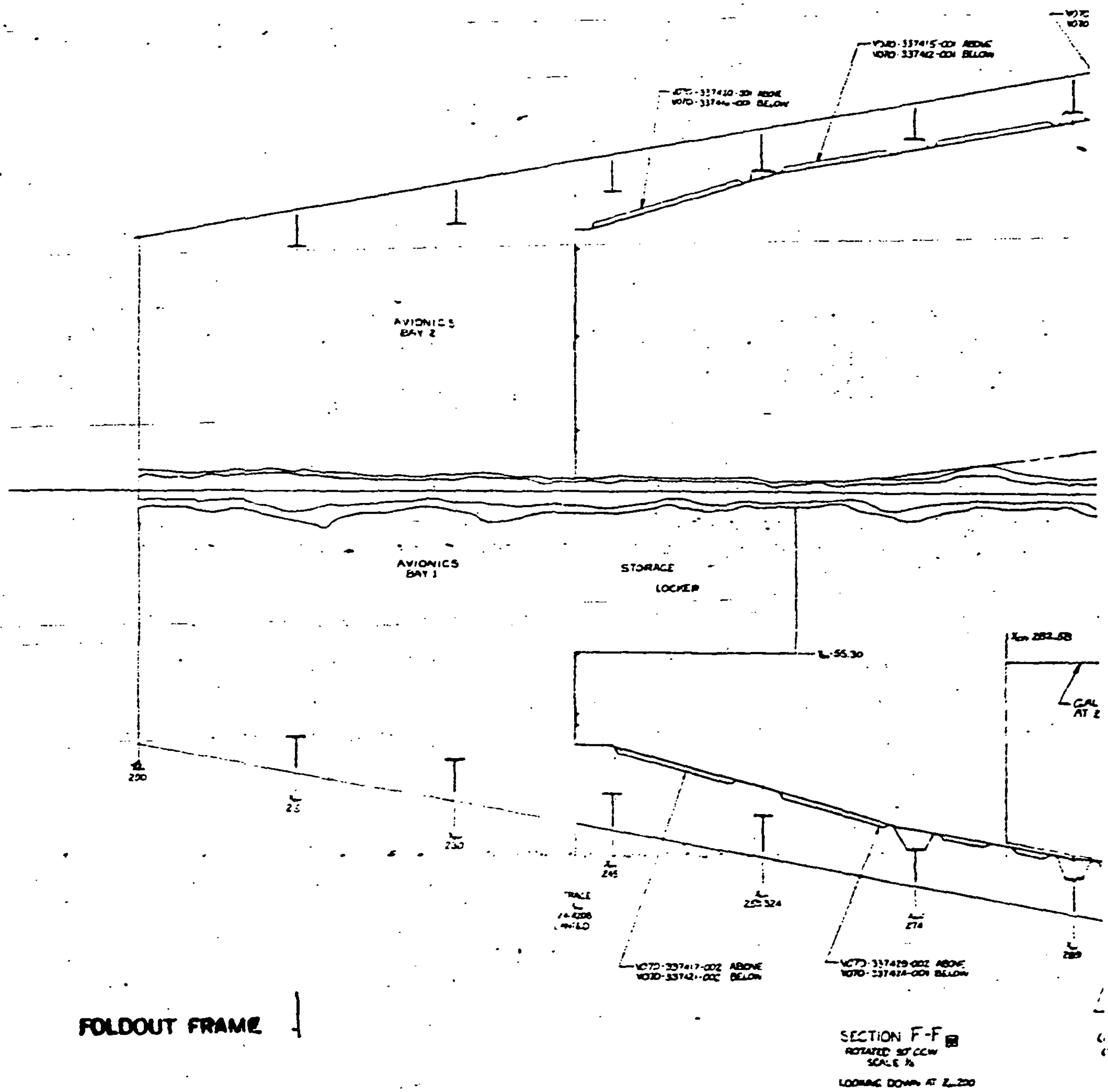
C4 SOD 79-0321



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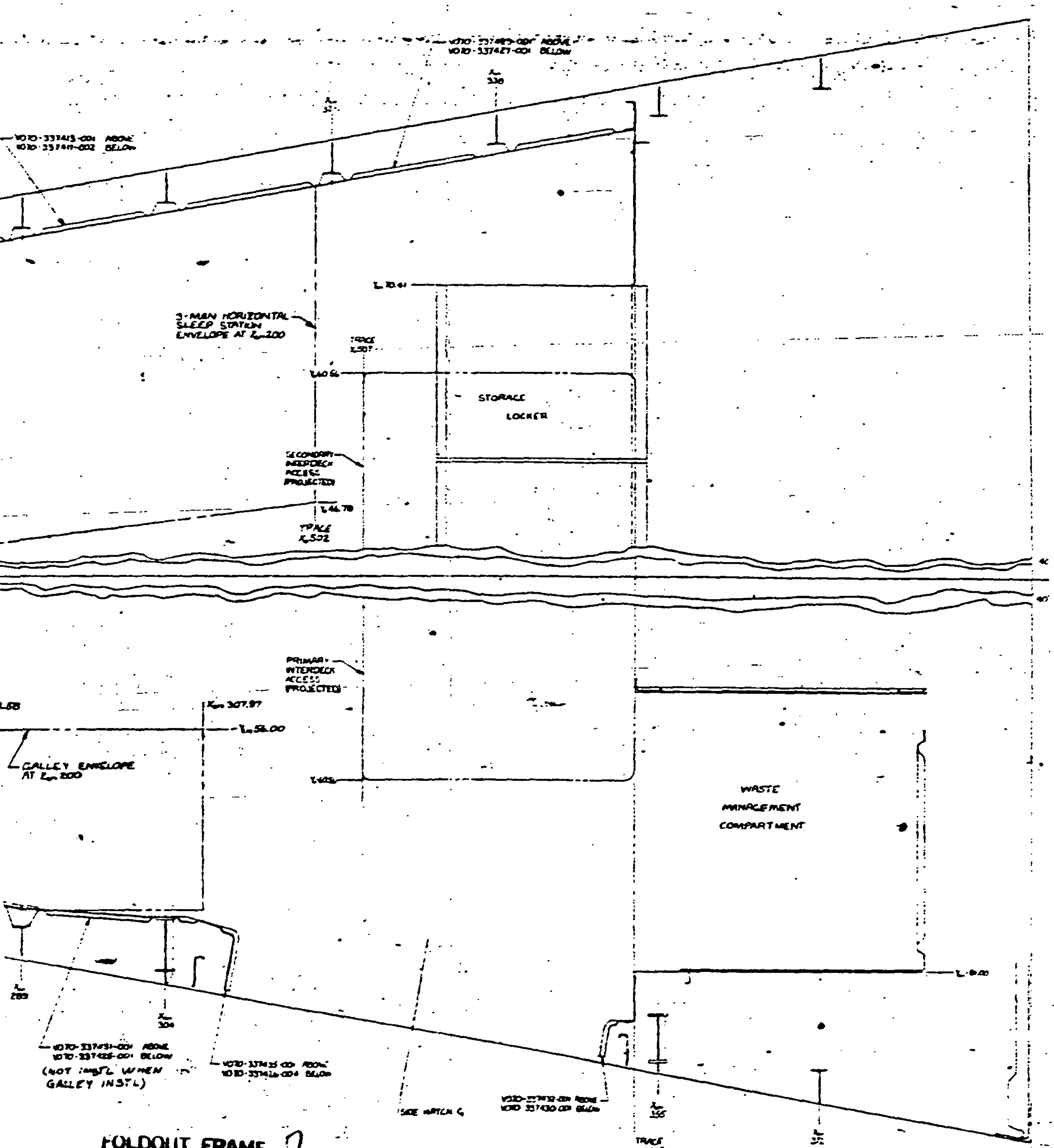
95 94 93 92 91



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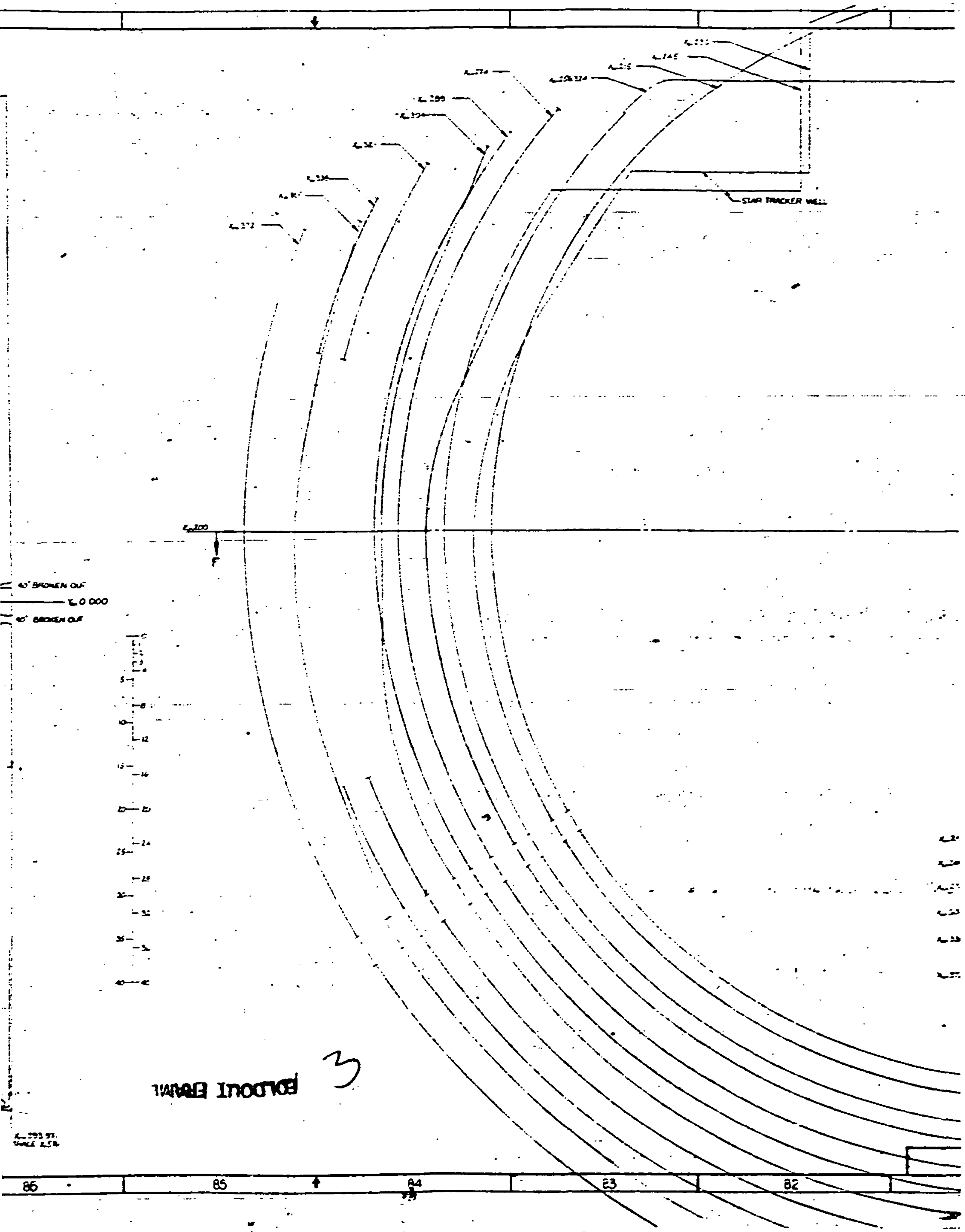
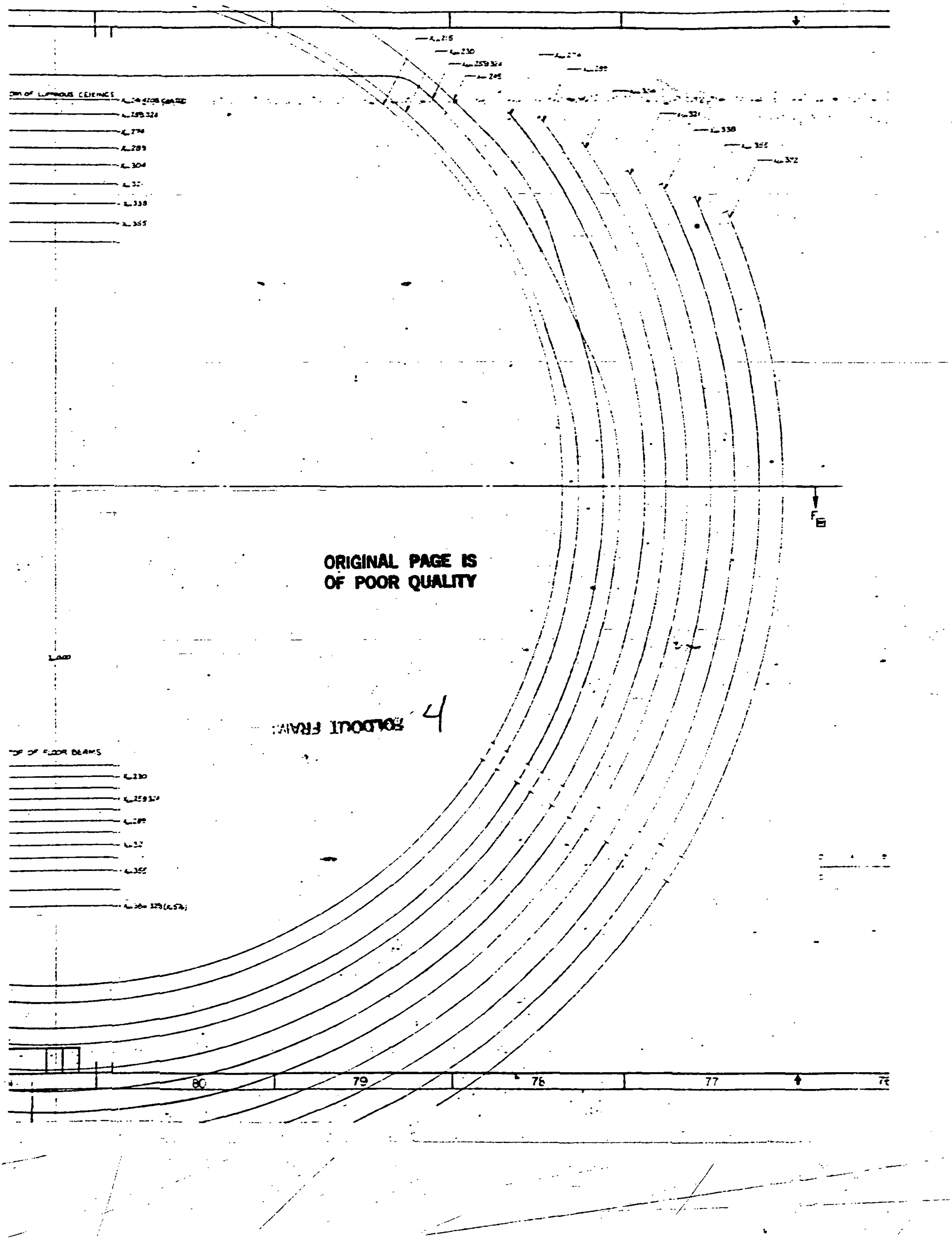
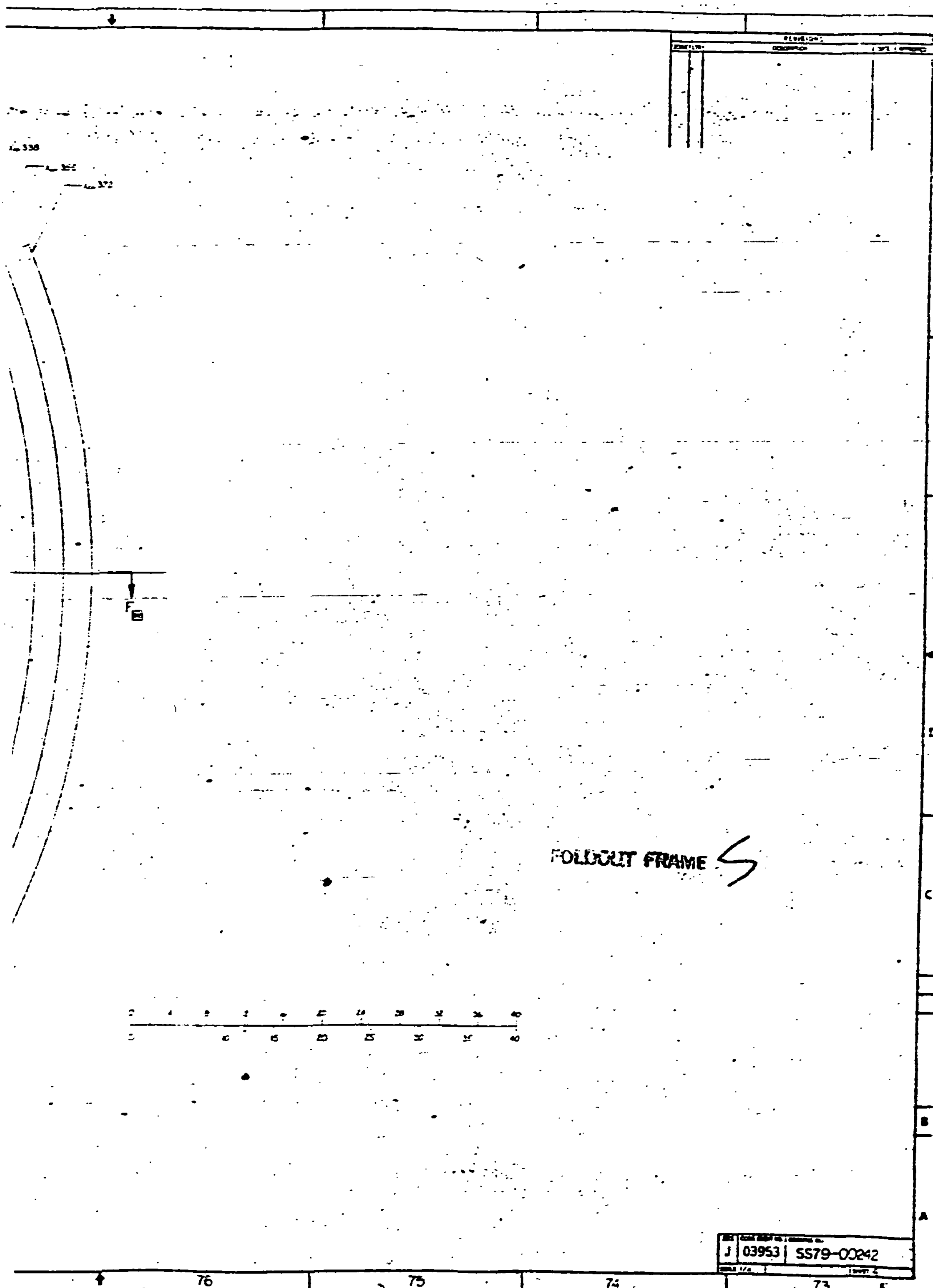
5579-00242 | 4

90	89	88	87	86


STAR TRACKER WELL
40° BROKEN OUT
40° BROKEN OUT
FOLDOUT FRAME
3
86
85
84
83
82


80
79
77



C5

SOD 79-0321

1