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UMBILICAL CONNECT TECHNIQUES IMPROVEMENT TECHNOLOGY STUDY

Donald C. Valkema

Convair Aerospace Division
General Dynamics
San Diego, California 92112

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16. Abstract The objective of this study was to develop concepts, specifications, designs, techniques, and procedures capable of significantly reducing the time required to connect and verify umbilicals for ground services to the Space Shuttle. The desired goal was to reduce the current time requirement of several shifts for the Saturn V/Apollo to an elapsed time of less than one hour to connect and verify all of the Space Shuttle ground service umbilicals.

The study was conducted in four phases: (1) literature and hardware examination, (2) concept development, (3) concept evaluation and tradeoff analysis, and (4) selected concept design. The final product of this study was a detail design of a rise-off disconnect panel prototype test specimen for a LO_2/LH_2 booster (or an external oxygen/hydrogen tank for an orbiter), a detail design of a swing-arm mounted pre-flight umbilical carrier prototype test specimen, and a part 1 specification for the Umbilical Connect and Verification Design for the vehicles as defined in the Space Shuttle Program RFP No. 9-BC421-67-2-40P.

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SUMMARY

The original Space Shuttle concept envisioned a minimum size fleet of fully reusable first and second stage rocket powered launch vehicles to carry a large number of payloads to orbit each year. This concept, entirely different than previous launch vehicles, imposes new requirements on the servicing disconnects (umbilicals).

First of all, the umbilical hardware must be reusable. This includes protection from the environments of engine exhaust and reentry heating as well as from contamination carried by the air. It also includes design features making refurbishment rapid and inexpensive.

Secondly, the umbilicals must be easily and rapidly engaged. This includes reducing the number of servicing disconnects to a minimum, combining them into a minimum number of integral carriers, reducing the weight and complexity of the carriers, and providing built-in handling means to allow rapid engagement without additional equipment, and with a minimum of personnel. This rapid engagement with a minimum of personnel is necessary in order to minimize impact on the rapid ground turnaround and minimum crew size inherent in the basic Space Shuttle concept.

Thirdly, and again to minimize ground turnaround time and ground crew, the engagement of umbilicals must be easy to verify. This includes visual checks, leak checks of fluid and gas couplings, and continuity checks of electrical disconnects.

And last, but not least, the inherent reliability of the umbilicals must be increased. At this point in time this last item must be judged on a qualitative basis. Certainly, reducing the number of disconnects, using a minimum number of carriers, and making the maximum number of disconnects pre-flight (rather than in-flight) are steps in the right direction on a qualitative analysis basis.

For this study, a specific Space Shuttle configuration was chosen for definition of umbilicals; i.e., the B9U booster configuration of the Convair Aerospace Division of General Dynamics and the 161C orbiter configuration of North American Rockwell. Both of these vehicles were fully reusable fly-back stages using LO_2/LH_2 main propulsion propellants. More specifically, the study centered on the booster fuel disconnect (umbilical) panel and the orbiter integrated umbilical carrier that contained 20 servicing couplings, all of which could be disconnected prior to engine start. The booster fuel disconnects are required to be connected to maintain ground control and to drain propellants in the event of an on-pad abort. Rather than introduce an additional failure mode associated with having to re-engage the disconnects remotely, they are to be disconnected by vehicle motion at liftoff.

Since the orbiter services being considered need not be connected in the event of an abort, this umbilical carrier has been defined as a preflight umbilical. By disconnecting and verifying disconnect prior to committing to flight, a critical failure mode is eliminated.

This study was conducted in four basic phases: 1) literature and hardware examination; 2) concept development; 3) concept evaluation and tradeoff analysis; and 4) selected concept design.

The concept selected for design for the booster fuel panel incorporates the following salient features:

a. The couplings are riseoff type and separate in the direction of flight as a direct result of vehicle motion.

b. The couplings incorporate dynamic slip seals to accommodate vertical relative motion of the vehicle due to wind, propellant loading, engine firing, and cutoff (abort).

c. Hazardous fluid couplings incorporate dual seals to enable leak verification and to conduct primary seal leakage to safe disposal.

d. The ground carrier is powered up and down with screw jacks to allow retraction during vehicle erection onto the launcher and to rapidly engage the carrier, including all of the couplings and disconnects, after vehicle erection.

e. The carrier has built-in lateral freedom of motion with guide pins to align it to the vehicle carrier during engagement. The lateral freedom also allows tracking of vehicle horizontal relative motion due to wind, propellant loading, engine firing, and cutoff (abort).

f. The ground carrier has a pneumatically actuated blast shield to protect it from engine exhaust during launch.

g. The couplings have individual debris protection poppets to limit the contamination from particles borne by the air to the immediately accessible portion of the disconnect for ease in refurbishment.

h. The couplings and adjacent lines incorporate provisions for automation of the leak check verification task.

The concept selected for design for the orbiter integrated umbilical carrier incorporates the following salient features:

a. The couplings are ball and cone (seal design) type and separate in a direction perpendicular to the direction of flight.

b. All couplings are contained in a single carrier that is attached to the vehicle by a single locking device. None of the couplings incorporate individual locking devices.

c. The locking device is a collet designed to allow it to be locked with the carrier held far enough away from the vehicle so that the couplings are not touching.

d. A manually operated gear-driven system translates the locking device and four corner guide pins to maintain the ground carrier in alignment with the vehicle carrier while the carrier and all couplings are engaged simultaneously.

e. A spring counterbalanced boom system provides support of the dead weight of the ground carrier, couplings, and attached hoses during manual engagement of the buide pins and collet locking device.

f. The counterbalanced boom also supplies pneumatically derived forces to retract the ground carrier away from the vehicle after collet release and carrier ejection. Ejection is by pneumatic cylinders in the carrier guide pins.

g. The couplings have individual debris protection poppets to limit the contamination from particles borne by the air to the immediately accessible portion of the disconnect for ease in refurbishment.

The detail design goal has been to reduce the time required to engage and verify all of the Space Shuttle umbilicals to an elapsed time of less than one hour, while at the same time reducing the number of personnel required to a minimum.

SECTION 1

INTRODUCTION

This document reports the activities of a technology study conducted by the Convair Aerospace Division of General Dynamics Corporation (GDCA) and funded by the Kennedy Space Center of the National Aeronautics and Space Administration (NASA KSC). This study contract, NAS10-7702, was entitled Umbilical Connect Techniques Improvement, and covered the period from 1 July 1971 through 1 May 1972.

The stated objective of this study was to develop concepts, specifications, designs, techniques, and procedures capable of significantly reducing the time required to connect and verify umbilicals for ground services to the space shuttle. The desired goal was to reduce the current time requirement of several shifts for the Saturn V/ Apollo to an elapsed time of less than one hour to connect and verify all of the space shuttle ground service umbilicals.

The study plan for this task was divided into four phases:

- Literature and Hardware Examination
- Concept Development
- Concept Evaluation and Tradeoff Analysis
- Selected Concept Design

The literature and hardware examination phase consisted of detailed reviews of drawings, specifications, procedures, unsatisfactory condition reports, and hardware. Primary emphasis was placed on Saturn IB/Apollo, Saturn V/Apollo, Atlas/Centaur, and Titan IIIC. In addition, interviews were conducted with operations personnel directly associated with umbilical hardware on the above mentioned programs.

These reviews were conducted with the purpose of understanding the good and bad features of current and past umbilical hardware. With this understanding, the following three phases of the program were enhanced. The results of these reviews are presented in tabular format in Section 3, Literature and Hardware Review.

The concept development phase generated candidate umbilical concepts for the following categories of components, subsystems, and handling systems:

- Couplings
  - Cryogenic
  - High Pressure Pneumatic and Hydraulic
  - Low Pressure Pneumatic, H_2O Glycol and JP-5

- Locking and Release Devices
- Engaging Mechanisms
- Electrical Connectors
- Booster Umbilical Carriers
- Booster Umbilical Handling Concepts (3)
- Orbiter Umbilical Handling Concepts (3)

In order to provide a baseline for these concepts, a requirements document was prepared based on the North American-Rockwell/General Dynamics - Convair Space Shuttle configuration that was current as of the beginning date of the study contract. The particular vehicle designators used were B9U for the booster, and 161C for the orbiter. One of the initial program ground-rules established was that this study plan would not respond to perturbations or variations in space shuttle evolving configurations.

The requirements further reflect a narrowing of scope to a consideration of only a fuel (LH_2) umbilical disconnect panel for the B9U booster and an integrated preflight umbilical disconnect panel (including both LO_2 and LH_2) for the 161C orbiter. While the handling and carrier concepts were generated for these two applications only, other applications and transferability of results were kept in mind to avoid deadended configurations.

The particular umbilical requirements which were generated for use are presented in Section 2, Requirements for Servicing Disconnect Concepts. The candidate concepts generated for evaluation are presented in Section 4, Concept Development. The concepts presented do not contain detail dimensions or analyses. They were developed only to the extent necessary to allow evaluation and tradeoff.

The concept evaluation and tradeoff analysis phase examined the various concepts generated in the concept development phase. This comparison was accomplished in matrix fashion by establishing the evaluation parameters (criteria) and weighting factors. Each of the concepts were evaluated on a comparative basis and the evaluation factors were totaled to arrive at final recommendations for the concepts. The results of this analysis are presented in Section 5, Concept Evaluation and Tradeoff Analysis.

Section 6, Selected Concept Requirements Definition provides a summary of the evaluation factors determined in Section 5, and indicates the various concepts selected for more detailed design. This summary illustrates the optimum design features that should be attained in the design. This section also provides an amplification of the salient features of each of the selected concepts. While this report does not contain the detail design drawings completed during the selected concept design phase, Appendices A and B list the numbers of the drawings which are available under separate cover. Appendix C contains pretinent calculation sheets.

GDCA was assisted in this study effort by the Florida Operations of Chrysler Corporation under Subcontract Number PO-70-00004. This subcontract covered the same period as the NASA KSC study contract.

SECTION 2

REQUIREMENTS FOR SERVICING DISCONNECT CONCEPTS

2.1 BOOSTER SERVICING DISCONNECT PANEL REQUIREMENTS

The services required in a typical booster fuel servicing disconnect panel are presented inTable 2-1.

Table 2-1. Servicing Disconnect Panel Requirements

Item No.	Description	Nominal Size	Nominal Operating Conditions
1	LH_2 Fill and Drain	10 in.	90 psig
2	Hydrocarbon Fuel Fill and Drain	2 - 3 in.	150 psig
3	GH_2 Fill (attitude Propulsion System Accumulator & Prepressurization)	1 in.	1000 psig
4	GH_e Fill	1 in.	3700 psig
5	GN_2 Ground Purge Vehicle Cavities	4 in.	150 psig
6	Electrical Ground Power LH_2 Recirculation	- -	24 kW 115V 400 Hz 3 phase
7	Data Bus	12 - No. 12	
8	Electrical Ground Power Avionics	- -	40 kW 115V 400 Hz 3 phase
9	Hydraulic Pressure	2 in.	2300 psig
10	Hydraulic Return	2 in.	2300 psig

2.2 BOOSTER DESIGN REQUIREMENTS

The following are design requirements that apply to a typical booster fuel servicing disconnect panel:

a. Temperature. (maximum, during boost and reentry). Base heat shield area = 2210°R; tail area, fuselage above wing = 1110°R.

b. Redundancy. After lift-off initiation - Fail Operational/Fail Operational for critical functions. Prior to liftoff - Fail Operational/Fail Safe with failure detection.

c. Alignment. Uncertainty in location and alignment of airborne disconnects with respect to fixed launcher base prior to umbilical system engagement, ± 2.0 inches and ± 1/2 degree in any direction.

d. Relative Motion. Movement of the airborne disconnects with respect to the fixed launcher base after system engagement and during transport, wind, propellant loading, engine start and cutoff, ± 1.0 inch in any direction. This amount of relative motion is based on the baseline B9U booster configuration with a short, stiff load path between the airborne umbilical carrier and the booster holddown and release arms. The holddown arms and the support pedestal also are stiff structures. It is recognized that other booster configurations might result in a requirement to accommodate larger relative motions. Accommodating these larger values can easily be done simply by scaling up the length of the disconnects and allowing greater sidewise freedom in the parallelogram linkage for the panel carrier.

e. Disconnect pressures. Internal fluid pressure and electrical power removed before disconnect. (Except for hydraulic disconnects.)

f. Leakage. Provide leak detection of primary dynamic seals. Provide disposal of H_2 and JP dynamic seal leakage.

g. Icing. Cryogenic connector critical areas shall be protected to prevent icing. This may be accomplished either by insulating the coupling adequately to raise the exterior surface temperature above the freezing point of the water vapor condensate, by purging the cold surfaces with an inert, dry, and non-condensable gas (such as nitrogen or helium), or a combination of these. The intent of this requirement is to avoid the build-up of an accumulation of solid ice which has a tendency to prevent coupling or carrier separation. It is further intended that none of the couplings/carriers will require reconnect shortly after ejection. It is therefore not required to prevent ice build-up on a coupling/carrier after ejection.

h. Purges. Provide inert environment in electrical connector.

i. Reusability. Provide heat and debris protection. Debris valves are not required to provide fluid shutoff function.

j. Ease of connection and verification. Provide the design features necessary to allow the fuel servicing disconnect panel to be engaged and verified in less than one hour and with a minimum of operating personnel. Verification includes a visual check of the proper engagement, a leak check of all fluid and pneumatic couplings and a continuity and contact resistance check for electrical connectors.

2.3 ORBITER SERVICING DISCONNECT PANEL REQUIREMENTS

The services required in a typical orbiter integrated umbilical carrier are presented in Table 2-2.

Table 2-2. Typical Orbiter Integrated Umbilical Carrier Coupling Requirements

Item No.	Description	Nominal Size (in.)	Nominal Operating Conditions (psig)
1	Power Generating System (PGS) LH_2 Vent No. 1	2	5
2	PGS LH_2 Vent No. 2	2	5
3	PGS LH_2 Fill No. 1	1	30
4	PGS LH_2 Fill No. 2	1	30
5	Fuel Cell (FC) GH_2 Purge Vent	1	5
6	JP-5 Fill	2	90
7	JP-5 Tank Pressure	1	150
8	FC H_2O Vent	1/2	5
9	Environmental Control/Life Support System (EC/LSS) Primary Heat Exchanger (PHX) Supply (H_2O/Glycol)	1	150
10	EC/LSS PHS Return	1	150
11	PGS LO_2 Vent No. 1	1	5
12	PGS LO_2 Vent No. 2	1	5
13	PGS LO_2 Fill No. 1	1	150
14	PGS LO_2 Fill No. 2	1	150
15	GO_2 Vent Aux Prop System Accumulator	1	150
16	GH_e Fill	1	3500
17	FC GO_2 Purge Vent	1/2	5
18	FC GO_2 Purge Vent	1/2	5
19	EC/LSS SHX Supply	1	150
20	EC/LSS SHX Return	1	150

2.4 ORBITER DESIGN REQUIREMENTS

The following are design requirements that apply to a typical orbiter integrated umbilical carrier:

a. Temperature. The maximum thermal protection system skin temperature expected during boost and reentry is approximately 1110°R.

b. Redundancy. After lift-off initiation (In-flight disconnect) fail operational/fail operational for critical functions. Prior to lift-off (pre-flight disconnect) fail operational/fail safe with failure detection.

c. Alignment. Uncertainty in location and alignment of airborne disconnects with respect to swing-arm structure prior to umbilical carrier engagement, ± 3.0 inches and ± 2 degrees in any direction.

d. Relative motion. Movement of the airborne disconnects with respect to the swing-arm structure after umbilical carrier engagement and during transport, wind, and propellant loading: ± 10 inches in either horizontal direction, + 2 inches up and -8 inches down.

e. Disconnect pressures. Internal fluid pressure removed before disconnect.

f. Leakage. Provide leak detection of primary dynamic seals. Provide disposal of hazardous cynamic seal leakage.

g. Icing. Cryogenic connector critical areas shall be protected to prevent icing.

h. Purges. Provide purges to separate carrier compartments to provide effective separation of couplings carrying incompatible fluids and gases.

i. Insulation. Cryogenic connectors (LH_2) shall be insulated to prevent the formation of liquid air.

j. Reuseability. Provide heat and debris protection. Debris valves are not required to provide fluid shutoff function.

k. Ease of connection and verification. Provide the design features necessary to allow the integrated umbilical carrier to be engaged and verified in less than one hour and with a minimum of operating personnel. Verification includes a visual check of the proper carrier locking and engagement and a leak check of all fluid and pneumatic connectors.

SECTION 3

LITERATURE AND HARDWARE REVIEW

A literature and hardware review was conducted and is contained herein as Tables 3-1 through 3-7. This data is self-explanatory and considered adequate as presented, therefore, very little effort was made to amplify on it.

The data presented in Tables 3-1 through 3-5 represents hardware design considerations and reflects input from visual hardware examination, drawing and specification reviews, as well as discussions with NASA KSC launch operations personnel. Table 3-6 presents the rationale used to determine the useability for the Space Shuttle of the hardware listed in Tables 3-1 through 3-5. The data contained in Table 3-7 represents installation and checkout procedure considerations and reflects input from written procedure reviews as well as discussions with NASA KSC launch operations personnel. Field trips were taken to launch complexes 36A and 36B (Atlas/Centaur) and 40 and 41 (Titan 3C) to discuss umbilical disconnect hardware and procedures.

An unsatisfactory condition report (UCR) summary tabulation for umbilical carriers and fluid couplings was derived from a review of data recorded since October of 1966 for Saturn IB and Saturn V vehicles and ground support equipment (GSE). This tabulation is presented in Table 3-8. The recorded data lists defects and/or failures classified as one of seven types. Each type is depicted in a separate column. The seven types of defects/failures are: malfunction, material, documentation, assembly, damage, contamination, and dimensional. The parameters of each are as follows:

a. Malfunction. Leakage, failure of poppet to close, or failure of coupling to function properly.

b. Material. Material defect, expired life limitation of component, or expired cure data of seal material.

c. Documentation. Cure date missing, name plate missing, quality control paperwork missing, or record of previous usage not attached.

d. Assembly. Incorrect assembly of component by manufacturer.

e. Damage. Damage incurred by component during fabrication, assembly, handling, or usage.

f. Contamination. Component was contaminated when received from vendor or after usage. Has resulted in damage to component in many cases.

g. Dimensional. Component parts out of tolerance.

A total of 275 defect/failure reports are included in the tabulation. The majority are minor in nature. However, many are repetitive to the extent that during review and tabulation of the data it becomes quite evident that improvements are mandatory in certain areas to assure more efficient, economical, and reliable operations. The discrepancies considered most serious are described in the following paragraphs.

Contamination of most of the fluid couplings has been a repetitive defect both upon receipt from the vendor and in use, and has often resulted in damage to sealing surfaces. The internal configuration of some couplings has provided a trap for foreign particles, particularly under seals, thus resulting in seal leakage. Good initial cleaning and handling procedures and conformance to packaging specifications along with proper quality control are obvious methods for preventing contamination. Attention should also be directed toward internal design configurations that minimize contamination traps. The simplest design with the fewest parts, particularly moving parts, will provide a better coupling design.

A large number of defects are attributed to the method of assembly. Positive retention of all component parts is of prime importance. Staking of retainer rings for retention has been a problem area for a significant number of couplings and is not considered a satisfactory method of retention.

The number of scratched and damaged sealing surfaces appearing as defects are attributed to two primary causes. One is adequate protection during handling and the other is a design configuration that allows the sealing surface to contact another metal surface during mating of the coupling halves, possibly due to misalignment. A coupling design that prevents contact of the sealing surface against another metal surface during mating and requires minimum engagement will preclude most damage.

Table 3-1. Umbilical Carriers

TYPE	P/N & MFR.	USED ON	LOCKING DEVICE	RELEASE & EJECTION	SERVICES NUMBER & SIZE	SIZE & WT. APPROX.	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE FOR SHUTTLE
MULTIPLE INTEGRATED LOCKED TO VEH.	75M02840 75M02841 KSC	S-IB AFT SCM 2 & 4	BALL LOCK	MECH CAM RELEASE WITH SPRING EJECTION, ACTUATION BY VEHICLE LIFTOFF	. 8-SHELL SIZE #40 ELECT. CONN. . 8-PNEU CONN. 1/4, 3/8 & 1/2	15 X 15 X 5 WT. 10 LBS WITHOUT CONNECTORS	. LIGHT WEIGHT . EASE OF MATING . SIMPLICITY . MIN. ADJUSTMENT . MIN. MAINTENANCE . REUSABLE, HIGHLY RELIABLE . DESIGNED FOR HIGH "G" VIBRATION LEVELS . LOW DISCONNECT FORCE . MIN. ENGAGEMENT . SUPPORTED BY MAST . NO ADDITIONAL EQUIPMENT REQUIRED FOR INSTALLATION	. DISCONNECTS PERPENDICULAR TO VEHICLE MOTION . CONNECTORS MUST BE REMOVED BEFORE CARRIER INSTALLATION . NOT SUITABLE FOR AUTO CONNECT	CARRIER MATED TO VEHICLE WITH ELECT. & PNEU. CONN. REMOVED. CONNECTORS THEN MATED INDIVIDUALLY. EXCESSIVE TIME REQUIRED FOR MATING TO VEHICLE; HOWEVER ONLY APPROX. 1 HOUR.	POSSIBLY, IF SEPARATE UMBILICALS USE FOR PROPELLANTS.
MULTIPLE INTEGRATED LOCKED TO VEH.	75M02049 KSC 65B64005 KSC	S-IB FWD S-IC FWD	BALL LOCK	. PRIMARY SYS PNEU RELEASE PNEU CYLINDER EJECTION . SECONDARY SYS MECH CAM HYD CYLINDER ACTUATED . REDUNDANT SYS MECH CAM STATIC LANYARD ACTUATED	. 8-SHELL SIZE #40 ELECT. CONN. . 8-PNEU CONN. 1/4, 3/8 1/2 & 3/4 . 2 - 4" DIA ECS CONN	15 X 30 X 5 WT. 57 LBS	. LIGHT WEIGHT . EASE OF MATING . SIMPLICITY . MIN. ADJUSTMENT . MIN. MAINTENANCE . REUSABLE . HIGHLY RELIABLE . DESIGNED FOR HIGH "G" VIBRATION LEVEL . LOW DISCONNECT FORCE . MIN. ENGAGEMENT . NO ADDITIONAL EQUIPMENT REQUIRED FOR INSTALLATION	. DISCONNECTS PERPENDICULAR TO VEHICLE MOTION . CONNECTORS MUST BE REMOVED BEFORE CARRIER INSTALLATION . NOT ADAPTABLE FOR AUTO CONNECT		NO
MULTIPLE INTEGRATED LOCKED TO VEH.	8037-820030 MSC NAR	S-IB S.M. SAT 5 S.M.	BALL LOCK	. PRIMARY SYS PNEU RELEASE PNEU CYLINDER EJECTION . SECONDARY SYS MECH CAM HYD CYLINDER ACTUATED . REDUNDANT SYS MECH CAM STATIC LANYARD ACTUATED	. 4-SHELL SIZE #40 ELECT CONN. . 6-PNEU CONN 1/4, 3/8 & 3/4 . 1 - 4" DIA ECS CONN	12 X 24 X 5 WT. 25 LBS	. LIGHT WEIGHT . EASE OF MATING . SIMPLICITY . MIN. ADJUSTMENT . MIN. MAINTENANCE . REUSABLE . HIGHLY RELIABLE . DESIGNED FOR HIGH "G" VIBRATION LEVEL . LOW DISCONNECT FORCE . MIN. ENGAGEMENT . NO ADDITIONAL EQUIPMENT REQUIRED FOR INSTALLATION	. DISCONNECTS PERPENDICULAR TO VEHICLE MOTION . CONNECTORS MUST BE REMOVED BEFORE CARRIER INSTALLATION . NOT ADAPTABLE FOR AUTO CONNECT		NO
MULTIPLE INTEGRATED LOCKED TO VEH. (TWO UMBILICAL HOUSINGS MOUNTED IN ONE CARRIER, S-IVB-B FWD & I.U.)	S-IVB FWD 1A77953 I.U. 11Z00001 MSFC MAC/DAC	SAT. IB SAT. 5	BALL LOCK	. PRIMARY SYS PNEU RELEASE PNEU CYLINDER EJECTION . SECONDARY SYS MECH CAM HYD CYLINDER ACTUATED . REDUNDANT SYS MECH CAM STATIC LANYARD ACTUATED	I.U. . 16-SHELL SIZE #40 ELECT CONN . 6-PNEU CONN 1/4, 3/8 & 3/4 . 1 - 6" DIA ECS CONN S-IV-B FWD . 8-SHELL SIZE #40 ELECT CONN . 1 - 8" DIA GH2 VENT	23 X 72 X 5 WT. 240 LBS	. REUSABLE . HIGHLY RELIABLE . DESIGNED FOR HIGH "G" VIBRATION LEVEL . LOW DISCONNECT FORCE . MIN. ENGAGEMENT . NO ADDITIONAL EQUIPMENT REQUIRED FOR INSTALLATION	. DISCONNECTS PERPENDICULAR TO VEHICLE MOTION . CONNECTORS MUST BE REMOVED BEFORE CARRIER INSTALLATION . LARGE SIZE . ADJUSTMENTS REQUIRED FOR UMB. HOUSING ALIGNMENT		NO
MULTIPLE INTEGRATED LOCKED TO VEH.	65B80001 MSFC BAC 65B80002 MSFC BAC 65B80003 MSFC BAC	TSM #1 S-IC	LOCKING FINGERS (COLLET)	MECH CAM RELEASE PNEU EJECTION	. 8-SHELL SIZE #40 ELECT CONN . 11-PNEU, HYD & CRYOGENIC CONN . 1 - 6" DIA LOX CONN . 8-SHELL SIZE #40 ELECT CONN . 10-PNEU, HYD & CRYOGENIC CONN . 1 - 6" DIA LOX CONN . 10-PNEU CONN . 2 - 4" DIA ECS CONN	24 X 28	. REUSABLE . RELIABLE	. NOT ADAPTABLE FOR AUTO CONNECT . CRITICAL ADJUSTMENT RE'QMTS. . INSUFFICIENT SPACE BETWEEN CONNECTORS AND ACTUATING MECHANISM FOR EASE OF CONNECTION . EXCESSIVE WEIGHT . NOT EASILY MAINTAINED . UNNECESSARILY COMPLEX . EXCESSIVE TIME REQUIRED FOR CONNECTION AND ADJUSTMENT	CARRIER MATED TO VEHICLE WITH CONNECTORS REMOVED, ADJUSTMENTS MADE, THEN CONNECTORS INSTALLED.	NO

Table 3-1. Umbilical Carriers (Cont)

TYPE	P/N & MFR.	USED ON	LOCKING DEVICE	RELEASE & EJECTION	SERVICES NUMBER & SIZE	SIZE & WT. APPROX.	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE FOR SHUTTLE
INDIVIDUAL LOCKED TO VEH.	G7-820065 MSFC NAR G7-820064 MSFC NAR	S-II SAT. 5	BALL LOCK	PRIMARY SYS PNEU. RELEASE SECONDARY SYS MECH RELEASE LANYARD ACTUATED	1 - 8" DIA LOX CONN 1 - 8" DIA LH2 CONN	21 X 72 250#	REUSABLE RELIABLE	. NOT ADAPTABLE FOR AUTO CONNECT . EXCESSIVE WEIGHT	MANUAL INSTALLATION	NO
INDIVIDUAL RISE OFF	75M02130 KSC 75M02129 KSC	S-IB AFT	NONE (COMPRESSION SEAL)	VEHICLE MOTION (LIFT OFF) RETRACTED BY PNEU. CYLINDER	1 - 6" DIA LOX CONN 1 - 6" DIA RP-1 CONN	100#	. EXTREME RELIABILITY . CAPABILITY FOR REMOTE AUTO RECONNECT . MINIMUM ADJUSTMENT REQ'D . WEIGHT SUPPORTED BY MAST		SEMI-AUTO CONNECT	NO, INCREASE I SIZE TO 10" DI PIPE AND CONNECTOR AND CHANGE IN DESIGN CONCEPT OF MATING VEH PART COULD ADAPT THE BASI CONCEPT.
INDIVIDUAL RISE OFF LOCKED TO VEH.	75M02882 KSC	S-IB AFT	LOCKING FINGERS	VEHICLE MOTION ACTUATED MECH. LINKAGE RELEASE	4 - 6" DIA AIR/H20 CONN	20#	. RELIABLE . SIMPLICITY	NOT ADAPTABLE FOR AUTO CONNECT	MANUALLY RETRACT LOCK RING, ENGAGE COUPLING, RELEASE LOCK RING.	NO
MULTIPLE RISE OFF	27-20418	ATLAS	NONE	VEHICLE MOTION (LIFT OFF)	1/4 PNEU (3) 3/8 PNEU 1/2 PNEU 3/4 PNEU 1" HYDR (2)	20#	. HIGHLY RELIABLE . REUSABLE . MIN. ADJUSTMENTS . ADAPTABLE FOR AUTO CONNECT . LIGHT WEIGHT . SIMPLICITY . PROVIDES FOR VEHICLE DEFLECTIONS . LAUNCHER SUPPORTED		INSTALLED MANUALLY IN USE AT AFETR. ALIGNED AND CONNECTED SIMULTANEOUSLY AS MISSILE MATED WITH ERECTOR FOR FIELD USE.	BASIC CONCEPT ADAPTABLE. NO SUITABLE IN PRESENT CONFIGURATION.
MULTIPLE INTEGRATED LOCKED TO VEH.	1A74896 MSFC MAC/DAC	SAT. IB S-IV-B AFT SAT. 5 S-IV-B AFT	DOUBLE BALL LOCK	. PRIMARY SYS PNEU RELEASE PNEU CYLINDER EJECTION . SECONDARY SYS MECH CAM HYD CYLINDER ACTUATED . REDUNDANT SYS MECH CAM STATIC LANYARD ACTUATED	. 6-SHELL SIZE #40 ELECT CONN . 14-PNEU CONN 1/4, 3/8, 1/2 & 3/4 . 1 - 10" DIA ECS CONN . 2 - 4" DIA LOX & LH2 FILL COUPLINGS	44-1/2 X 57 X 12 WT. 300 LBS	. REUSABLE . HIGHLY RELIABLE . DESIGNED FOR HIGH "G" VIBRATION LEVEL . LOW DISCONNECT FORCE	. DISCONNECTS PERPENDICULAR TO VEH. MOTION . CONNECTORS MUST BE REMOVED BEFORE CARRIER INSTALLATION . LARGE SIZE & HEAVY WEIGHT . NOT ADAPTABLE FOR AUTO CONNECT	CARRIER MATED TO VEHICLE WITH SERVICE CONNECTORS REMOVED. SERVICE CONNECTORS THEN MANUALLY CONNECTED INDIVIDUALLY. LH2 COUPLING INSULATED AFTER CONNECTION. EXCESSIVE TIME REQUIRED.	NO
MULTIPLE INTEGRATED LOCKED TO VEH.	G7-820041 MSFC NAR	SAT. 5 S-II AFT	DOUBLE BALL LOCK	. PRIMARY SYS PNEU RELEASE PNEU CYLINDER EJECTION . SECONDARY SYS MECH CAM PNEU CYLINDER ACTUATED . REDUNDANT SYS MECH CAM STATIC LANYARD ACTUATED	. 12-SHELL SIZE #40 ELECT CONN . 28-PNEU CONN 1/4, 1/2, 3/4, 1 & 1-1/2 . 1 - 12" DIA ECS CONN . 1 - 4" DIA ECS CONN	71-1/2 X 79 X 12 WT. 500 LBS.				NO
MULTIPLE INTEGRATED LOCKED TO VEH.	G7-820042 MSFC NAR	SAT. 5 S-II FWD	DOUBLE BALL LOCK	. PRIMARY SYS PNEU RELEASE PNEU CYLINDER EJECTION . SECONDARY SYS MECH CAM PNEU CYLINDER ACTUATED . REDUNDANT SYS MECH CAM STATIC LANYARD ACTUATED	. 8-SHELL SIZE #40 ELECT CONN . 13-PNEU CONN 1/4, 1/2, 3/4, 1 & 1-1/2 . 2 - 7" DIA LH2 VENT CONN . 1 - 4" DIA ECS CONN	65 X 72 X 12 WT. 499 LBS.				NO

Table 3-1. Umbilical Carriers (Contd)

TYPE	P/N & MFR.	USED ON	LOCKING DEVICE	RELEASE & EJECTION	SERVICES NUMBER & SIZE	SIZE & WT. APPROX.	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE FOR SHUTTLE
MULTIPLE, LOCKED TO VEH.	65B80036 MSFC BAC	SAT. 5 S-IC INT.	INTERNAL PAWLS	. PNEU RELEASE . PNEU RETRACT	2 - 6" DIA LOX CONN	15 X 31 WT. 150 LBS.	. REMOTE RECONNECT CAPABILITY AFTER INITIAL MATING ADJUSTMENTS . CONTAINS REMOTE CONTROLLED SELF VERIFICATION OF CORRECT MATING	. EXCESSIVE WEIGHT OF SUPPORT AND ACTUATING MECHANISM. . EXCESSIVE INITIAL CRITICAL ADJUSTMENTS REQUIRED WITH CLOSE TOLERANCES		NO
INDIVIDUAL, LOCKED TO VEH.	55-06274 GD/A GRAY & BULEGUARD 676-440	CENTAUR	LOCKING DOGS	. PRIMARY SYS ELECT RELEASE SPRING EJECT . SECONDARY SYS LANYARD RELEASE SPRING EJECT	1 ELECTRICAL CONN	3.82 DIA. WT. 3 LBS.	. LIGHTWEIGHT . RELIABLE	NOT ADAPTABLE FOR AUTO CONNECT.	MANUAL, 90# PUSH TO CONNECT.	NO
INDIVIDUAL, LOCKED TO VEH.	GD/C 27-06172 GRAY & BULEGUARD 562-700	ATLAS	COLLET	. ELECT. SOLENOID PIN RELEASE, SPRING LOADED EJECT . LANYARD BACKUP	1 ELECT. CONN. OF 140 #16 PINS.	6" DIA. X 12" LONG WT. 40#	. RELIABLE	NOT ADAPTABLE FOR AUTO CONNECT. HEAVY.	MANUAL	NO
INDIVIDUAL, LOCKED TO VEH. MATES WITH CANNON RECEPTACLE 017070 VEH. PART.	GD/A 27-04992 CANNON 017069-1239 CANNON 017069-1240 CANNON 017069-1241 CANNON 017069-1042 CANNON 017069-1043 CANNON 017069-1044	ATLAS	COLLET	. ELECT. SOLENOID RELEASE, SPRING EJECT . LANYARD BACKUP	1 ELECT. CONN, UP TO 124 - #16 CONTACTS, PIN & SOCKET, DEAD FACE TYPE.	3.6" X 6.2" WT. 9.5#	. LIGHT WEIGHT, RELIABLE . PROVIDES DEAD FACE OF EXPOSED CONNECTOR FOR VEHICLE AND GROUND PART . EXPOSED DEAD FACE PLATE CONTAINING CONTACTS IS EASILY REPLACED . CONTACTS GOLD PLATED	NOT ADAPTABLE FOR AUTO CONNECT.	MANUAL. ENGAGE COLLET AND TORQUE BY HAND TO MATE CONNECTOR.	NO ELECT. CONN. CONTAINED IN THIS CARRIER IS SUITABLE.
INTEGRATED, LOCKED TO VEH.	CANNON GM100124-5	POLARIS	CAM LOCK	LANYARD, CAM LEVER RELEASE, SPRING EJECT	1 - ELECT. CONN. OF 104 CONTACTS 2 - 1/2 H20 CONNECTORS	5" X 8" WT. 10#	LIGHT WEIGHT, RELIABLE, DEAD FACE CONNECTOR.	NOT ADAPTABLE FOR AUTO CONNECT.	MANUAL	NO ELECT. CONN. SUITABLE

Table 3-2. Cryogenic Couplings

TYPE	USED ON	MFR. & P/N	SIZE	SEALS & MATERIAL	SELF SEALING (POPPETS)	OPR. PRESS. PSI	MEDIA	RETAINING METHOD	RELEASE & EJECTION	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE FOR SHUTTLE
BALL & CONE	S-IB FILL S-IVB FILL LO2 S-II FILL LH2 & LOX S-II VENT S-IC FILL S-IV FILL S-IVB LH2 VENT S-IB REPLEN. JUPITER S-IVB FILL LH2	KSC 75M00253 MSFC/DAC 1A49970 MSFC/NAR ME144-0005 ROYAL IND. MSFC/NAR ME273-0017 ROYAL IND. MSFC/BAC 65B80103 KSC MSFC/DAC 1A48848 KSC 10425257 KSC MSFC/DAC 1A49978	6" 4" 8" 7" 6" 3" 8" 3" 1" 4"	PRESSURE LOADED RING SEAL, TEFLON	NONE (DEBRIS VALVE)	0 TO 150	LO2 LN2 LH2 GH2 VENT	CARRIER, MAST, OR EXTERNAL BALL LOCK	CARRIER, PNEU. ACT., RISEOFF	. NO DISCONNECT FORCE REQ'D . SELF ALIGNING . LIGHTWEIGHT . EASILY ADAPTABLE FOR AUTOMATED CONNECT . HIGHLY RELIABLE . SIMPLICITY . REUSABLE . MIN. ADJUSTMENT REQ'D . NO DETRIMENTAL EFFECTS FROM VIBRATION . MIN. ENGAGEMENT	. TENDS TO LEAK WHEN FIRST INSTALLED. SPRING FORCE OF BELLOWS CAUSES COLD FLOW OF TEFLON SEAL & SMOOTHES MINUTE IMPERFECTIONS AND SCRATCHES IN SEAL SURFACES THUS PROVIDING EXCELLENT SEAL AFTER EXTENDED TIME. WITH SHORT SHUTTLE TURN-AROUND, LEAKAGE COULD BE A PROBLEM. . THRUST LOAD FROM BELLOWS DUE TO MEDIA PRESSURE IMPOSES HIGH LOADS ON CARRIER LOCKING DEVICE FOR LARGER SIZES. . INSULATION REQ'D TO PREVENT AIR LIQUEFACTION WHEN USED WITH LH2.	MINIMUM TIME REQ'D. SOME HANDLING DIFFICULTIES ENCOUNTERED WITH LARGE VJ FLEX HOSES ATTACHED. S-IC INTERTANK COUPLINGS AND CARRIER HAVE REMOTE RECONNECT CAPABILITY, HOWEVER CRITICAL ADJUSTMENTS ARE REQUIRED FOR INITIAL CONNECTION. COUPLINGS USED IN CARRIERS ARE REMOVED FROM CARRIER PRIOR TO CARRIER MATING TO VEHICLE AND THEN CONNECTED. S-IB LOX FILL MAST COUPLING-MAST REQUIRES MINOR INITIAL ADJUSTMENT THEN HAS CAPABILITY FOR REMOTE SEMI-AUTOMATIC RECONNECT.	YES
PRESSURE BALANCED, VACUUM JACKETED, BAYONET	NERVA TESTING	LASL P/N UNKNOWN	8"	LIP SEALS, TEFLON	NONE	0 TO 900	LH2	CARRIER	CARRIER, HYDR. ACT.	. MEDIA PRESSURE IMPOSES NO SEPARATION FORCES . ADAPTABLE TO AUTOMATED CONNECT . NO ADDITIONAL INSULATION REQ'D	LENGTH OF ENGAGEMENT. NEEDS ADDITION OF TEFLON GUIDE RINGS TO PREVENT SCORING OF SEALING SURFACES OR HARDENING OF EITHER SURFACE.	MIN. TIME REQ'D. AUTOMATICALLY CONNECTED BY REMOTE OPERATION.	YES
BAYONET, VACUUM JACKETED	CENTAUR	AEROFLEX 55-21600	3/4"	LIP SEAL, KEL-F	NONE	0 TO 40	LHe	CARRIER	CARRIER	NO ADDITIONAL INSULATION REQ'D	SEPARATION FORCE DUE TO MEDIA PRESS. IMPOSES LOAD ON CARRIER LOCKING DEVICE. PRESENTS ALIGNMENT PROBLEMS FOR AUTOMATED CONNECT.	MIN. TIME REQ'D.	YES
SELF LOCKING SLIP COUPLING	S-IV GH2 VENT	STRATOS	8"	LIP SEAL, KEL-F	YES	0 TO 25	GH2 VENT	SPLIT RING & COLLET	PNEU. ACT. & LANYARD REDUNDANT	LIGHTWEIGHT AND EASILY HANDLED	REPEATED FAILURES IN USE. PNEU. RELEASE & PUSH-OFF CYLINDERS FAILED. POPPET FAILED TO CLOSE. INSULATION REQUIRED. FAILS DUE TO ICE FORMATION. NOT SUITABLE FOR AUTOMATED CONNECT.	ALIGNMENT CRITICAL AND DIFFICULT TO ATTAIN.	NO
SELF LOCKING SLIP COUPLING	JUPITER	CHRYSLER	6"	LIP SEAL, KEL-F	NONE	0 TO 150	LO2	LOCKING DOGS, CAM ACTION	PNEU. ACT.	GOOD SEALING FEATURES.	CRITICAL AXIAL ALIGNMENT REQ'D FOR CONNECT AND DISCONNECT. RELEASE MECHANISM NOT RELIABLE AT CRYOGENIC TEMPERATURES DUE TO SHRINKAGE. NOT SUITABLE FOR AUTOMATED CONNECT.	MAST MOUNTED, EASILY CONNECTED AFTER ALIGNMENT.	NO

Table 3-2. Cryogenic Couplings (cont)

TYPE	USED ON	MFR. & P/N	SIZE	SEALS & MATERIAL	SELF SEALING (POPPETS)	OPR. PRESS. PSI	MEDIA	RETAINING METHOD	RELEASE & EJECTION	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE FOR SHUTTLE
BAYONET (SLIP)	ATLAS	GD/C 27-80279	1-1/4"	LIP, KEL-F	NONE	0 TO 25	LH2	LAUNCHER SUPPORTED	RISEOFF	SIMPLICITY, FLOATING MOUNT FOR ALIGNMENT, INEXPENSIVE, NO MOVING PARTS, SINGLE SEAL. ALLOWS FOR VERTICAL VEHICLE DEFLECTIONS. LIGHTWEIGHT. EASILY MAINTAINED. ADAPTABLE FOR AUTO CONNECT.	LENGTH OF ENGAGEMENT EXCESSIVE FOR SHUTTLE REQUIREMENT.	SLIPS TOGETHER, FLOATING MOUNT MINIMIZES ALIGNMENT REQUIREMENTS.	YES
BAYONET (SLIP)	ATLAS	GD/C 27-29006	6"	LIP, KEL-F	DEBRIS VALVE ADJACENT	0 TO 90	LO2, RP-1	LAUNCHER SUPPORTED	RISEOFF	MINIMUM ENGAGEMENT. FLEXIBILITY PROVIDED BY BELLOWS. SIMPLICITY. GOOD SEALING FEATURES. ADAPTABLE FOR AUTO CONNECT.	HIGH CONNECT FORCE (125#) FOR MANUAL OPERATION.	MANUAL CONNECTION, SLIPS TOGETHER.	YES
SELF LOCKING	S-II	MSFC/NAR ME144-0011 ROYAL IND.	1"	LIP		1,250	GH2, GO2	LOCKING DOGS	CARRIER	NONE FOR SHUTTLE	SELF LOCKING FEATURE NOT CONSIDERED RELIABLE FOR SHUTTLE.	PUSH TO CONNECT, 70# FORCE REQUIRED.	NO
BAYONET (SLIP)	ATLAS INTERSTAGE	GD/C SPEC. 27-02248 ROYAL IND. 310722 310723	11"	LIP (SELF FORMING) KEL-F	FEMALE ONLY	117	LO2	VEHICLE STRUCTURE	INTERSTAGE SEPARATION	SIMPLICITY, PROVIDES SELF ALIGNMENT, MIN. ENGAGEMENT, LIGHTWEIGHT. HIGHLY RELIABLE, PROVEN THROUGH 300+ LAUNCHES. ADAPTABLE FOR AUTO CONNECT. BELLOWS COMPRESSION PROVIDES FOR VEHICLE DEFLECTIONS.	HIGH SEPARATION FORCE DUE TO MEDIA PRESSURE.	PUSH TO CONNECT.	YES
BOLTED FLANGE	CENTAUR	GD/C	4"	COMPRESSION	BOTH PARTS	100	LH2, LO2	BOLTS	LANYARD BREAKS NECKED-DOWN BOLTS IN TENSION	SIMPLE, RELIABLE	NOT ADAPTABLE FOR AUTO CONNECT. TORQUE VERIFICATION OF BOLTS.	BOLTED TO VEHICLE.	NO

Table 3-3. Pneumatic and Hydraulic Connectors

TYPE & SIZE	MFR. & P/N	USED ON	SEALS & MATERIAL	SELF SEALING (POPPETS)	OPR. PRESS. PSI	MEDIA	RETAINING METHOD	RELEASE & EJECT	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE SHUTTLE
SELF LOCKING BAYONET 1/4, 3/8, 1/2, 3/4, 1 1-1/4	WIGGINS 10001377	S-IB I.U. S-I JUPITER	O-RINGS BUNA-N	OPTIONAL	0 TO 3000 500	GN2 GHe GO2 AIR	LOCKING DOGS	CARRIER PNEU. ACT. WITH LANYARD BACKUP	. HIGHLY RELIABLE . NO LOADS IMPOSED ON CARRIER LOCKING DEVICE DUE TO MEDIA PRESSURE . CAN BE REFURBISHED . LOW DISCONNECT FORCE . SUITABLE FOR HIGH LEVEL VIBRATION	. NOT SUITABLE FOR SEMI-AUTOMATIC CONNECT . EXCESSIVE TIME REQ'D WHEN MULTIPLE CONNECTORS USED IN A CARRIER, DIFFICULT TO LEAK CHECK . NOT EASILY MAINTAINED	INSTALLED INDIVIDUALLY AFTER CARRIER INSTALLED	NO
PRESSURE BALANCED BAYONET 1/2 3/4 1 1-3/4 2	PUROLATOR 65B64001 65B64002 65B64003	S-IC	COMPATIBLE W/MEDIA	YES	0 TO 3300 3200 3300 1700 1500 2300	GN2 GHe NaNO2 in H2O RJ-1 RP-1 FREON 12 MILH 5606 LO2 (GO2)	CARRIER	CARRIER	. MAX. OF 1-1/4" ENGAGEMENT . REFURBISHABLE . LOW SEPARATION FORCES EXERTED ON CARRIER LOCKING DEVICE . LOW DISCONNECT FORCE . EASILY MAINTAINED . ADAPTABLE FOR AUTO CONNECT. CAPABLE OF DISCONNECT UNDER PRESS.	. LARGE DIA. & WEIGHT	INSTALLED INDIVIDUALLY AFTER CARRIER INSTALLED	YES
BAYONET 1/4 3/8 1	PUROLATOR 65B64001 65B64002 65B64003	S-IC	COMPATIBLE W/MEDIA	OPTIONAL	3300 750 1000	GN2 GHe	CARRIER	CARRIER	. MIN. ENGAGEMENT, 1-1/4" MAXIMUM . REFURBISHABLE . LOW DISCONNECT FORCE . ADAPTABLE FOR AUTO CONNECT	EXERT SEPARATION FORCE ON CARRIER LOCKING DEVICE DUE TO MEDIA PRESSURE	INSTALLED INDIVIDUALLY AFTER CARRIER INSTALLED.	YES
SELF LOCKING BAYONET 1/2 1/4, 3/8, 1/2	CALMEC 7851844 PUROLATOR 1449956	S-IVB	COMPATIBLE W/MEDIA	YES OPTIONAL	3100 3200	COLD GHe GHe, GH2 ETHY. GLYCOL	COLLET COLLET	CARRIER	. NO LOADS IMPOSED ON CARRIER LOCKING DEVICE DUE TO MEDIA PRESSURE . POSSIBLY ADAPTABLE FOR AUTO CONNECT	. EXCESSIVE TIME REQUIRED FOR INSTALLATION IN CARRIER . NOT EASILY MAINTAINED . NOT ADAPTABLE FOR AUTO CONNECT	INSTALLED INDIVIDUALLY AFTER CARRIER INSTALLED. RETAINED IN CARRIER BY PLATE & TWO SCREWS, EXCESSIVE TIME REQ'D FOR INSTALLATION	NO
1/4	PUROLATOR 7851823			YES	3100	GHe	COLLET					
3/4	CALMEC 7851861			YES	500	GHe	COLLET					
SLIP COUPLING, VAC. 1/4	PUROLATOR 1B41065			YES	5		CARRIER	CARRIER		LOW PRESS. CAPABILITY		
SELF LOCKING 1/2"	MSFC/NAR ME144-0010 SNAPTITE	S-II	COMPATIBLE W/MEDIA	YES	1000	GHe	BALL LOCK	CARRIER	NO SEPARATION LOADS EXERTED ON CARRIER	NOT SUITABLE FOR AUTOMATED CONNECT. BRINELLING. NOT EASILY MAINTAINED.	MANUAL, PUSH TO CONNECT. INSTALLED IN CARRIER AFTER CARRIER INSTALLED.	NO
BAYONET (SLIP) 1/4, 1/2, 3/4, 1, 1-1/2	MSFC/NAR ME273-0055 CONSOLIDATED CONTROLS	S-II	COMPATIBLE W/MEDIA	OPTIONAL	LOW	GHe	CARRIER	CARRIER	. LOW DISCONNECT FORCE . ADAPTABLE FOR AUTO CONNECT	LOW PRESS. DESIGN	MANUAL, INSTALLED INDIVIDUALLY IN CARRIER. PUSH TO CONNECT.	YES
BAYONET (SLIP) 4"	MSFC/NAR ME273-0016 ROYAL IND.	S-II	LIP	OPTIONAL	5	AIR, GN2 GHe	CARRIER	CARRIER	. MIN. ENGAGEMENT . ADAPTABLE FOR AUTO CONNECT	LOW PRESS. DESIGN	MANUAL, PUSH TO CONNECT.	YES

Table 3-3. Pneumatic and Hydraulic Connectors (cont)

TYPE & SIZE	MFR. & P/N	USED ON	SEALS & MATERIAL	SELF SEALING (POPPETS)	OPR. PRESS. PSI	MEDIA	RETAINING METHOD	RELEASE & EJECT	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE F SHUTTLE
BAYONET 1"	MSFC/NAR ME273-0013 ROYAL IND.	S-II		OPTIONAL		GHe	CARRIER	CARRIER	ADAPTABLE FOR AUTO CONNECT.	DUAL CONNECTIONS ON GROUND HALF.	PUSH TO CONNECT	NO
SELF LOCKING BAYONET 1/4"	GD/C 55-02126 WIGGINS	CENTAUR	LIP KEL-F-5500	OPTIONAL	0 TO 460	GHe	LOCKING DOGS	LANYARD	LOW DISCONNECT FORCE.	NOT EASILY MAINTAINED. NOT SUITABLE FOR AUTO CONNECT.	PUSH TO CONNECT MANUAL	NO
SELF LOCKING BAYONET 1/2", 3/4"	GD/C 55-08111 -1 THRU -23	CENTAUR	O-RING	YES	0 TO 3360	GHe	LOCKING DOGS	LANYARD	CAPABLE OF DISCONNECT UNDER PRESSURE	NOT SUITABLE FOR AUTO CONNECT. NOT EASILY MAINTAINED.	MANUAL PUSH	NO
BAYONET 1/2"	GD/C 55-08111 -25 THRU -31	CENTAUR	O-RING	NO	0 TO 3360	GHe	CARRIER	CARRIER	. CAPABLE OF DISCONNECT UNDER PRESSURE . LOW DISCONNECT FORCE . ADAPTABLE FOR AUTO CONNECT . HIGHLY RELIABLE	EXERTS SEPARATION FORCE ON CARRIER DUE TO MEDIA PRESSURE.	MANUAL PUSH	YES
	GD/C 55-02110 WIGGINS	CENTAUR	KEL-F- 50% 5500 50% 800	YES	0 TO 460	HYDROGEN PEROXIDE	LOCKING DOGS	LANYARD (RISEOFF)				NO
BAYONET (SLIP) 1"	GD/C 27-08557	ATLAS	O-RING	YES	500	HYDR. FLUID.	CARRIER	CARRIER (RISEOFF)	. ADAPTABLE FOR AUTOMATED CONNECT . SELF SEALING	MEDIA PRESSURE EXERTS LOAD ON CARRIER	MANUAL	YES
BAYONET (SLIP) 1/4	GD/C	ATLAS		NO	1000	GN2	CARRIER	CARRIER (RISEOFF)	. ADAPTABLE FOR AUTOMATED CONNECT, VERY LOW CONNECT AND DISCONNECT FORCE . PROVEN RELIABILITY	MEDIA PRESSURE EXERTS LOAD ON CARRIER	MANUAL INSERTION MIN. TIME REQ'D	YES
3/8	27-20416				1000							
1/2	27-20414				1000							
3/4	27-20415				1000							

Table 3-4. Electrical Connectors

TYPE	MFR. & P/N	USED ON	SIZE	SEALED AND/OR PURGED	RETAINING METHOD	RELEASE & EJECT METHOD	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE FOR SHUTTLE
PIN & SOCKET 74 - #20 CONTACTS 12 - #16 CONTACTS	GRAY & HULEGUARD 676-400 676-300 GD/C 55-06272 GD/C 55-06273	CENTAUR	2.40" DIA.	MIL-C-26500B NOT PURGED	LOCKING DOGS	LANYARD & SPRINGS	CRIMP-TYPE PINS LIGHTWEIGHT - 6# HIGHLY RELIABLE	NOT SUITABLE FOR AUTOMATED CONNECT	MANUAL, 90# MAX. FORCE FOR CONNECT OR DISCONNECT	NO
PIN & SOCKET 52 - #16 CONTACTS 1 - RG115U COAX	GRAY & HULEGUARD GD/C 55-06785 GD/C 55-06786	CENTAUR	3.00 DIA.	MIL-C-26500B NOT PURGED	LOCKING DOGS	LANYARD & SPRINGS	LIGHTWEIGHT - 6# HIGHLY RELIABLE	NOT SUITABLE FOR AUTOMATED CONNECT	MANUAL, 75# MAX. FORCE FOR CONNECT OR DISCONNECT	NO
PIN & SOCKET 140 #16 AND OTHER VARIATIONS. THIS IS VEHICLE PART THAT MATES WITH GD/C 27-06172, GRAY & HULEGUARD P/N 562-700 CARRIER	GRAY & HULEGUARD 562-600 GD/C 27-06171	ATLAS	4.0 DIA.	NO	VEHICLE PART	CARRIER, ELECT. SOLENOID WITH LANYARD BACKUP	CRIMP-TYPE PINS VARIETY OF CONTACT ARRANGEMENTS AVAILABLE	NOT SUITABLE FOR AUTO CONNECT. REQUIRES CLOSE TOLERANCE ALIGNMENT	MANUAL	NO
PIN & SOCKET 6 CONTACTS 1 - #12 1 - RG62 4 - RG214	CANNON CS3106A-40-74S	S-IC S-II S-IVB	2.5 DIA.	INSERT SEAL	CARRIER	CARRIER	ADAPTABLE FOR AUTO CONNECT		MANUAL, 50# FORCE, CONNECTED AFTER CARRIER INSTALLATION	YES
PIN & SOCKET 10 - #16 CONTACTS	MS3106R-18-1P	S-II	1.125 DIA.	INSERT SEAL	CARRIER	CARRIER		NOT SUITABLE FOR AUTO CONNECT.	MANUAL, CONNECTED AFTER CARRIER INSTALLATION.	NO
PIN & SOCKET 29 CONTACTS 16 - #16 9 - #8 4 - #4	CANNON CA3100R-40-10S	S-IVB	2.5 DIA.	INSERT SEAL	CARRIER	CARRIER	ADAPTABLE FOR AUTO CONNECT		MANUAL, CONNECTED AFTER CARRIER INSTALLATION.	YES
PIN & SOCKET	CANNON CA22520-5	S-IVB	2.5 DIA.	INSERT SEAL	CARRIER	CARRIER	ADAPTABLE FOR AUTO CONNECT		MANUAL, CONNECTED AFTER CARRIER INSTALLATION.	YES
PIN & SOCKET 4 - 1/0 CONTACTS	CANNON CA22259-20	S-IB	2.5 DIA.	INSERT SEAL	CARRIER, PLATE WITH SCREWS	CARRIER	ADAPTABLE FOR AUTO CONNECT		MANUAL, 50# FORCE, CONNECTED AFTER CARRIER INSTALLATION, RETAINING PLATE WITH SCREWS.	YES
PIN & SOCKET 4 - #RG-63B/U	BENDIX SC3100E-40-66P	S-IB	2.5 DIA.	INSERT SEAL	CARRIER, THREADED BUSHING ON BACK SHELL OF CONNECTOR	CARRIER	ADAPTABLE FOR AUTO CONNECT		MANUAL, CONNECTED AFTER CARRIER INSTALLATION, BUSHINGS TORQUED BY HAND FOR RETENTION.	YES
PIN & SOCKET 4 - #RG63	40M30668	S-IB	2.5 DIA.							
PIN & SOCKET 60 - #16 CONTACTS	40M30672 CANNON CA22511-0	S-IB	2.5 DIA.							

Table 3-4. Electrical Connectors (cont)

TYPE	MFR. & P/N	USED ON	SIZE	SEALED AND/OR PURGED	RETAINING METHOD	RELEASE & EJECT METHOD	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE FOR SHUTTLE
PIN & SOCKET 47 CONTACTS 1 - #8 22 - #18 24 - #16	MS3100E-40-9P	S-IB	2.5 DIA.	INSERT SEAL, CARRIER PURGED	CARRIER, THREADED BUSHING ON BACK SHELL OF CONNECTOR	CARRIER	. ADAPTABLE FOR AUTO CONNECT . RELIABLE . CAN BE ADAPTED FOR AUTO CONNECT . INEXPENSIVE	REQUIRES CLOSE ALIGNMENT TOLERANCES AND ADDITIONAL HARD-WARE FOR ADAPTATION TO AUTO CONNECT.	MANUAL, CONNECTED AFTER CARRIER INSTALLATION, BUSHING TORQUED BY HAND FOR RETENTION. INDI-VIDUAL CONTINUITY & MEGGER TESTING.	YES
PIN & SOCKET 60 - #16 CONTACTS	CANNON CA22259-25	S-IB	2.5 DIA.							
PIN & SOCKET 60 - #16 CONTACTS	CANNON CA22511-23P	S-IC S-II S-IVB	2.5 DIA.							
PIN & SOCKET 60 - #16 CONTACTS	CANNON CA22259-166	S-IC	2.5 DIA.							
PIN & SOCKET 60 - #16 CONTACTS	CANNON GM-100596-100	S-II S-IVB	2.5 DIA.							
PIN & SOCKET 6 - #20 CONTACTS	BENDIX PT06-10-6S-365	S-IC	.859 DIA.	INSERT SEAL	CARRIER	CARRIER		NOT SUITABLE FOR AUTO CONNECT	MANUAL	NO
PIN & SOCKET, SPRING LOADED, DEAD FACED. UP TO 124 - #16 CONTACTS	INSERT FROM CANNON 017069 SERIES CARRIER	ATLAS	3.6 X 6.2	NO	CARRIER	CARRIER PLUS SPRINGS IN CONNECTOR	ADAPTABLE FOR AUTO CONNECT. LIGHTWEIGHT, RELIABLE. PRO-VIDES DEADFACE OF EXPOSED VEHICLE AND GROUND PARTS. EXPOSED DEADFACE PLATE CON-TAINING CONTACTS IS EASILY REPLACED. CONTACTS GOLD PLATED. CONTAINS GUIDE PINS FOR ASSURING ALIGNMENT.		MANUAL	YES
PIN & SOCKET, SPRING LOADED, DEAD FACED, 102 - #16 CONTACTS 2 - COAX CONTACTS MATES W/RECEPTACLE GM100125-5	INSERT FROM CANNON GM100124-5	POLARIS	4" X 4"	SEALED	CARRIER	CARRIER PLUS SPRING LOADED DEAD FACE				YES

Table 3-5. ECS Connectors

TYPE & SIZE	MFG. & P/N	USED ON	SEALS & MATERIAL	SELF SEALING (POPPETS)	OPR. PRESS. PSI	MEDIA	RETAINING METHOD	RELEASE & EJECT	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE SHUTTLE
FLAT FACE 4" DIA.	KSC	S-IB FWD.	COMPRESSION SEAL	VEHICLE PART ONLY	5.0	AIR, GN2	CARRIER	CARRIER	• ZERO ENGAGEMENT • MIN. ADJUSTMENT • HIGH RELIABILITY • EASILY MAINTAINED	CONNECTION MADE AFTER MATING OF CARRIER. SEAL COMPRESSED BY MANUAL TORQUING OF BUSHING.	MANUAL	NO
SELF LOCKING 6" DIA.	KSC JACK & HEINZ	S-IB AFT	O-RING BUNA-N	NO	150	AIR GN2 H2O	LOCKING DOGS	MECH. PULL RODS RISEOFF	• SERVES AS BOATTAIL CONDITIONING AND WATER QUENCH UMBILICAL • HIGHLY RELIABLE	• NOT ADAPTABLE FOR AUTOMATED CONNECT • HEAVY • REPLACED AFTER LAUNCH	MANUAL	NO
FLAT FACE 5" DIA.	MSFC/BAC 65B80148	S-IC AFT TSM #3	COMPRESSION SEAL	NO	5.0	AIR, GN2	CARRIER	CARRIER	• ZERO ENGAGEMENT • MIN. ADJUSTMENT • EXTREME RELIABILITY • EASILY MAINTAINED	• NOT SUITABLE FOR AUTOMATED CONNECT • NOT GUIDED, SEAL COMPRESSED BY MANUAL TORQUING OF BUSHING	MANUAL, AFTER CARRIER INSTALLATION	NO
FLAT FACE 4" DIA.	MSFC/BAC 65B80060	S-IC FWD.	COMPRESSION SEAL	NO	5.0	AIR, GN2	CARRIER	CARRIER	• ZERO ENGAGEMENT • MIN. ADJUSTMENT • EXTREME RELIABILITY • EASILY MAINTAINED	• NOT SUITABLE FOR AUTO CONNECT. MANUAL TORQUE OF BUSHING TO COMPRESS SEAL.	MANUAL, AFTER CARRIER INSTALLATION	NO
FLAT FACE 12" DIA.		S-II AFT	COMPRESSION SEAL	NO	1.0	AIR, GN2	CARRIER	CARRIER	• ZERO ENGAGEMENT • MIN. ADJUSTMENT • EXTREME RELIABILITY • EASILY MAINTAINED	NOT SUITABLE FOR AUTO CONNECT. CRITICAL ADJUSTMENT NOT READILY ACHIEVED OTHER THAN MANUALLY.	MANUAL MIN. TIME REQ'D.	NO
FLAT FACE 4" DIA.	MSFC/NAR G7-820600	S-II AFT	COMPRESSION SEAL	NO	1.0	AIR, GN2	CARRIER	CARRIER	• ZERO ENGAGEMENT • MIN. ADJUSTMENT • EXTREME RELIABILITY • EASILY MAINTAINED	NOT SUITABLE FOR AUTO CONNECT, CRITICAL ADJUSTMENT NOT READILY ACHIEVED OTHER THAN MANUALLY.	MANUAL MIN. TIME REQ'D.	NO
BAYONET (SLIP) 10"	MSFC/DAC 1A79377	S-IVB AFT	ROUND HOLLOW SEAL	VEHICLE ONLY	1.0	AIR, GN2 GHe	CARRIER	CARRIER	• MINIMUM ENGAGEMENT • LIGHTWEIGHT • HIGHLY RELIABLE • EASILY MAINTAINED	• NOT SUITABLE FOR AUTOMATED CONNECT • REQUIRES CLOSE ALIGNMENT	MANUAL, AFTER CARRIER INSTALL.	NO

Table 3-5. ECS Connectors (cont)

TYPE & SIZE	MFR. & P/N	USED ON	SEALS & MATERIAL	SELF SEALING (POPPETS)	OPR. PRESS. PSI	MEDIA	RETAINING METHOD	RELEASE & EJECT	DESIRABLE FEATURES	UNDESIRABLE FEATURES	CONNECT FEATURES	SUITABLE F SHUTTLE
BAYONET (SLIP) 5"	MSFC/IBM 11Z00001 F/N 33	IU	NONE	VEHICLE HALF ONLY	1.5	AIR, GN2	CARRIER	CARRIER	• MINIMUM ENGAGEMENT • HIGHLY RELIABLE • EASILY MAINTAINED	• NOT SUITABLE FOR AUTOMATED CONNECT • REQUIRES CLOSE ALIGNMENT	MANUAL AFTER CARRIER INSTALL.	NO
BAYONET (SLIP) RECTANGULAR 3" X 4"	MSC/MAR 8G37-820001	SM	LIP RUBBER	VEHICLE ONLY	1.5	AIR, GN2	CARRIER	CARRIER	• MINIMUM ENGAGEMENT • LIGHTWEIGHT • HIGHLY RELIABLE • EASILY MAINTAINED • ADAPTABLE FOR AUTO CONNECT		MANUAL AFTER CARRIER INSTALL.	YES
SELF LOCKING (DETENT) 6"	GD/C 27-80318	ATLAS	COMPRESSION TYPE HOLLOW GASKET	NO	2.0	AIR, GN2	SPRING DETENT LATCH	LANYARD	• LOW DISCONNECT FORCE • SIMPLICITY • HIGHLY RELIABLE • ADAPTABLE FOR AUTOMATED CONNECT • LIGHTWEIGHT • PROVIDES GUIDING FEATURE		MANUAL, LOW FORCE REQ'D TO CONNECT. MIN. TIME REQ'D.	YES
SELF LOCKING BY SEAL INFLATION 4" DIA.	GD/C 55-80043	CENTAUR	INFLATABLE SEAL	NO	1.5	AIR, GN2	SEAL COMPRESSION BY TORQUING OF RING NUTS AND SEAL INFLATION	LANYARD	GOOD SEALING FEATURES	MULTIPLE OPERATIONAL STEPS FOR CONNECTION. CRITICAL ADJUSTMENTS. SIZE AND WEIGHT OF GROUND PART EXCESSIVE. REQUIRES 25 PSI PNEU. SOURCE FOR SEAL INFLATION.	MANUAL INSERTION, INFLATE SEAL FOR RETENTION.	NO
GROMMET & GROOVE 6" DIA.	GD/C 57-08301	CENTAUR ATLAS	HOLLOW COMPRESSION	NO	1.0	AIR	RUBBER SEAL GROMMET FITS INTO GROOVE WITH INTERFERENCE FIT	LANYARD	• SIMPLICITY • LIGHTWEIGHT • RELIABILITY • EASILY MAINTAINED	NOT ADAPTABLE FOR AUTOMATED CONNECT DUE TO FLEXIBILITY.	MANUAL, PUSH TO CONNECT.	NO
GROMMET & GROOVE 4"	GD/C 55-08312	CENTAUR	HOLLOW COMPRESSION	NO	2.0	AIR	RUBBER SEAL GROMMET FITS INTO GROOVE WITH INTERFERENCE FIT	LANYARD	• SIMPLICITY • LIGHTWEIGHT • RELIABILITY • EASILY MAINTAINED	NOT ADAPTABLE FOR AUTOMATED CONNECT DUE TO FLEXIBILITY.	MANUAL, PUSH TO CONNECT.	NO
SELF LOCKING BY SEAL INFLATION 8"	GD/C 55-81005	SURVEYOR	INFLATABLE SEAL	NO	1.5	GN2	SEAL INFLATION	LANYARD	LOW DISCONNECT FORCE	MULTIPLE OPERATIONAL STEPS FOR CONNECTION. REQUIRES 25 PSI PNEU. SOURCE FOR SEAL INFLATION.	MANUAL INSERTION, INFLATE SEAL FOR RETENTION.	NO

Table 3-6. Rationale for Suitability of Existing Hardware for Space Shuttle Umbilicals

Type	Part Number and Manufacturer	Suitable for SS?	Rationale
UMBILICAL CARRIERS			
Multiple Integrated Locked to Vehicle	75M02840 75M02841 KSC	No	Not large enough for amount of SS services required in integrated panel. Requires time reducing features.
Multiple Integrated Locked to Vehicle	75M02049 65B64005 KSC	No	Not large enough for amount of SS services required in integrated panel. Requires time reducing features.
Multiple Integrated Locked to Vehicle	8G37-820030 MSC NAR	No	Not large enough for amount of SS services required in integrated panel. Requires time reducing features.
Multiple Integrated Locked to Vehicle	S-IVB FWD 1A77953 I.U. 11Z00001 MSFC MAC/DAC	No	Too large and complicated alignment requirements. Requires handling and time reducing features.
Multiple Integrated Locked to Vehicle	65B80001 MSFC BAC 65B80002 MSFC BAC 65B80003 MSFC BAC	No	Too complex. Not adaptable for time reducing features.
Individual Locked to Vehicle	G7-820065 MSFC NAR G7-820064 MSFC NAR	No	Too heavy. Not adaptable for time reducing features
Individual Rise Off	75M02130 75M02129 KSC	No	Increase in size to 10 inches diameter pipe and connector and change in design concept of mating vehicle part could adapt the basic concept.

Table 3-6. Rationale for Suitability of Existing Hardware for Space Shuttle Umbilicals (Continued)

Type	Part Number and Manufacturer	Suitable for SS?	Rationale
Individual Rise Off Locked to Vehicle	75M02882	No	Has individual locking mechanism which is not acceptable for SS integrated services.
Multiple Rise Off	27-20418	No	Basic concept is adaptable. Not suitable in present configuration because of dissimilarity in services.
Multiple Integrated Locked to Vehicle	1A74896 MSFC MAC/DAC	No	Too large, heavy and complex. Not adaptable for time reducing features.
Multiple Integrated Locked to Vehicle	G7 820041 G7 822042 MSFC NAR	No	Too large, heavy and complex. Not adaptable for time reducing features.
Multiple Locked to Vehicle	65B80036 MSFC BAC	No	Support and actuating mechanism too heavy. Excessive initial critical adjustments required with close tolerances.
Individual Locked to Vehicle	55-06274 GD/C 676-440 G&H	No	Has individual locking mechanism. Not adaptable for time reducing features.
Individual Locked to Vehicle	27-06172 GD/C 562-700 G&H	No	Has individual locking mechanism. Not adaptable for time reducing features.
Individual Locked to Vehicle	27-04992 GD/C 017069-1239 Thru 1241 & 1042 thru 1044 Cannon	No	Has individual locking mechanism. Not adaptable for time reducing features. Electrical connector insert may be adapted for use in integrated carrier.
Integrated Locked to Vehicle	GM100124-5	No	Has individual locking mechanism. Not adaptable for time reducing features. Electrical connector insert may be adapted for use in integrated carrier.

Table 3-6. Rationale for Suitability of Existing Hardware for Space Shuttle Umbilicals (Continued)

Type	Part Number and Manufacturer	Suitable for SS?	Rationale
CRYOGENIC COUPLINGS			
Ball and Cone	All	Yes	Will require some redesign to adapt to rapid connect and verify requirements.
Pressure Balanced, Vacuum Jacketed, Bayonet	LASL P/N Unknown	Yes	Will require some redesign to adapt to rapid connect and verify requirements.
Bayonet, Vacuum Jacketed	55-21600 Aeroflex	Yes	Minimum time required. No additional insulation required. Long engagement is disadvantage.
Self Locking Slip Coupling	Stratos	No	Has individual locking mechanism. Unreliable. Alignment is critical and difficult to attain. Requires additional insulation. Not adaptable for time reducing features.
Self Locking Slip Coupling	Chrysler	No	Has individual locking mechanism. Critical alignment required. Unreliable. Not adaptable for time reducing features.
Bayonet (Slip)	27-80279 GD/C	Yes	Requires modification to incorporate debris protection.
Bayonet (Slip)	27-29006 GD/C	Yes	Easily adapted for rise off disconnect carrier.
Self Locking	ME144-0011 Royal Ind.	No	Has individual locking mechanism.
Bayonet (Slip)	27-02248 GD/C 310722 310723 Royal Ind.	Yes	Easily adapted for rise off disconnect carrier.
Bolted Flange	GD/C	No	Has individual locking mechanism. Not adaptable for time reducing features.

Table 3-6. Rationale for Suitability of Existing Hardware for Space Shuttle Umbilicals (Continued)

Type	Part Number and Manufacturer	Suitable for SS?	Rationale
PNEUMATIC AND HYDRAULIC CONNECTORS			
Self Locking Bayonet	10C01377	No	Has individual locking mechanism.
Pressure Balanced and Unbalanced Bayonet	65B64001 Thru 64003 Purolator	Yes	Requires modification to adapt to time reducing features. Must remain in carrier during engagement.
Bayonet Self Locking	7851844 7851861 Calmec 1A49958 7851823 Purolator	No	Has individual locking mechanism.
Self Locking	ME144-0010 Snaptite	No	Has individual locking mechanism.
Slip Bayonet	ME273-0055 Consolidated Controls	Yes	Must be adapted to remain in carrier during engagement to reduce time.
Slip Bayonet	ME273-0016 Royal Ind.	Yes	Must be adapted to remain in carrier during engagement to reduce time.
Bayonet	ME273-0013 Royal Ind.	No	Not adaptable for time reducing features.
Self Locking Bayonet	55-02126 Wiggins	No	Has individual locking mechanism.
Self Locking Bayonet	55-08111-1 Thru - 23 GD/C	No	Has individual locking mechanism.
Bayonet	55-08111 -25 thru -31	Yes	Easily adapted for locking carrier.
Bayonet	55-02110 Wiggins	No	Has individual locking mechanism.
Bayonet Slip	27-08557 GD/C	Yes	Easily adapted for rise off carrier.

Table 3-6. Rationale for Suitability of Existing Hardware for Space Shuttle Umbilicals (Continued)

Type	Part Number and Manufacturer	Suitable for SS?	Rationale
Bayonet Slip	27-20414 27-20415 27-20416 GD/C	Yes	Easily adapted for rise off carrier.
ELECTRICAL CONNECTORS			
Pin and Socket	676-400 676-300 G&H	No	Has individual locking mechanism. Not adaptable for time reducing features.
Pin and Socket	55-06785 55-06786 G&H	No	Has individual locking mechanism. Not adaptable for time reducing features.
Pin and Socket	562-600 G&H	No	Has individual locking mechanism. Not adaptable for time reducing features.
Pin and Socket	CS3106A-40-74S Cannon	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	MS3106R-18-1P	No	Not adaptable for time reducing features.
Pin and Socket	CA3100R-40-10S Cannon	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	CA22520-5 Cannon	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	CA22259-20 Cannon	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	SC3100E-40-66P Bendix	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	40M30668	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	40M30672 CA22511-0 Cannon	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	MS3100E-40-9P	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	CA22259-25 CA22511-23P CA22259-166 GM-100596-100 Cannon	Yes	Must be adapted to remain in carrier during engagement.

Table 3-6. Rationale for Suitability of Existing Hardware for Space Shuttle Umbilicals (Continued)

Type	Part Number and Manufacturer	Suitable for SS?	Rationale
Pin and Socket	PT06-10-6S-365	No	Not adaptable for time reducing features.
Pin and Socket	017069 Insert Cannon	Yes	Must be adapted to remain in carrier during engagement.
Pin and Socket	GM100124-5 Insert Cannon	Yes	Must be adapted to remain in carrier during engagement.
ECS CONNECTORS			
Flat Face 4" Dia.	KSC	No	Not adaptable for time reducing features.
Self Locking 6" Dia.	Jack & Heinz	No	Has individual locking mechanism.
Flat Face 5" Dia.	65B80148 MSFC/BAC	No	Not adaptable for time reducing features.
Flat Face 4" Dia.	65B80060 MSFC/BAC	No	Not adaptable for time reducing features.
Flat Face 12" Dia.		No	Not adaptable for time reducing features.
Flat Face 4" Dia.	G7-820600 MSFC/NAR	No	Not adaptable for time reducing features.
Slip Bayonet 10"	1A79377 MSFC/DAC	No	Not adaptable for time reducing features.
Slip Bayonet 5"	11Z00001 F/N 33 IBM	No	Not adaptable for time reducing features.
Slip Bayonet Rect. 3 x 4	8G37-820001 MSC/NAR	Yes	Must be adapted to remain in carrier during engagement.
Self Locking (Detent) 6"	27-80318 GD/C	Yes	Must be adapted for carrier locking and to remain in carrier during engagement.
Self Locking (Seal Infl) 4"	55-80043 GD/C	No	Has individual locking mechanism. Not adaptable for time reducing features.

Table 3-6. Rationale for Suitability of Existing Hardware for Space Shuttle Umbilicals (Continued)

Type	Part Number and Manufacturer	Suitable for SS?	Rationale
Grommet and Groove 6"	57-08301 GD/C	No	Has individual locking mechanism. Not adaptable for time reducing features.
Grommet and Groove 4"	55-08312 GD/C	No	Has individual locking mechanism. Not adaptable for time reducing features.
Self Locking (Seal Infl) 8"	55-81005 GD/C	No	Has individual locking mechanism. Not adaptable for time reducing features.

Table 3-7. Umbilical Connect and Verification Procedure Review

ITEM	OPERATIONS	PROCEDURE STEPS	TIME (EST.)	PERSONNEL (Min., REQ'D)	EVALUATION
S-IC Aft Umbilicals (TSM) 1, 2 & 3	Installation				. Aft Umb. Carriers weigh more than 600 lbs. each - require use of hoist, winch and sling to install. . Many adjustments and measurements required during installation - some adjustments and measurements difficult to make due to poor accessibility. Tolerances, in some cases, difficult to maintain. . Work platforms required for access to carrier. . All adjustments change after post-launch refurbishment. . All pneu., fluid, elect. connectors must be removed from carrier and re-installed during each installation. . Leak check time consuming, many points to check. *. These operations accomplished twice, carrier is disconnected and reconnected after initial installation. . Above data represent one typical installation. Minor variations exist between three aft umbilical installations.
	1. Preparation	24	3 hrs	4	
	2. Carrier Inst.	128*	4 hrs	3	
	3. Pneu. & Fluid Conn.	90*	2 hrs	2	
	4. Elect. Conn.	98*			
	5. 6" LOX & Fuel Coupling Inst.	20*	1 hr	2	
	6. Sensor Switch Adjust.	10*	20 min	1	
		370	10.3 hr		
	Verification				
	1. Preparation	2	20 min	1	
	2. Carrier Inst.	8	1 hr	1	
	3. Pneu. & Fluid Conn.				
	4. Elect. Conn.				
	5. 6" LOX & Fuel Coupling Inst.	1	10 min	1	
	6. Sensor Switch Adjust.	1	10 min	1	
		12	1.7 hrs		
S-IC Intertank Umbilical (LO_2)	Installation				. Intertank umbilical assembly is quite large (15'x4"x9.5') and heavy (6700 lbs.) . Initial mating to stage requires many measurements and adjustments. Tolerances on adjustments difficult to hold. . Difficulties encountered in latching and locking mechanisms due to binding and high friction, etc. . After initial mating to stage, disconnect, retract, extend and reconnect are automatically accomplished. However, operating times not always consistent. Internal pressure in LO_2 lines often slows or prevents retraction. . LO_2 line vacuum probes not easily accessible.
	1. Preparation	34	2 hrs	3	
	2. Mating to Stage	45	4 hrs	3	
		79	6 hrs		
	Verification				
	1. Preparation	21	1 hr	1	
	2. Mating to Stage	20	1 hr	1	
		41	2 hrs		
S-IC Fwd. Umbilical	Installation				. Umbilical fairly lightweight, easily installed by two men . Most time consumed in making and verifying proper adjustments to release mechanism, and installing each electrical connector separately following carrier installation. *. Pneumatic systems leak checks and electrical systems checkout not considered. These operations are usually carried out over a period of several days and are accomplished simultaneously with system checkout. Note: S-IC Fwd. Umbilical is nearly identical in configuration and installation to S-IB Fwd.
	1. Preparation	13	30 min	1	
	2. Carrier Inst.	39	40 min	2	
	3. Pneu. Conn.*	11	30 min	1	
	4. Elect. Conn.*	7	45 min	1	
	5. ECS Conn.	1	15 min	1	
		71	2.7 hrs		
	Verification				
	1. Preparation	13	30 min	1	
	2. Carrier Inst.	12	40 min	1	
	3. Pneu. Conn.	-	--	1	
	4. Elect. Conn.	-	--	1	
	5. ECS Conn.	-	--	1	
		25	1.2 hrs		

Table 3-7. Umbilical Connect and Verification Procedure Review (cont)

ITEM	OPERATIONS	PROCEDURE STEPS	TIME (EST.)	PERSONNEL (Min.,REQ'D)	EVALUATION
S-II Aft Umbilical Carrier	Installation				
	1. Preparation	18*	50 min	2	. S-II Aft Umbilical is quite heavy. Requires use of hoist for handling during installation
	2. Carrier Inst.	77	3 hrs	3	. Numerous measurements and adjustments required
	3. Pneu & Fluid Connections	171	6 hrs	2	. Special tools (wrenches, adapters, spring scales, etc.) required for installation and verification
	4. Elect. Conn.	84	2 hrs	1	
		350	11.8 hr		
	Verification				
	1. Preparation	6*	30 min	1	
	2. Carrier Inst.	19	1.5 hr	2	
	3. Pneu & Fluid Conn.	-	--	-	
	4. Elect. Conn.	-	--	-	
		25	2 hrs		*Leak checks of pneumatic systems and checkout of electrical systems not included.
S-II LOX Fill Disconnect	Installation				. S-II LOX Fill Disconnect requires use of hoist and come-alongs to position for installation
	1. Preparation	9*	45 min	1	. Special tools required for installation and verification
	2. Carrier Inst.	39	3 hr		
	3. Pneu. & Fluid Conn.	23	1 hr	1	
	4. Elect. Conn.	4	15 min	1	
		75	5 hrs		
	Verification				
	1. Preparation	4*	15 min	1	
	2. Carrier Inst.	13	30 min	1	
	3. Pneu & Fluid Conn.	1	10 min	1	
	4. Elect. Conn.	-	--	-	
		18	55 min		*Functional checks, leak checks and checkout of electrical indications not included.
S-II LH_2 Fill Disconnect	Installation				. S-II LH_2 Fill Disconnect requires use of hoist and come-alongs to position for installation
	1. Preparation	9*	45 min	1	. Special tools required for installation and verification
	2. Carrier Inst.	99	4 hr	3	. Helium purged nylon bag cover, with fiberglass bulkheads, installed to prevent condensation of liquid air.
	3. Pneu. & Fluid Conn.	23	1 hr	1	
	4. Elect. Conn.	4	15 min	1	
		135	6 hrs		
	Verification				
	1. Preparation	4*	15 min	1	
	2. Carrier Inst.	22	1 hr	1	
	3. Pneu. & Fluid Conn.	1	10 min	1	
	4. Elect. Conn.	-	--	-	
		27	1 hr 25 min		*Functional checks, leak checks and checkout of electrical indications not included.
S-II Fwd. Umbilical Carrier	Installation				. S-II Fwd Umbilical is quite heavy, requires use of hoist for handling during installation
	1. Preparation	18*	50 min	2	. Numerous measurements and adjustments required
	2. Carrier Inst.	77	3 hrs.	3	. Special tools (wrenches, adapters, spring scales, etc.) required for installation and verification.
	3. Pneu. & Fluid Conn.	129	5 hrs	2	
	4. Elect. Conn.	56	1.5 hr	1	
		280	10.3 hr		
	Verification				
	1. Preparation	6*	30 min	1	
	2. Carrier Inst.	19	1.5 hr	2	
	3. Pneu. & Fluid Conn.	3	15 min	1	
	4. Elect. Conn.	-	--	-	
		28	2.3 hr		*Leak checks of pneumatic systems and checkout of electrical systems not included.

Table 3-7. Umbilical Connect and Verification Procedure Review (cont)

ITEM	OPERATIONS	PROCEDURE STEPS	TIME (EST.)	PERSONNEL (Min.,REQ'D)	EVALUATION
S-II LOX Fill Disconnect	Installation				. S-II LOX Fill Disconnect requires use of hoist and come-alongs to position for installation
	1. Preparation	9*	45 min	1	. Special tools required for installation and verification
	2. Carrier Inst.	39	3 hr		
	3. Pneu. & Fluid Conn.	23	1 hr	1	
	4. Elect. Conn.	4	15 min	1	
		75	5 hrs		
	Verification				
	1. Preparation	4*	15 min	1	
	2. Carrier Inst.	13	30 min	1	
	3. Pneu & Fluid Conn.	1	10 min	1	
	4. Elect. Conn.	-	--	-	
		18	55 min		*Functional checks, leak checks and checkout of electrical indications not included.
S-II LH_2 Fill Disconnect	Installation				. S-II LH_2 Fill Disconnect requires use of hoist and come-alongs to position for installation
	1. Preparation	9*	45 min	1	. Special tools required for installation and verification
	2. Carrier Inst.	99	4 hr	3	. Helium purged nylon bag cover, with fiberglass bulkheads, installed to prevent condensation of liquid air.
	3. Pneu. & Fluid Conn.	23	1 hr	1	
	4. Elect. Conn.	4	15 min	1	
		135	6 hrs		
	Verification				
	1. Preparation	4*	15 min	1	
	2. Carrier Inst.	22	1 hr	1	
	3. Pneu. & Fluid Conn.	1	10 min	1	
	4. Elect. Conn.	-	--	-	
		27	1 hr 25 min		*Functional checks, leak checks and checkout of electrical indications not included.
S-II Fwd. Umbilical Carrier	Installation				. S-II Fwd Umbilical is quite heavy, requires use of hoist for handling during installation
	1. Preparation	18*	50 min	2	. Numerous measurements and adjustments required
	2. Carrier Inst.	77	3 hrs	3	. Special tools (wrenches, adapters, • spring scales, etc.) required for installation and verification.
	3. Pneu. & Fluid Conn.	129	5 hrs	2	
	4. Elect. Conn.	56	1.5 hr	1	
		280	10.3 hr		
	Verification				
	1. Preparation	6*	30 min	1	
	2. Carrier Inst.	19	1.5 hr	2	
	3. Pneu. & Fluid Conn.	3	15 min	1	
	4. Elect. Conn.	-	--	-	
		28	2.3 hr		*Leak checks of pneumatic systems and checkout of electrical systems not included.
Service Module Umbilical	Installation				. S/M Umbilical is light and small, easily handled by one man.
	1. Preparation	5	30 min	1	
	2. Carrier Inst.	7	20 min	1	
	3. Pneu. & Fluid Conn.	8	20 min	1	
	4. Elect. Conn.	4	15 min	1	
	5. ECS Conn.	4	15 min	1	
		28	1 hr 40 min		
	Verification				
	1. Preparation	3	10 min	1	
	2. Carrier Inst.	3	10 min	1	
	3. Pneu. & Fluid Conn.	-	--	-	
	4. Elect. Conn.	-	--	-	
	5. ECS Conn.	1	5 min	1	
		7	25 min.		

Table 3-7. Umbilical Connect and Verification Procedure Review (cont)

ITEM	OPERATIONS	PROCEDURE STEPS	TIME (EST.)	PERSONNEL (Min., REQ'D)	EVALUATION
S-IB Fwd Umbilical	Installation				. Umbilical relatively lightweight . Easily installed by two men . Most time is consumed in making and verifying proper adjustments to release mechanism and installing each electrical connector separately following carrier installation . This umbilical is quite reliable, no major problems during S-IB series . Pneumatic systems leak checks and electrical connector verification not considered. These operations are carrier out over a period of several days following installation. . This umbilical is nearly identical in configuration and installation to S-IC Fwd.
	1. Preparation	13	30 min	1	
	2. Carrier Inst.	39	40 min	2	
	3. Pneu. Conn.	11	30 min	1	
	4. Elect. Conn.	7	45 min	1	
	5. ECS Conn.	1	15 min	1	
		71	2.7 hrs		
	Verification				
	1. Preparation	13	30 min	1	
	2. Carrier Inst.	12	40 min	1	
	3. Pneu. Conn.	-	--	1	
	4. Elect. Conn.	-	--	1	
	5. ECS Conn	-	--	1	
		25	1.2 hrs		
S-IB Short Cable Mast Umbilicals II and IV	Installation				. S-IB Short Cable Mast Umbilical is relatively lightweight and easy to install . Work platforms and ladders must be installed for access to umbilicals . Most time is consumed in making and verifying proper adjustments and measurements and installing each electrical connector following carrier installation . Pneumatic systems leak checks and electrical systems checkout not considered. These operations are usually accomplished over a period of several days following installation.
	1. Preparation	4	90 min	2	
	2. Carrier Inst.	28	60 min	2	
	3. Pneu. Conn.	11	30 min	1	
	4. Elect. Conn.	5	30 min	1	
		48	3.5 hrs		
	Verification				
	1. Preparation	2	15 min	1	
	2. Carrier Inst.	13	20 min	1	
	3. Pneu. Conn.	9	10 min	1	
	4. Elect. Conn.	-	--	-	
		24	.75 hrs		
S-IVB Aft Umbilical	Installation				. Most operations and verification steps serial - few simultaneous functions . Crank-operated hoist and muscle power required for installation of large components; i.e. carrier, LO_2 and LH_2 fill lines . Work platforms and ladders required for access to work area . Installation requires many measurements, adjustments, gage points and torque applications . Application of insulation wrap by hand required for LH_2 connector.
	1. Preparation	3	15 min	2	
	2. Carrier Inst.	18	4 hrs	4	
	3. Elect. Conn.	54	3 hrs	2	
	4. Pneu. Conn.	82	50 min	2	
	5. LO_2 Conn.	26	1.5 hr	4	
	6. LH_2 Conn.	30	3.5 hr	4	
	7. ECS Conn.	5	20 min	2	
		218	13.4 hrs		
	Verification				
	1. Preparation	9	15 min	1	
	2. Carrier Inst.	9	20 min	1	
	3. Elect. Conn.	1	5 min	1	
	4. Pneu. Conn.	-	--	-	
	5. LO_2 Conn.	10	45 min	1	
	6. LH_2 Conn.	10	45 min	1	
	7. ECS Conn.	2	10 min	1	
		41	2.3 hrs		
S-IVB Fwd and I.U. Umbilical	Installation				. S-IVB Fwd. is a dual service umbilical, servicing S-IVB stage and I.U. stage. Installation requires joint action by MDAC, IBM and Boeing (or Chrysler for S-IB). . Installation requires many measurements and verification points. . Leak checks of pneumatic systems and electrical system verification not included in time estimates *. Includes reinstallation following disconnect after initial installation
	1. Preparation	12	45 min	1	
	2. Carrier Inst.	51*	90 min	3	
	3. Elect. Conn.	147	180 min	1	
	4. Pneu. Conn.	14	30 min	1	
	5. GH_2 Vent Conn.	13	30 min	2	
	6. ECS Conn.	5	20 min	1	
	7. Insulation	6	45 min	1	
		248	7.3 hrs		
	Verification				
	1. Preparation	12	20 min	1	
	2. Carrier Inst.	16*	25 min	1	
	3. Elect. Conn.	-	--	-	
	4. Pneu. Conn.	-	--	-	
	5. GH_2 Vent Conn.	8		1	
	6. ECS Conn.	-	--	-	
	7. Insulation	-	--	-	
		36	.9 hrs		

Table 3-7. Umbilical Connect and Verification Procedure Review (cont)

ITEM	OPERATIONS	PROCEDURE STEPS	TIME (EST.)	PERSONNEL (Min.,REQ'D)	EVALUATION
S-IB LOX Mast	Installation				. Installation fairly simple . Few problem areas . Requires few people . Major problem has been leakage of Teflon seal. Seal often leaks immediately after installation but leakage ceases after seal has "cold flowed."
	1. Preparation	3	40 min	2	
	2. Component Test	40	60 min	1	
	3. Mate to Vehicle	20	15 min	1	
	4. Functional Test	12	15 min	1	
	5. Leak Test	4	15 min	1	
		79	2.4 hrs		
	Verification				
	1. Preparation	1	10 min	1	
	2. Component Test	31	40 min	1	
	3. Mate to Vehicle	11	10 min	1	
	4. Functional Test	6	10 min	1	
	5. Leak Test	3	15 min	1	
		52	1.4 hrs		
		Total	3.8 hrs		
S-IB Fuel Mast	Installation				. Installation is fairly simple . Few problem areas . Requires few people . Major problem has been leakage of Teflon seal. Seal often leaks immediately after installation but leakage ceases after seal has "cold flowed."
	1. Preparation	3	40 min	2	
	2. Component Test	20	15 min	1	
	3. Mate to Vehicle	12	15 min	1	
	4. Functional Test	40	60 min	1	
	5. Leak Test	4	15 min	1	
		77	2.4 hrs		
	Verification				
	1. Preparation	1	10 min	1	
	2. Component Test	31	40 min	1	
	3. Mate to Vehicle	11	10 min	1	
	4. Functional Test	6	10 min	1	
	5. Leak Test	3	15 min	1	
		52	1.4 hrs		
		Total	3.8 hrs		
Fill & Drain Valve (Centaur) (LO_2 and LH_2)	Installation				. Installation utilizes necked-down tension bolts to secure ground half of valve to vehicle. Bolts break away when predetermined load transmitted from swing arm pull-off lanyard to F&D valve shroud. . Major reported problem area has been leakage past seal.
	1. Preparation	16	20 min	1	
	2. Valve Inst.	33	2.5 hr	1	
	3. Pneu & Fluid Conn.	18	45 min	1	
	4. Elect. Conn.	2	10 min	1	
		69	3.75 hrs		
	Verification				
	1. Preparation	4	10 min	1	
	2. Valve Inst.	13	30 min	1	
	3. Pneu & Fluid Conn.	9	20 min	1	
	4. Elect. Conn.	2	10 min	1	
		28	1.2 hrs		

Table 3-8. UCR Summary

	DEFECT/FAILURE TYPE AND NUMBER									
ITEM	MAL-FUNCTION	MATERIAL	DOCU-MENTATION	ASSEMBLY	DAMAGE	CONTAM-INATION	DIMEN-SIONAL	USED ON	VENDOR	PREDOMINANT DEFECT/FAILURE
DISCONNECT VALVE ME273-0013	3							S-II	HADLEY 04650	IMPROPER SEAL SIZE JAMS POPPET
DISCONNECT VALVE ME273-0016		1						S-II		FLARE SCRATCHED
DISCONNECT VALVE ME273-0017	1			1				S-II	HADLEY 04650	EXCESSIVE LENGTH OF MOUNTING BOLT INTERFERES WITH ADJUSTING NUT
DISCONNECT, VENT 1A48848	1			1	6	9		S-IVB	FAIRCHILD STRATOS	SCRATCHED SEALING SURFACES
QUICK DISCONNECT ASS'Y 1A49958	14				3	10	2	S-IVB	PUROLATOR	EXCESSIVE EXTERNAL LEAKAGE
DISCONNECT LO_2 GROUND 1A49970					1		1	S-IVB	FAIRCHILD STRATOS	DEFECTIVE SEALING SURFACE ON FLANGE
DISCONNECT LH_2 GROUND 1A49978				1	1			S-IVB	FAIRCHILD STRATOS	SCRATCHED SEALING SURFACES & IMPROPER ASS'Y
CARRIER, UMBILICAL 1A74896	1				1			S-IVB	DOUGLAS A/C	LEAKAGE BETWEEN DISCONNECT & DEBRIS VALVE AND DAMAGED THREADS
DISCONNECT 1B41065	1						1	S-IVB	PUROLATOR	DEFORMED SEAL
DISCONNECT LO_2 FILL (AIRBORNE) 1B66932	4	1	1	2	4	6		S-IVB	FAIRCHILD STRATOS	DAMAGE TO SEALING SURFACES RESULTING FROM CONTAMINATION
UMBILICAL HOUSING ASS'Y 11Z00001				4	2			IU	IBM	MANUFACTURING ERRORS
NIPPLE ASS'Y, Q.D. AIRBORNE 60C20113	3		1	1	1			S-IB	WIGGINS	SEAL DISLODGED WHEN DISCONNECTED UNDER PRESSURE
NIPPLE ASS'Y, Q.D. AIRBORNE 20C30138	2							S-IB	WIGGINS	POPPET STICKING OPEN, LEAKAGE
NIPPLE ASS'Y, Q.D. AIRBORNE 20C30140	1							S-IB	WIGGINS	SEAL DISLODGED WHEN DISCONNECTED UNDER PRESSURE
NIPPLE ASS'Y, Q.D. AIRBORNE 20C30389	1							S-IB	WIGGINS	FLARE TUBE FITTING END DAMAGED BY OVER TORQUING OF B-NUT

Table 3-8. UCR Summary (cont)

	DEFECT/FAILURE TYPE AND NUMBER									
ITEM	MAL-FUNCTION	MATERIAL	DOCU-MENTATION	ASSEMBLY	DAMAGE	CONTAM-INATION	DIMEN-SIONAL	USED ON	VENDOR	PREDOMINANT DEFECT/FAILURE
UMBILICAL VEHICLE PLATE 65B80014-1					2			S-IC	BOEING	DAMAGED HELI-COILS
UMBILICAL VEHICLE PLATE 65B80015					1					DAMAGED HELI-COILS
UMBILICAL SUB HOUSING 65B80026-9							1			RELIEF CUTS OMITTED, CAUSING INTERFERENCE
UMBILICAL VEHICLE PLATE 65B80027-3							1			ALIGNMENT HOLES DO NOT MATE WITH ALIGN. PINS
UMBILICAL SUB HOUSING 65B80028-9							1			RELIEF CUTS OMITTED, CAUSING INTERFERENCE
UMBILICAL VEHICLE PLATE 65B80029-1A				1						HELI-COILS MISSING
UMBILICAL SUB HOUSING 65B80030-9							1	S-IC	BOEING	RELIEF CUTS OMITTED, CAUSING INTERFERENCE
QUICK DISCONNECT 7851823-503					2	9		S-IVB	MDAC	RUST, DIRT & DIS-COLORATION
QUICK DISCONNECT 7851823-505	1			1	2	1			PUROLATOR	INTERNAL MATING SURFACE BURRED
QUICK DISCONNECT 7851844-501						3				CONTAMINATED DURING TESTING
QUICK DISCONNECT 7851861-1					3	2				CONTAMINATED DURING TESTING
QUICK DISCONNECT 7851861-501	2				1			S-IVB	CALMEC	LEAKAGE

Table 3-8. UCR Summary (cont)

ITEM	DEFECT/FAILURE TYPE AND NUMBER: MAL-FUNCTION	MATERIAL	DOCU-MENTATION	ASSEMBLY	DAMAGE	CONTAM-INATION	DIMEN-SIONAL	USED ON	VENDOR	PREDOMINANT DEFECT/FAILURE
FLUID COUPLING 65B64001-1	5	6			4			S-IC	PUROLATOR	SEAL MAT'L EXCEEDED USEFUL LIFE LIMITATION
FLUID COUPLING 65B64001-2	1	8	2		4					SEAL DEFORMED AND EXPANDED
FLUID COUPLING 65B64001-3				1		1				LOOSE RETAINER
FLUID COUPLING 65B64001-4			1		1	2				RUST ON INTERIOR SURFACES
FLUID COUPLING 65B64001-5				2	1	2				DAMAGE TO SEALING SURFACES RESULTING FROM CONTAMINATION
FLUID COUPLING 65B64001-6			2			1				NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-7	1			5	2	3				LOOSE RETAINER
FLUID COUPLING 65B64001-8			3			5				RUST ON INTERIOR SURFACES
FLUID COUPLING 65B64001-9				1				S-IC	PUROLATOR	LOOSE RETAINER
FLUID COUPLING 65B64001-11				3		1		S-IC	PUROLATOR	LOOSE RETAINER
FLUID COUPLING 65B64001-12		1	2		2	1				SCRATCHED SEALING SURFACES & GALLED THREADS
FLUID COUPLING 65B64001-14			1							NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-15						1				CONTAMINATED DURING HANDLING
FLUID COUPLING 65B64001-16			1			1				CONTAMINATED DURING HANDLING
FLUID COUPLING 65B64001-18	1					1				FOREIGN OBJECT LODGED IN POPPET
FLUID COUPLING 65B64001-20			2							NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-22	1		17	1		8				NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-23	2			4		1		S-IC	PUROLATOR	LOOSE RETAINER LEAKING

Table 3-8. UCR Summary (cont)

ITEM	DEFECT/FAILURE TYPE AND NUMBER: MAL-FUNCTION	MATERIAL	DOCU-MENTATION	ASSEMBLY	DAMAGE	CONTAM-INATION	DIMEN-SIONAL	USED ON	VENDOR	PREDOMINANT DEFECT/FAILURE
FLUID COUPLING 65B64001-24			2		1	1		S-IC	PUROLATOR	NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-25				3		1				LOOSE RETAINER
FLUID COUPLING 65B64001-26			2							NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-28			2			1				NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-31	2					2				LEAKAGE
FLUID COUPLING 65B64001-32	1		5			2				NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-33				1						MATERIAL NOT PER SPEC.
FLUID COUPLING 65B64001-34			1							NO RECORD OF PREVIOUS USAGE
FLUID COUPLING 65B64001-131	1							S-IC	PUROLATOR	LEAKAGE WHEN DISCONNECTED

SECTION 4

CANDIDATE CONCEPT DEFINITION

Candidate concepts were generated for the following categories of components, subsystems, and handling systems:

a. Coupling:

   1. Cryogenic

   2. High pressure pneumatic and hydraulic

   3. Low pressure pneumatic, H_20 glycol and JP-5

b. Locking and release devices

c. Engaging mechanisms

d. Debris protection devices

e. Booster umbilical carriers

f. Booster umbilical handling concepts (3)

g. Orbiter umbilical handling concepts (3)

Figures 4-1 through 4-44 are sketches depicting these various concepts. These sketches are conceptual only and do not include details or dimensions. They were prepared only to the extent necessary to allow evaluation and tradeoff analysis. Table 4-1 is a summary of the service requirements for booster riseoff umbilical carrier concepts A, B, and C.

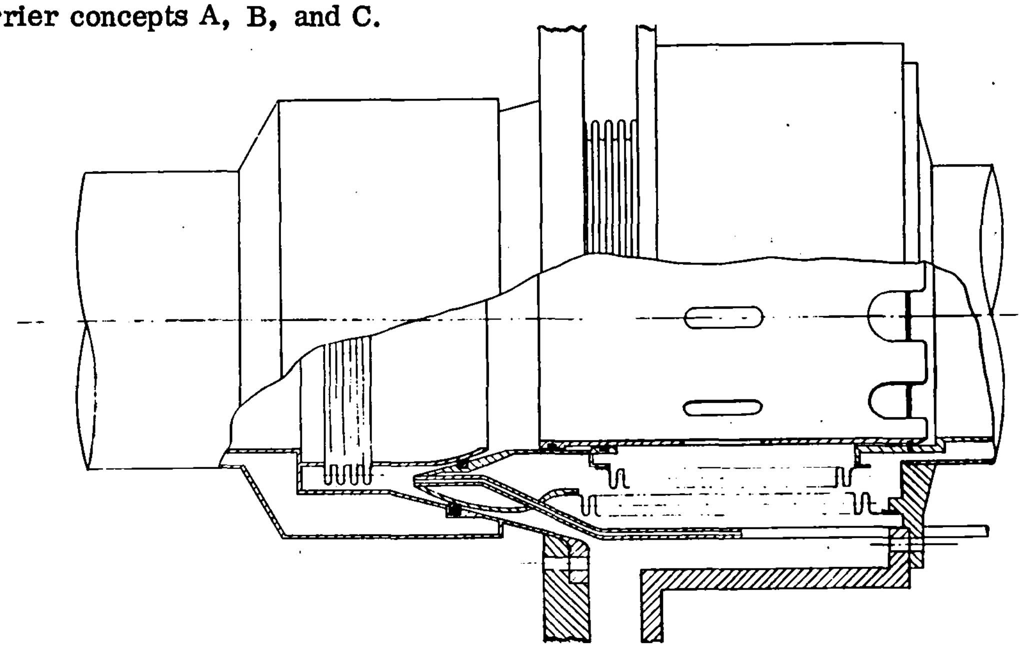

Figure 4-1. Ten Inch Cryogenic V. J. Ball and Cone Dual Seal

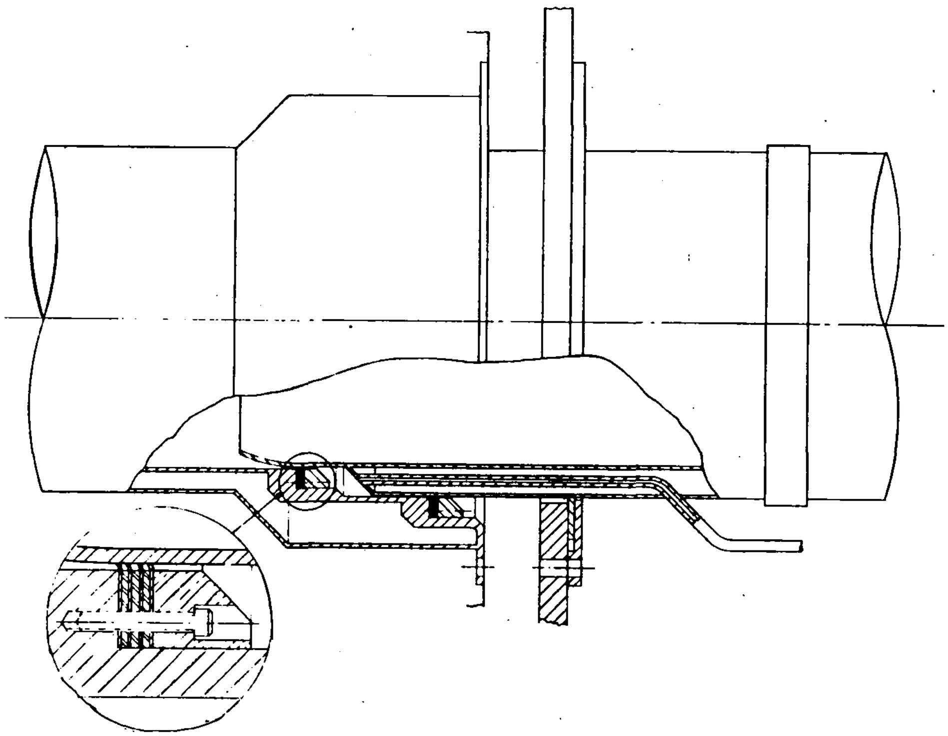

Figure 4-2. Ten Inch Cryogenic V.J. Slip Coupling-
Self Forming Lip Seals

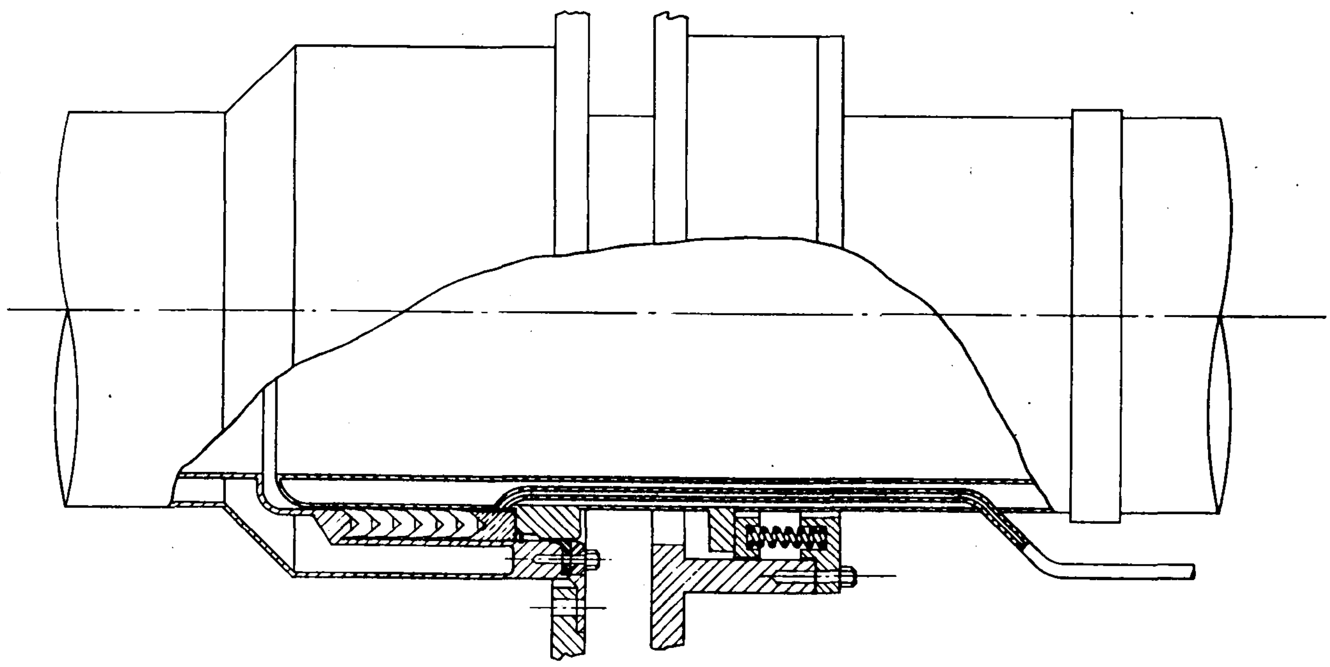

Figure 4-3. Ten Inch Cryogenic V.J. Slip Coupling-
Chevron Seals

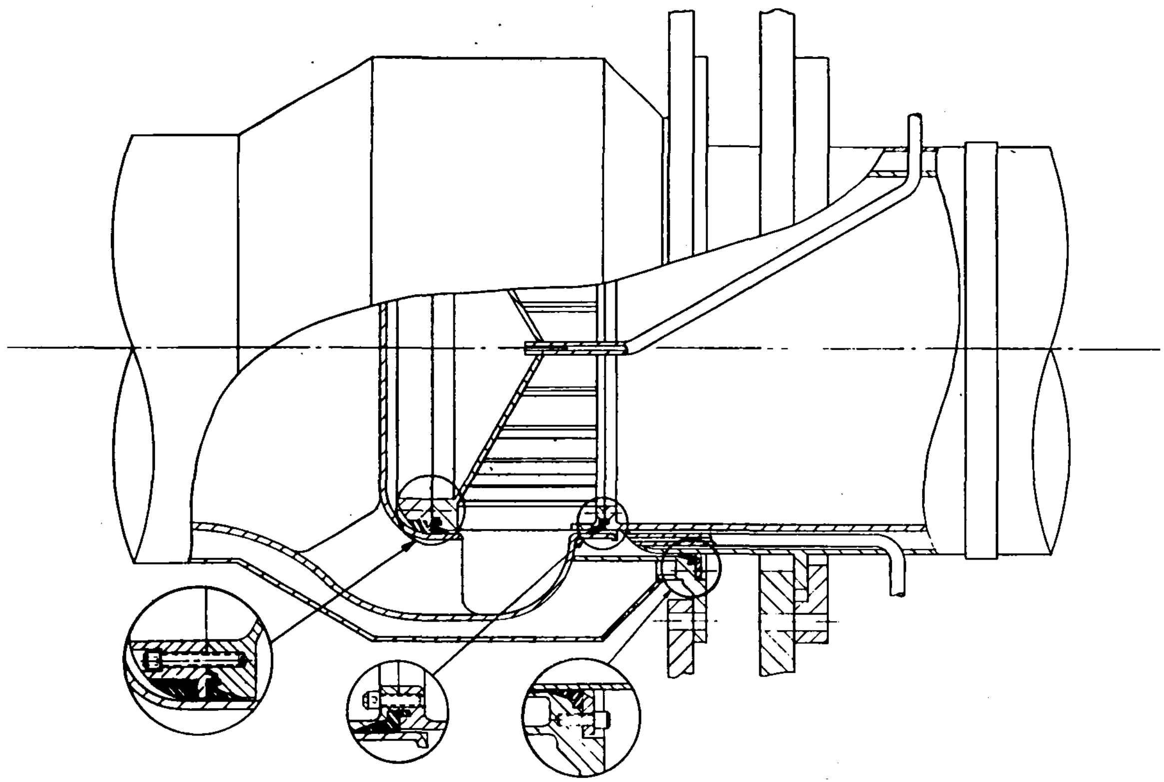

Figure 4-4. Ten Inch Cryogenic V.J. Pressure Balanced Slip Coupling

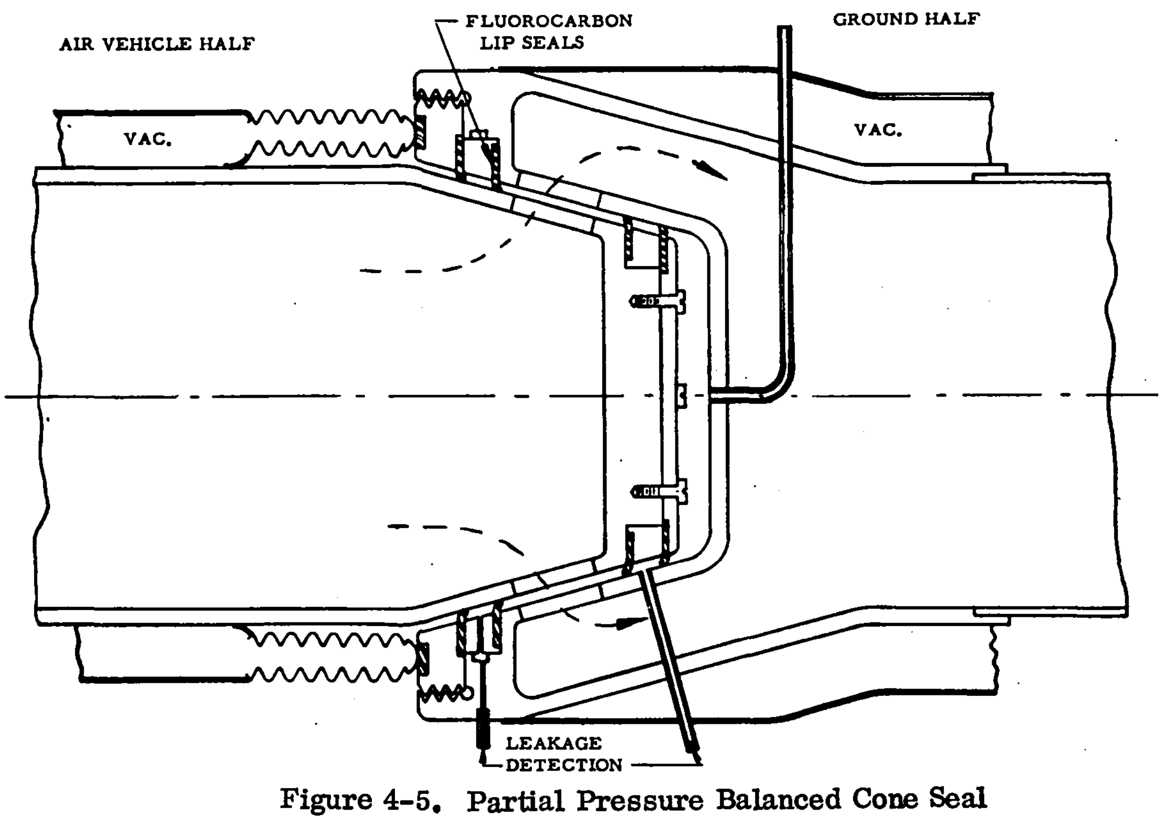

Figure 4-5. Partial Pressure Balanced Cone Seal

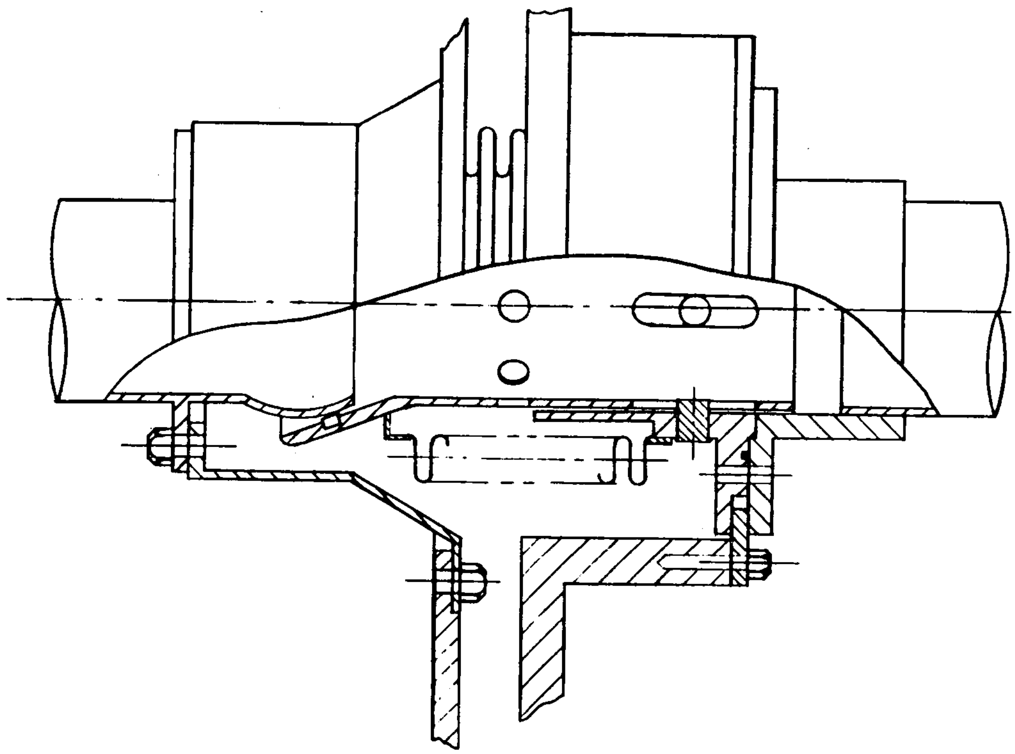

Figure 4-6. Three Inch Ball and Cone Coupling

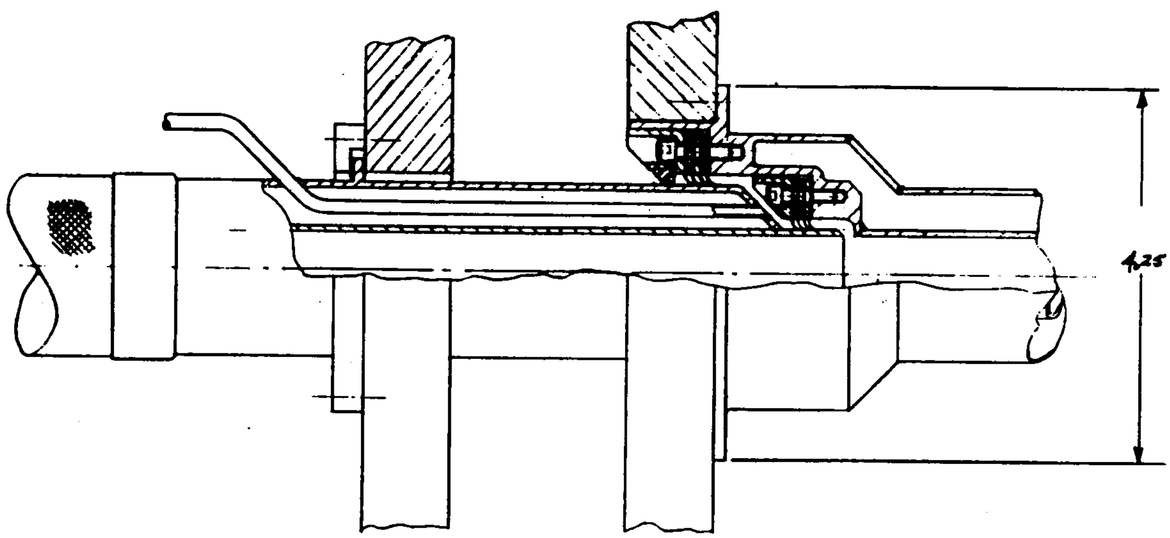

Figure 4-7. LH_2 - V.J. (1 in.)

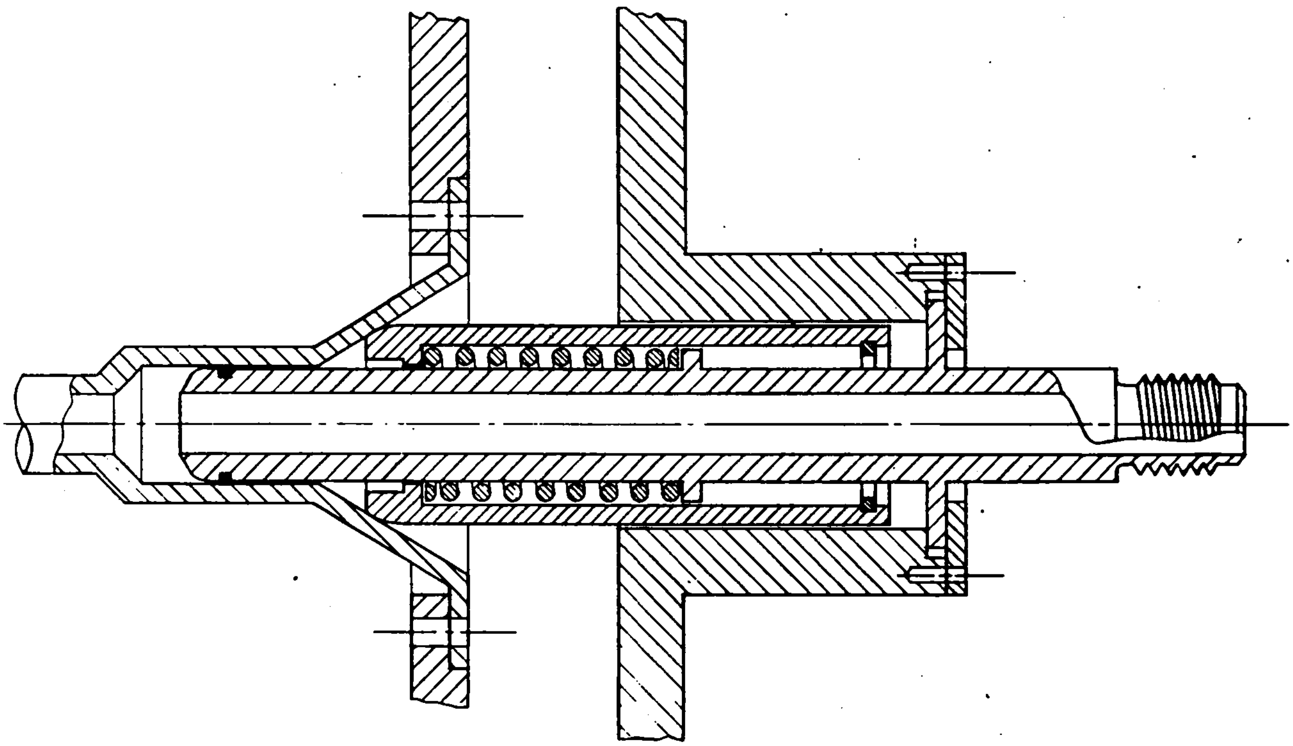

Figure 4-8. Pneumatic Slip Coupling (1 in.)

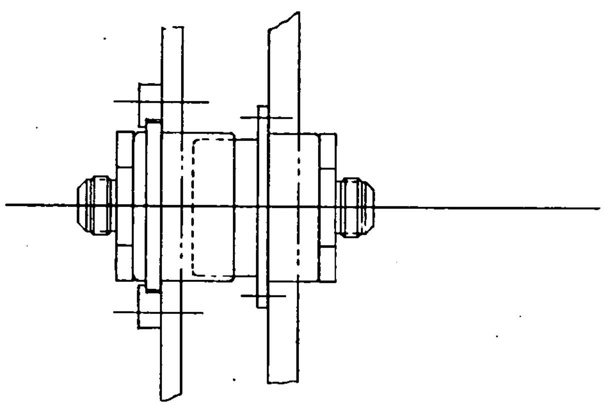

Figure 4-9. Pneumatic Pressure Balanced Coupling (1 in.)

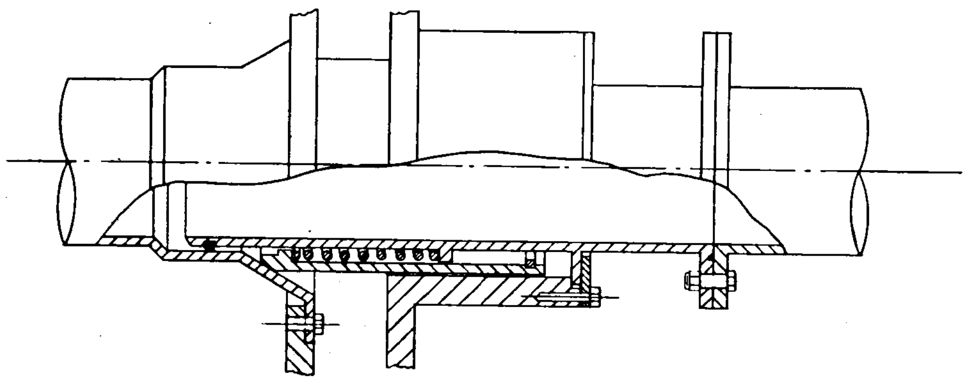

Figure 4-10. Pneumatic Coupling, 150 psi (4 in.)

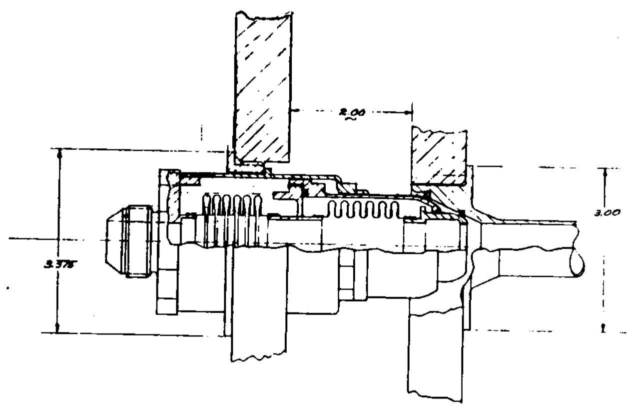

Figure 4-11. 150 psi (1 in.)

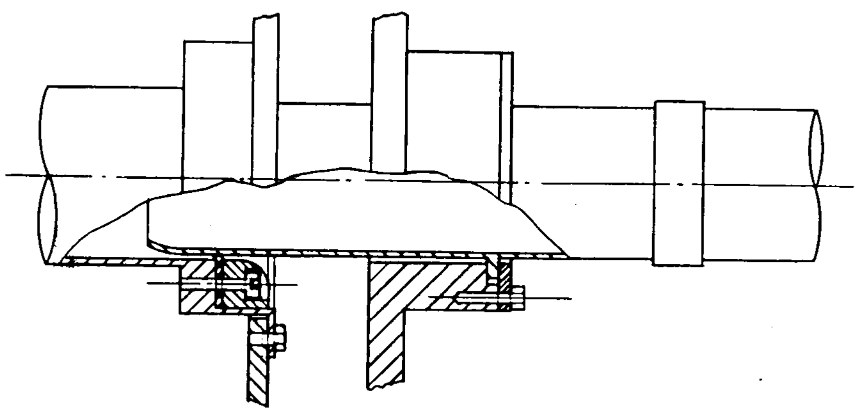

Figure 4-12. Pneumatic Coupling, 5 psi (3 in.)

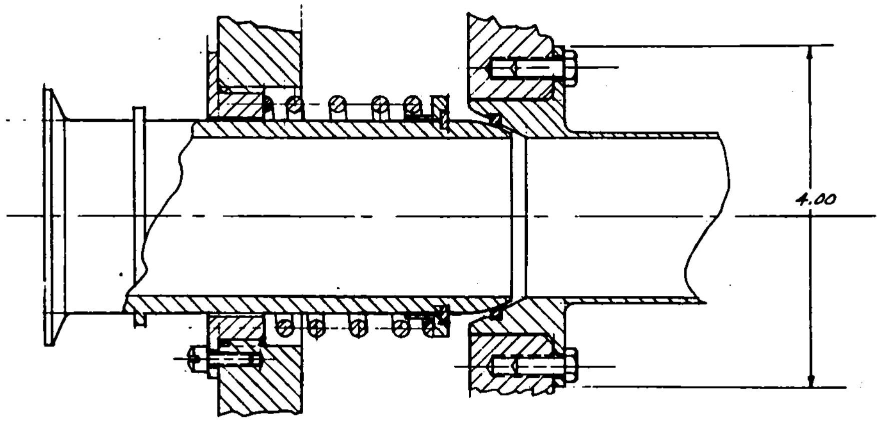

Figure 4-13. Two Inch

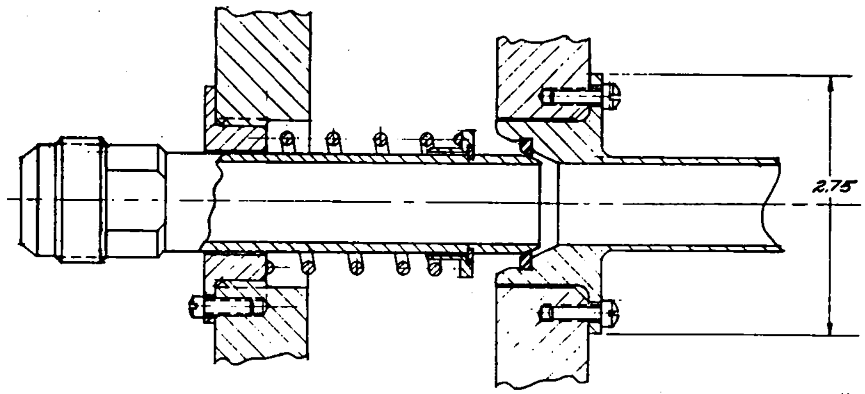

Figure 4-14. One Inch

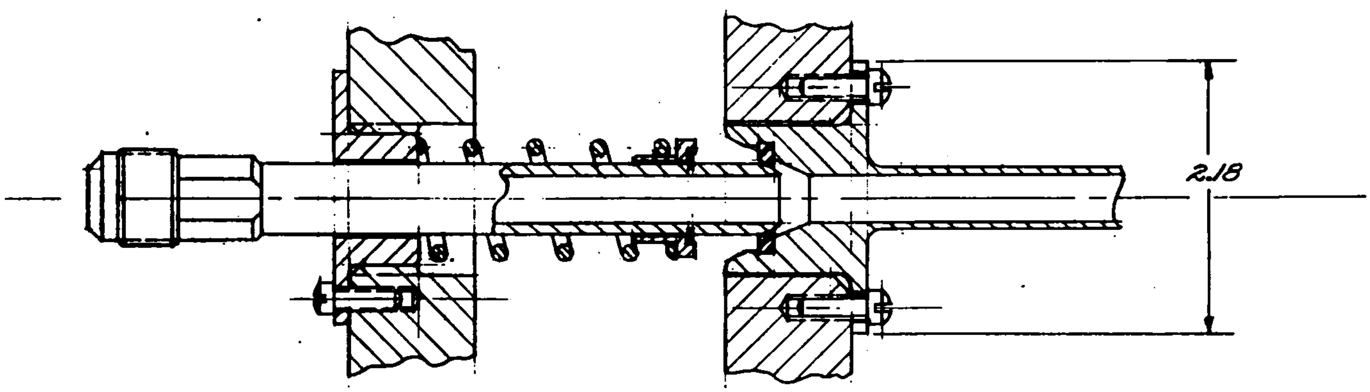

Figure 4-15. One-Half Inch

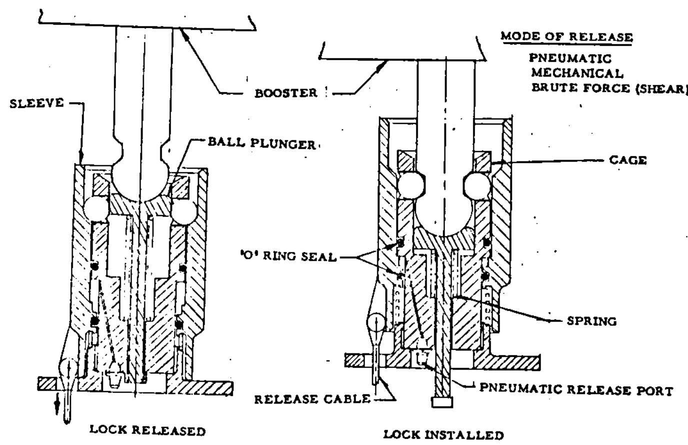

Figure 4-16. Ball Lock

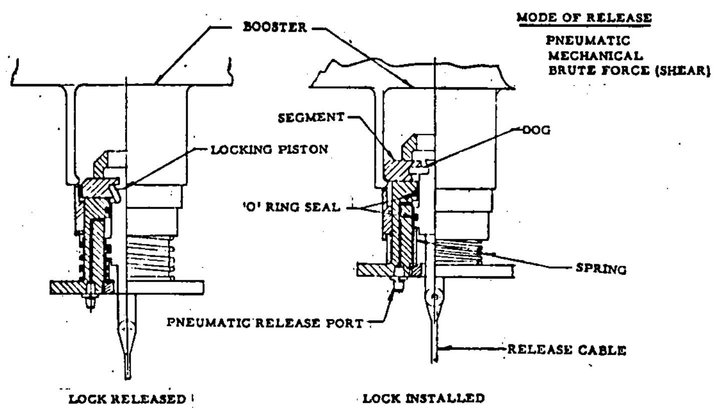

Figure 4-17. Toggle Lock

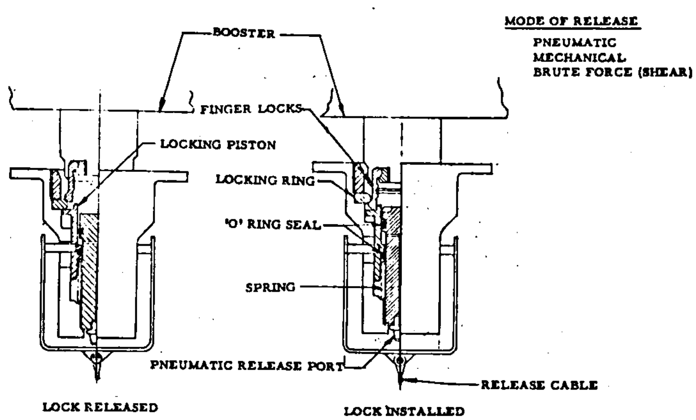

Figure 4-18. Finger Lock

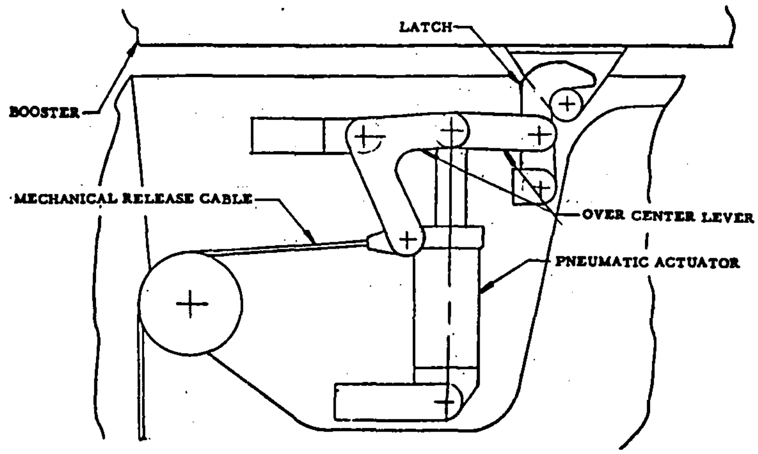

Figure 4-19. Latch Release Mechanism

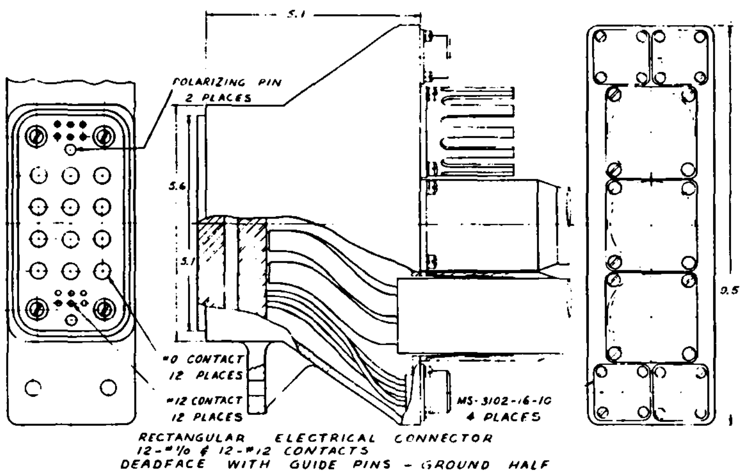

Figure 4-20. Rectangular Electrical Connector, Ground Half

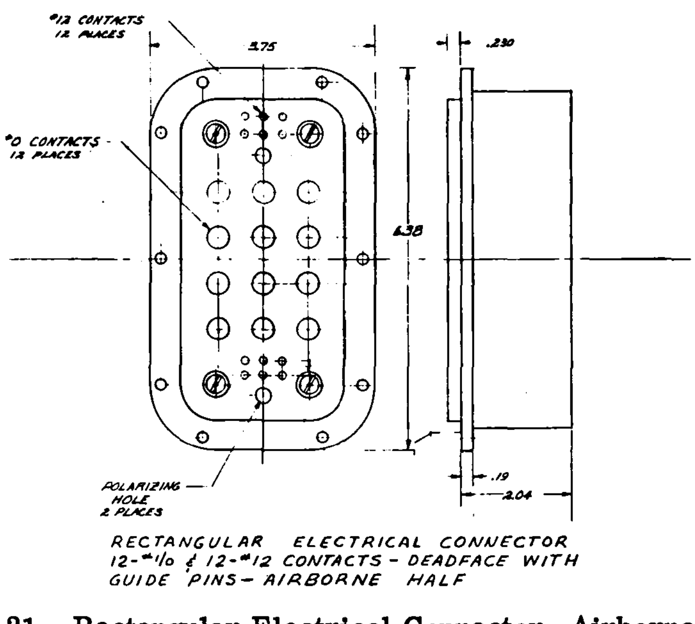

Figure 4-21. Rectangular Electrical Connector, Airborne Half

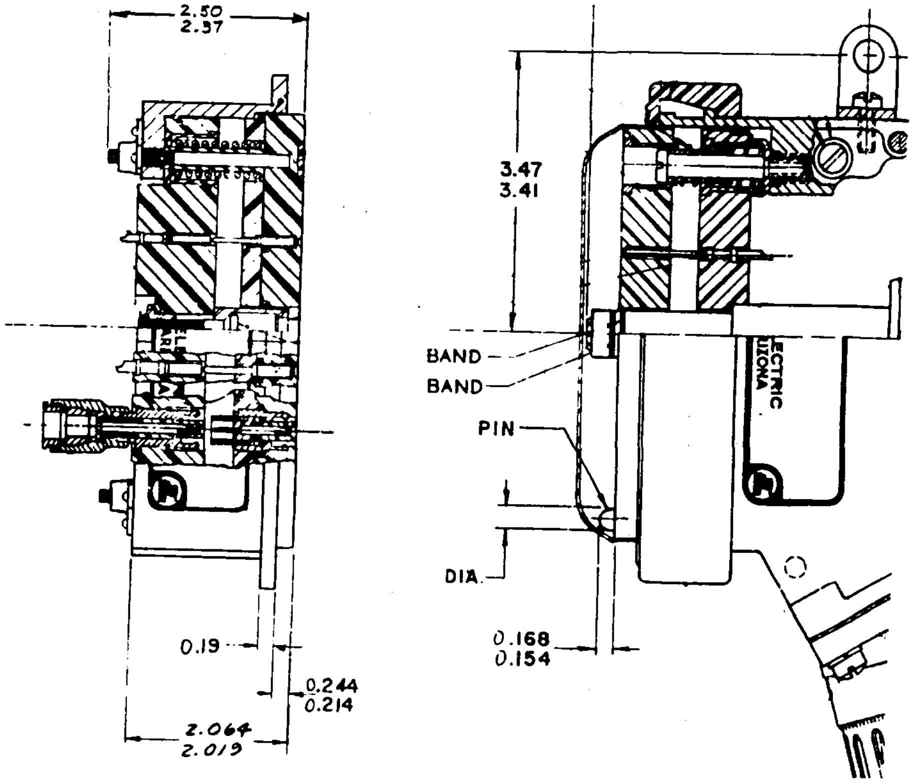

Figure 4-22. Typical Deadface Electrical Connector

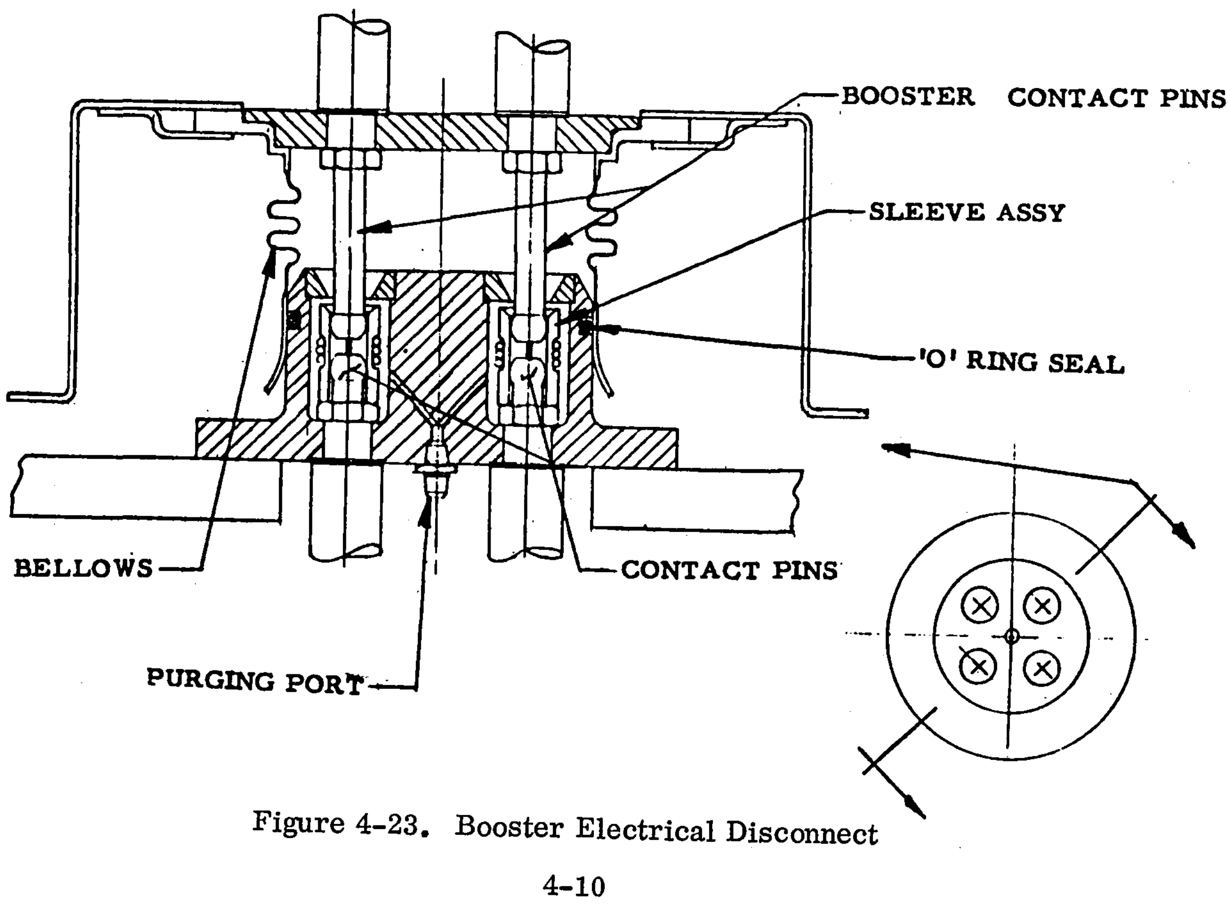

Figure 4-23. Booster Electrical Disconnect

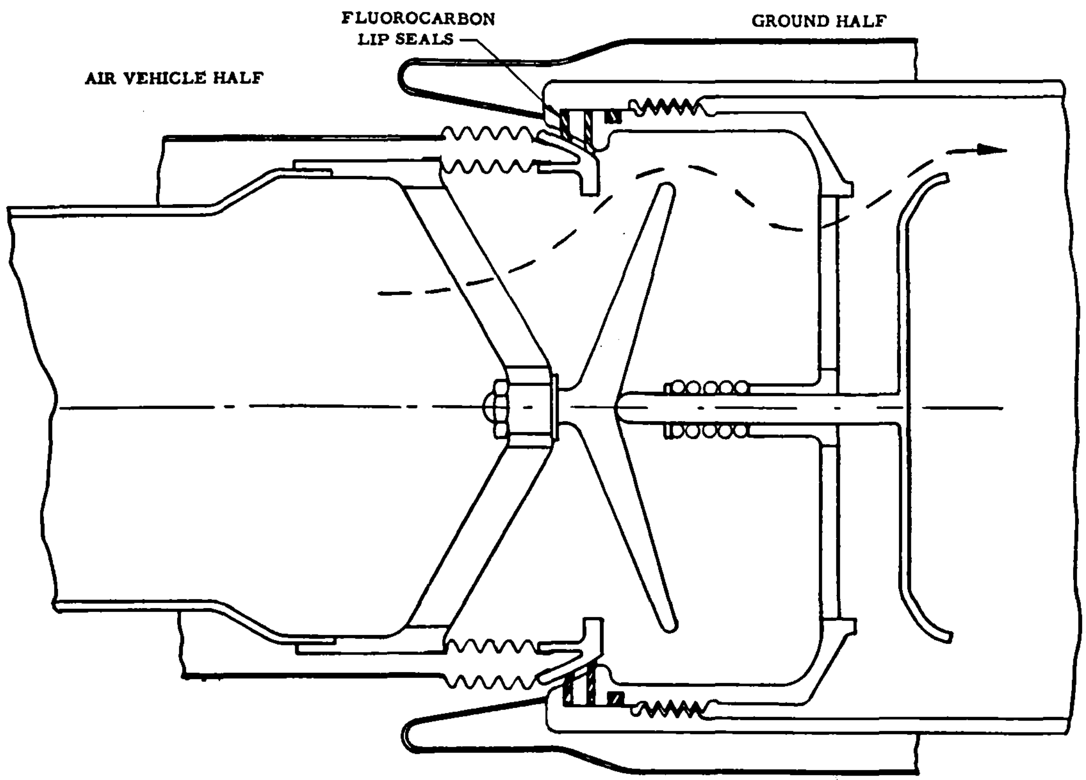

Figure 4-24. Cone Seal With Internal Actuated Poppet Closures

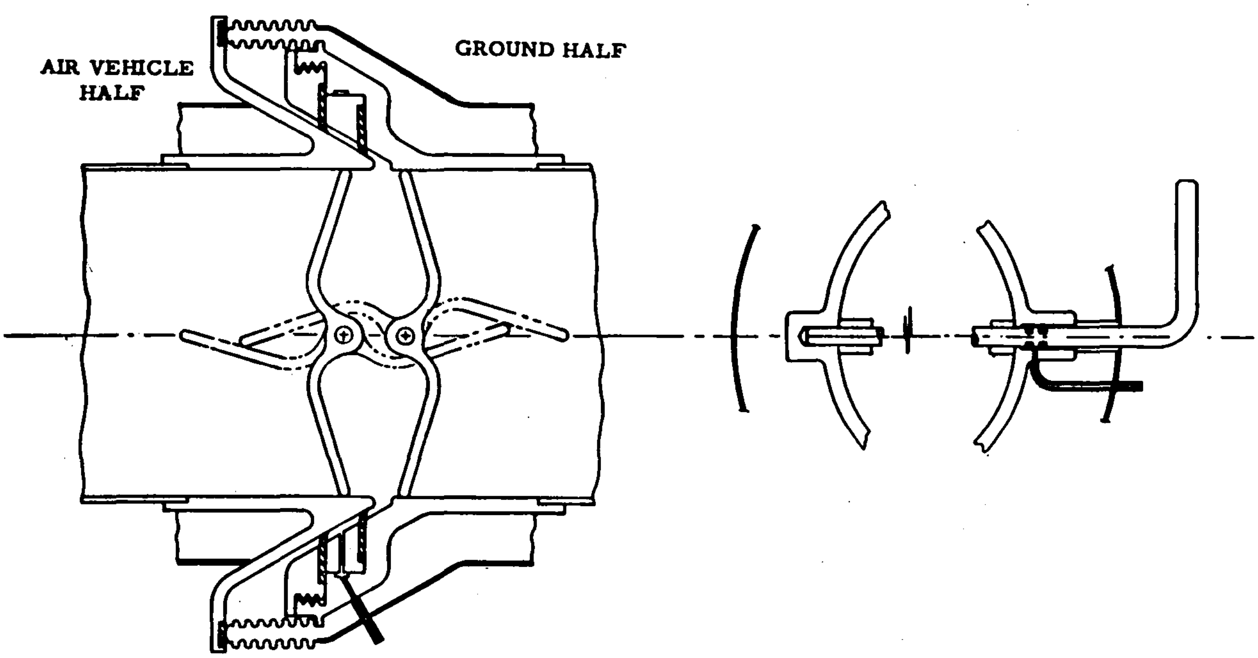

Figure 4-25. Butterfly Valve

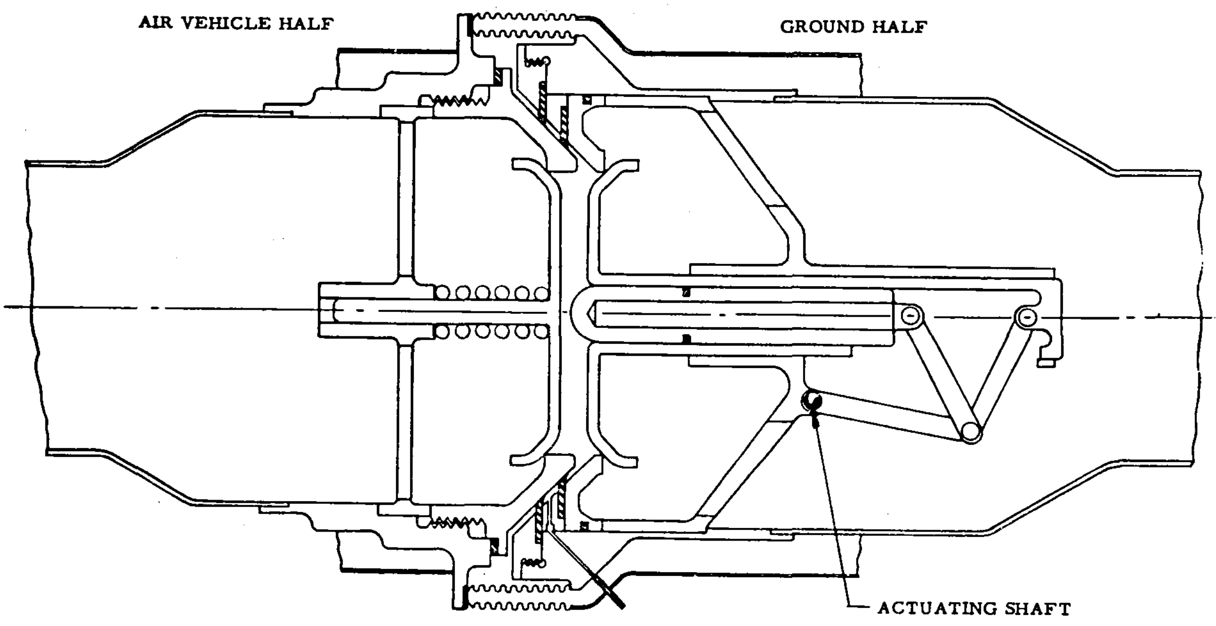

Figure 4-26. Poppet Valves, External Mechanical Actuated

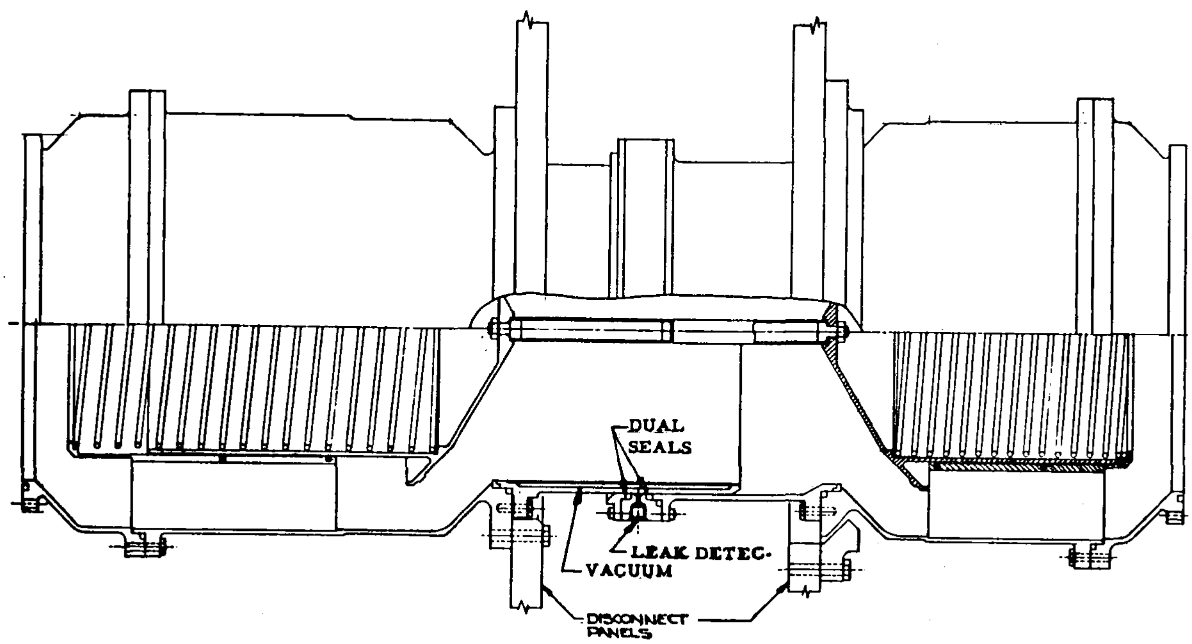

Figure 4-27. Poppet Valves, Internal Mechanical Actuated

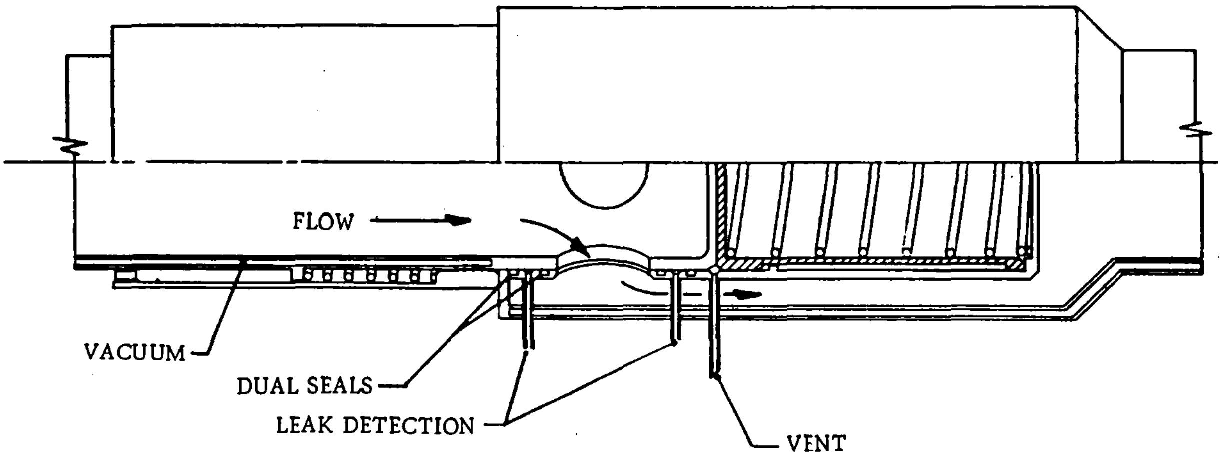

Figure 4-28. Disconnect, Balanced Poppet, Vacuum Jacket

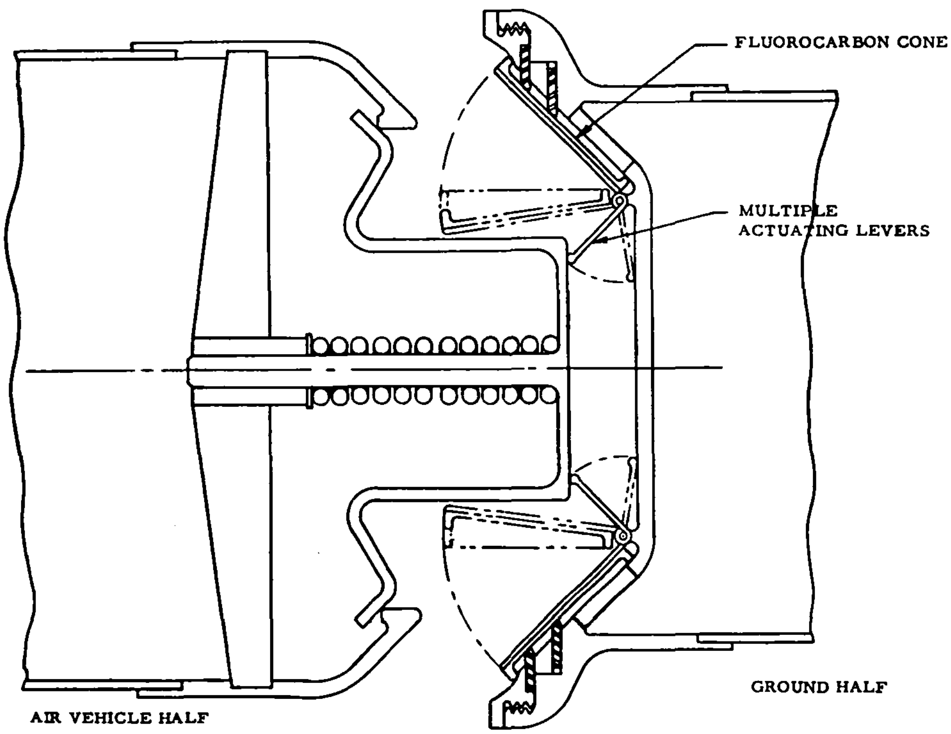

Figure 4-29. Debris Valves, Flexible Cone and Poppet

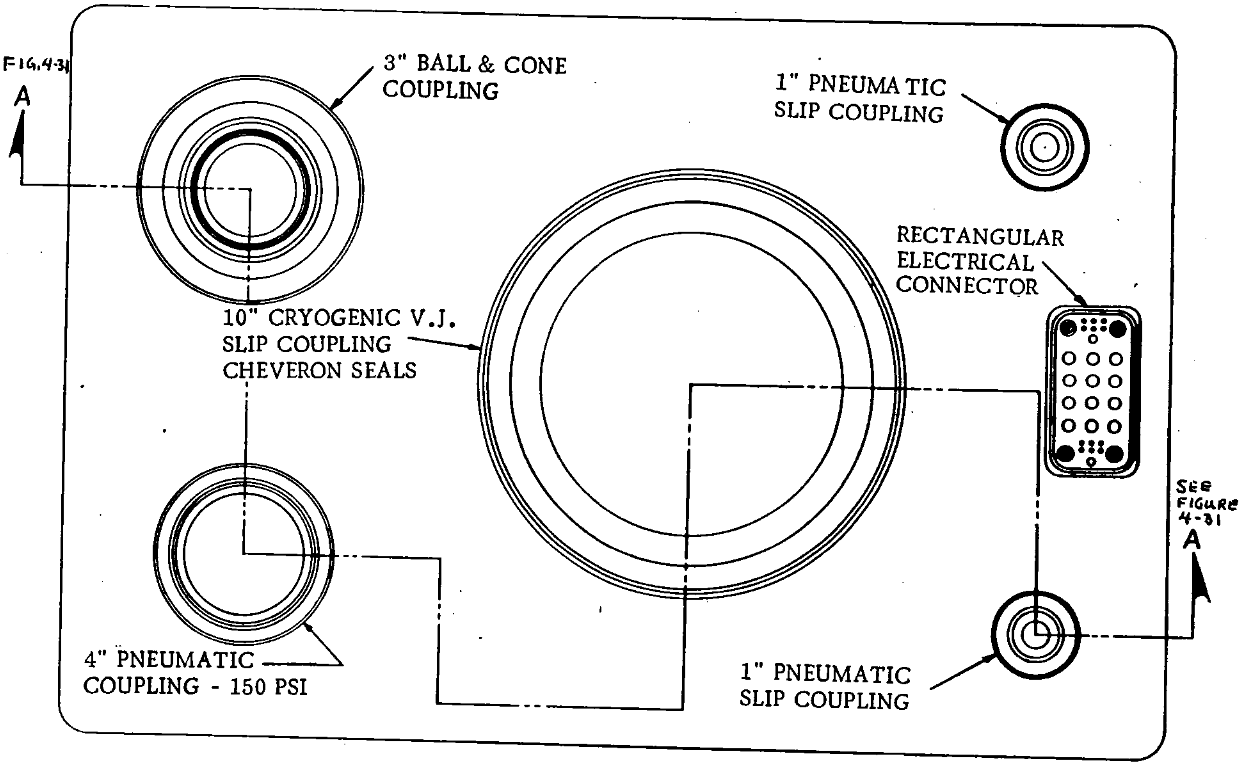

Figure 4-30. Booster Rise-off Ground Umbilical, Concept A

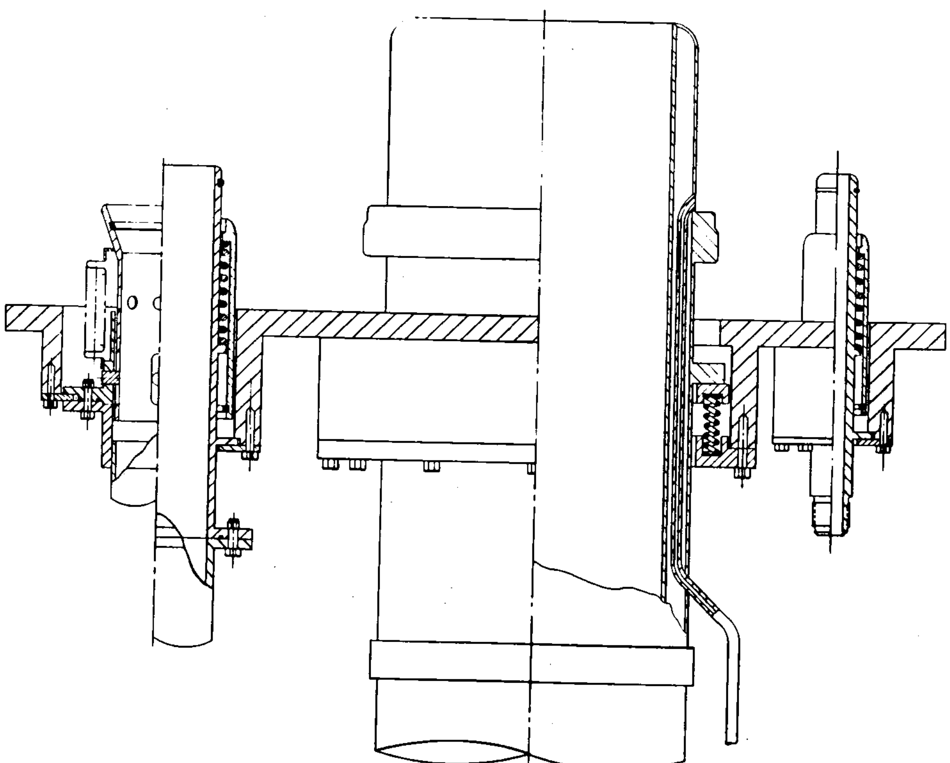

Figure 4-31. Booster Rise-off Ground Umbilical, Concept A (Section AA)

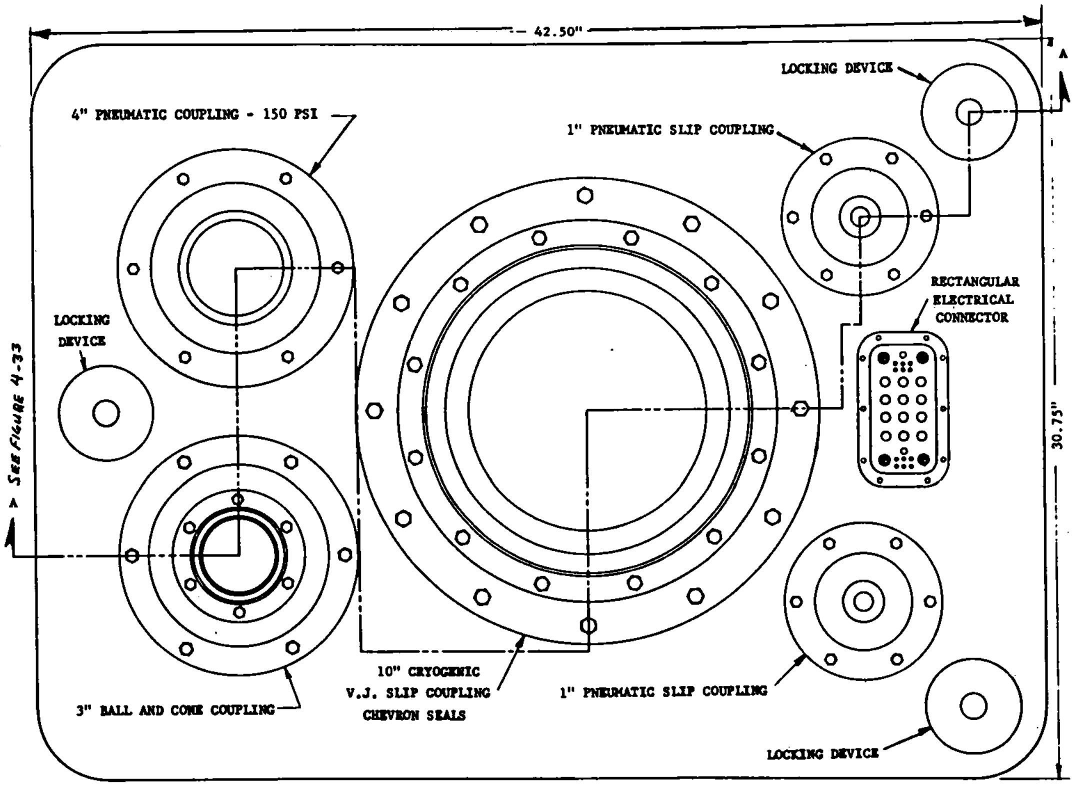

Figure 4-32. Booster Rise-off Airborne Umbilical, Concept A

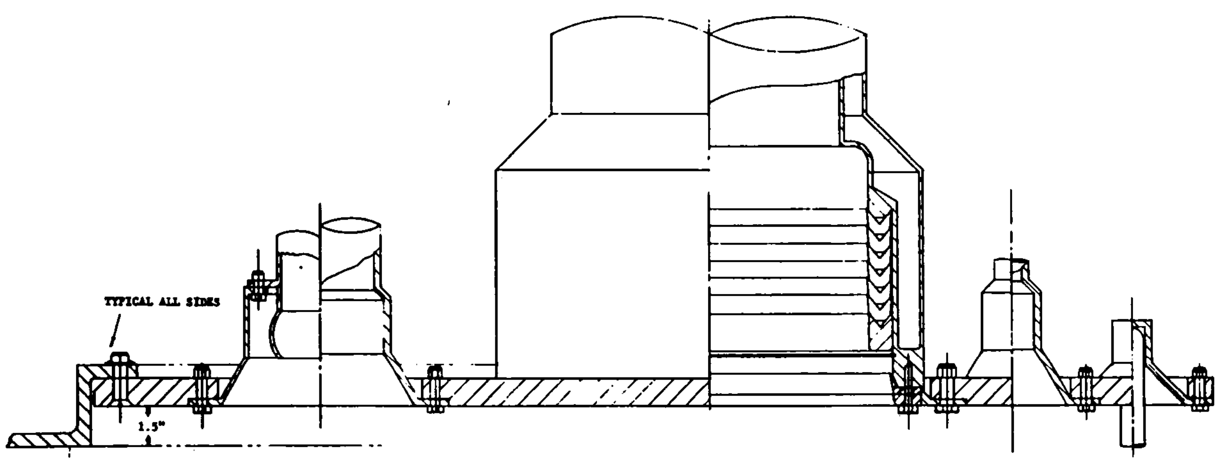

Figure 4-33. Booster Rise-off Airborne Umbilical, Concept A (Section AA)

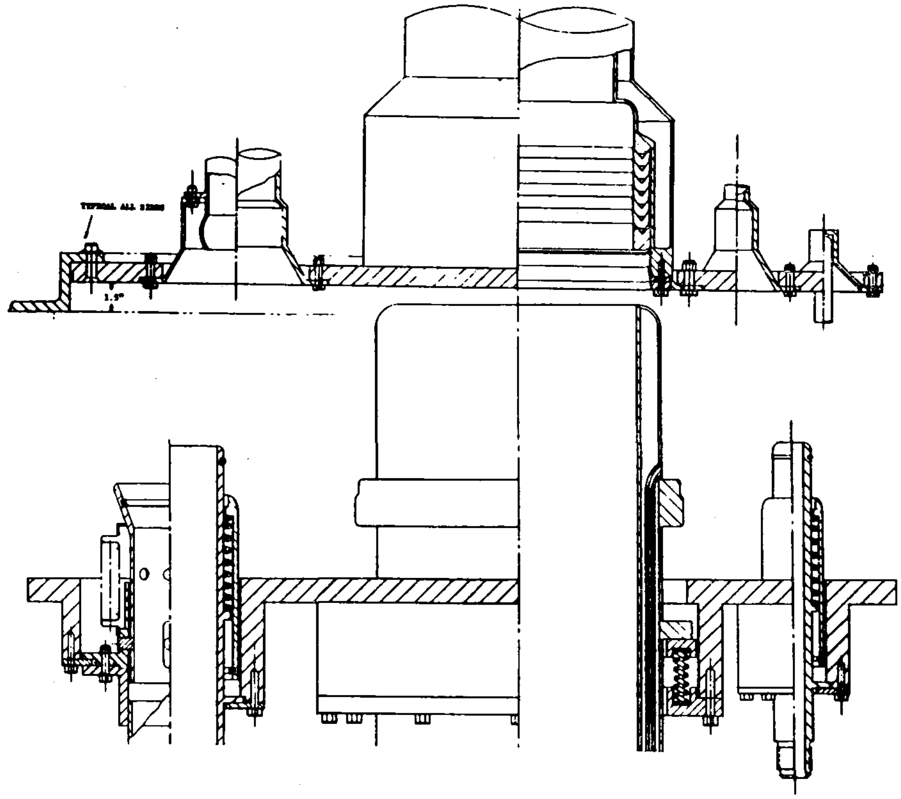

Figure 4-34. Booster Rise-off Umbilical, Ground and Vehicle

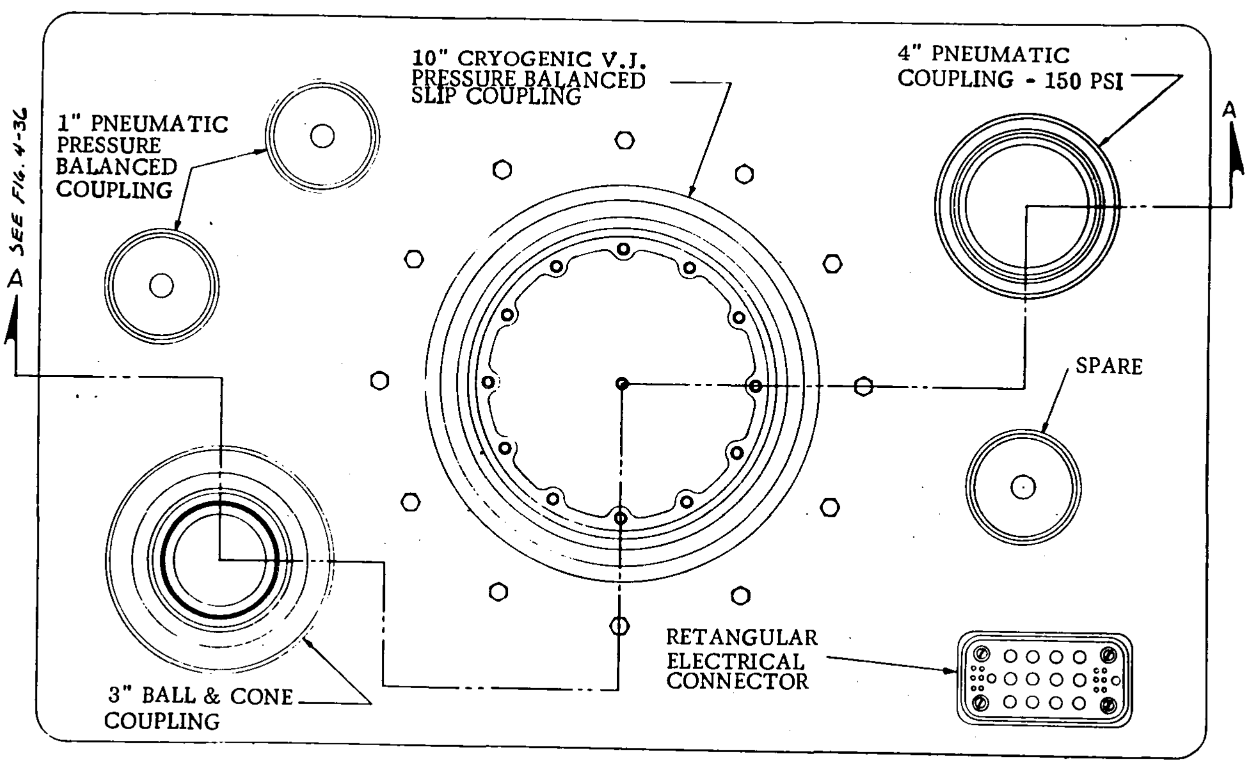

Figure 4-35. Booster Rise-off Ground Umbilical, Concept B

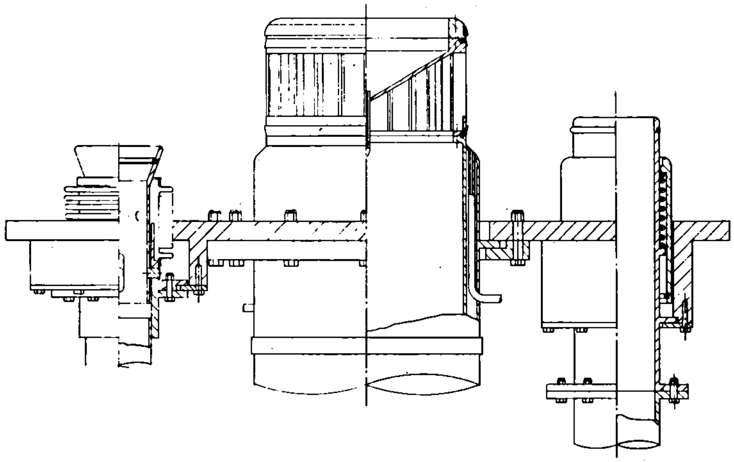

Figure 4-36. Booster Rise-off Ground Umbilical, Concept B (Section A-A)

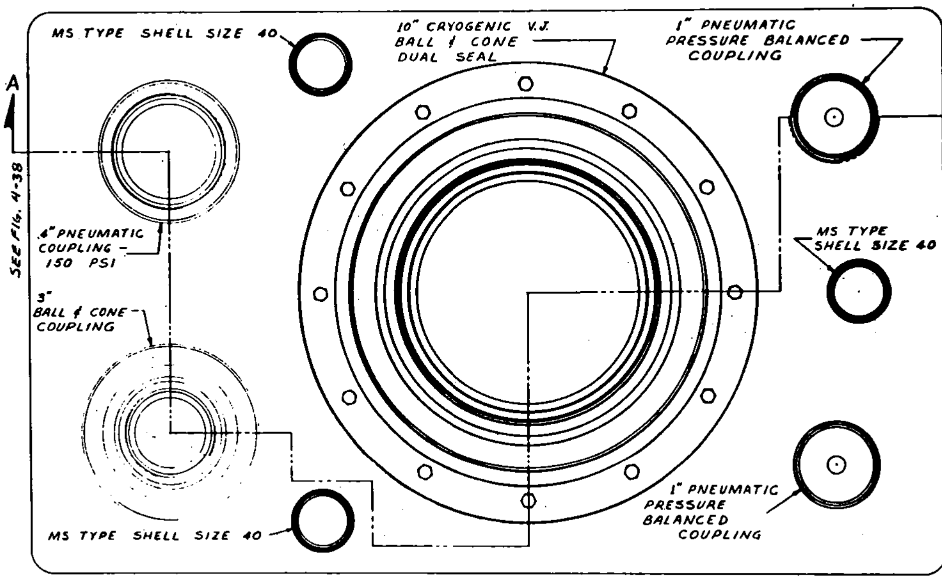

Figure 4-37. Booster Rise-off Ground Umbilical, Concept C

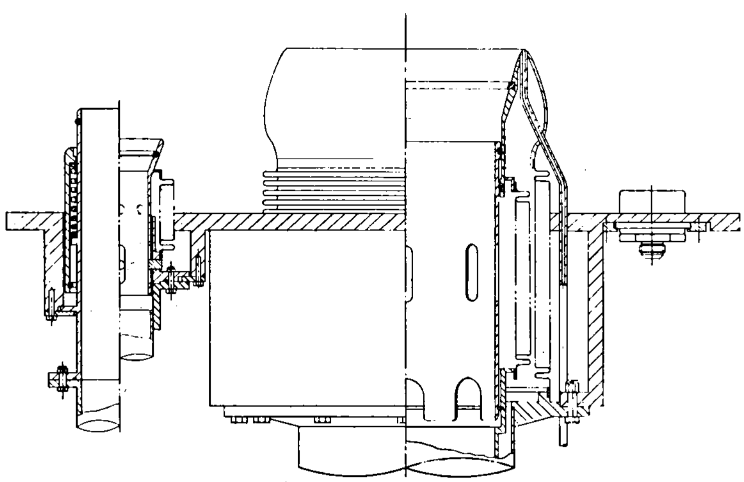

Figure 4-38. Booster Rise-off Ground Umbilical, Concept C (Section A-A)

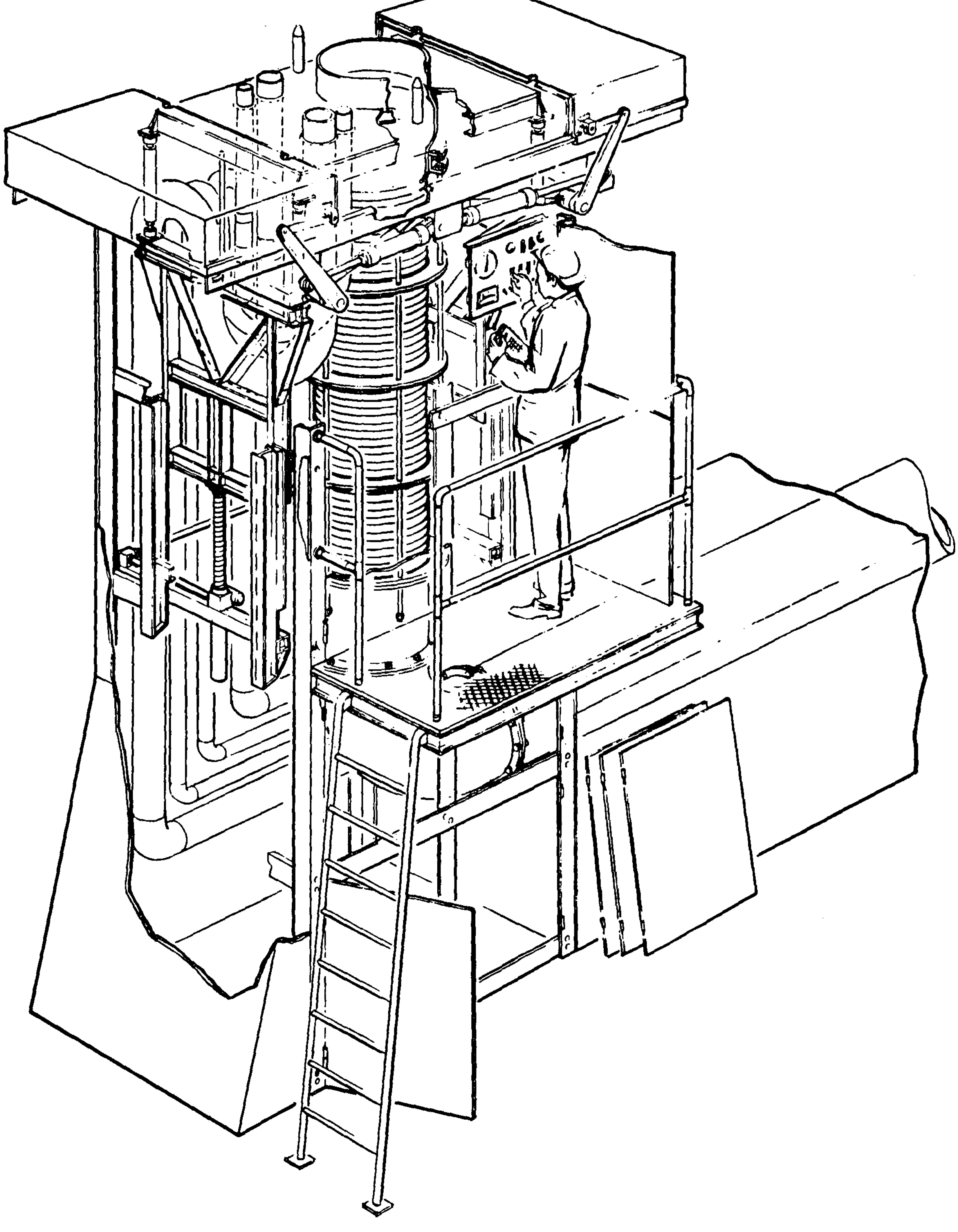

Figure 4-39. Booster Umbilical Handling Concept No. 1, Fixed Elevation

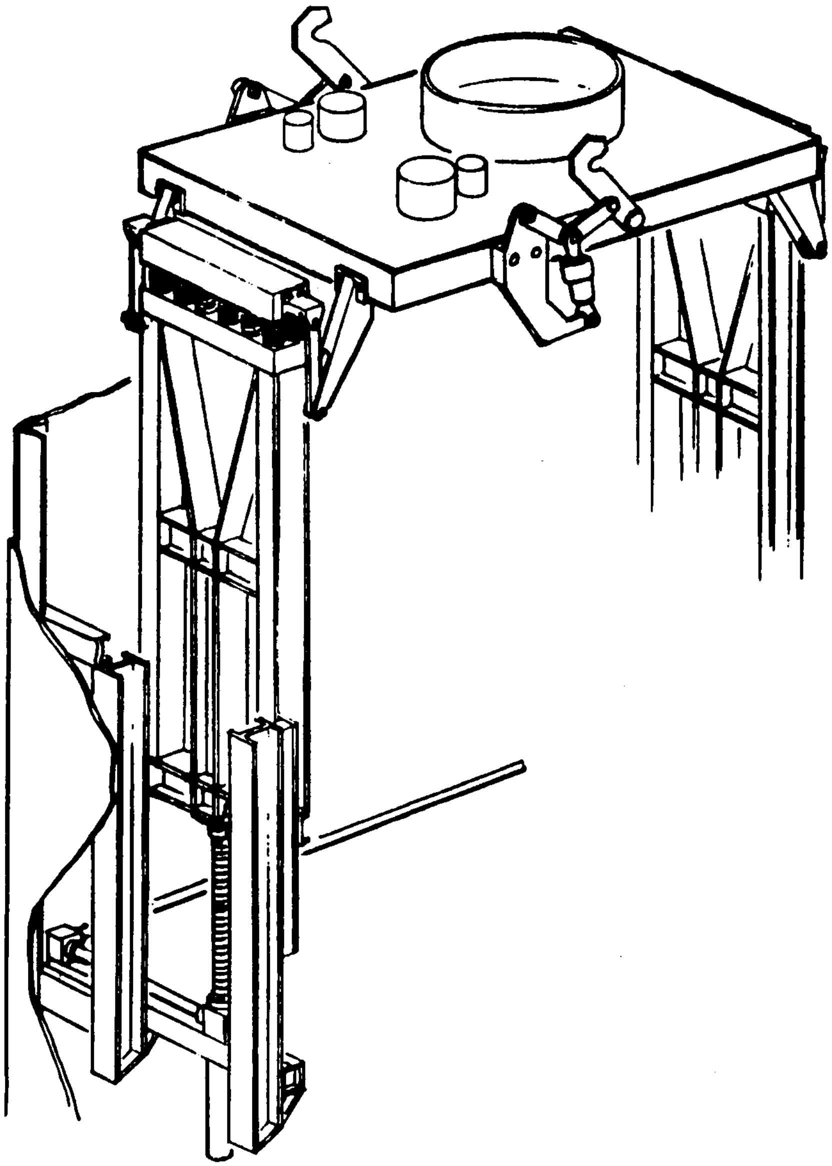

Figure 4-40. Booster Umbilical Handling Concept No. 2, Spring Mounted and Locked to Vehicle

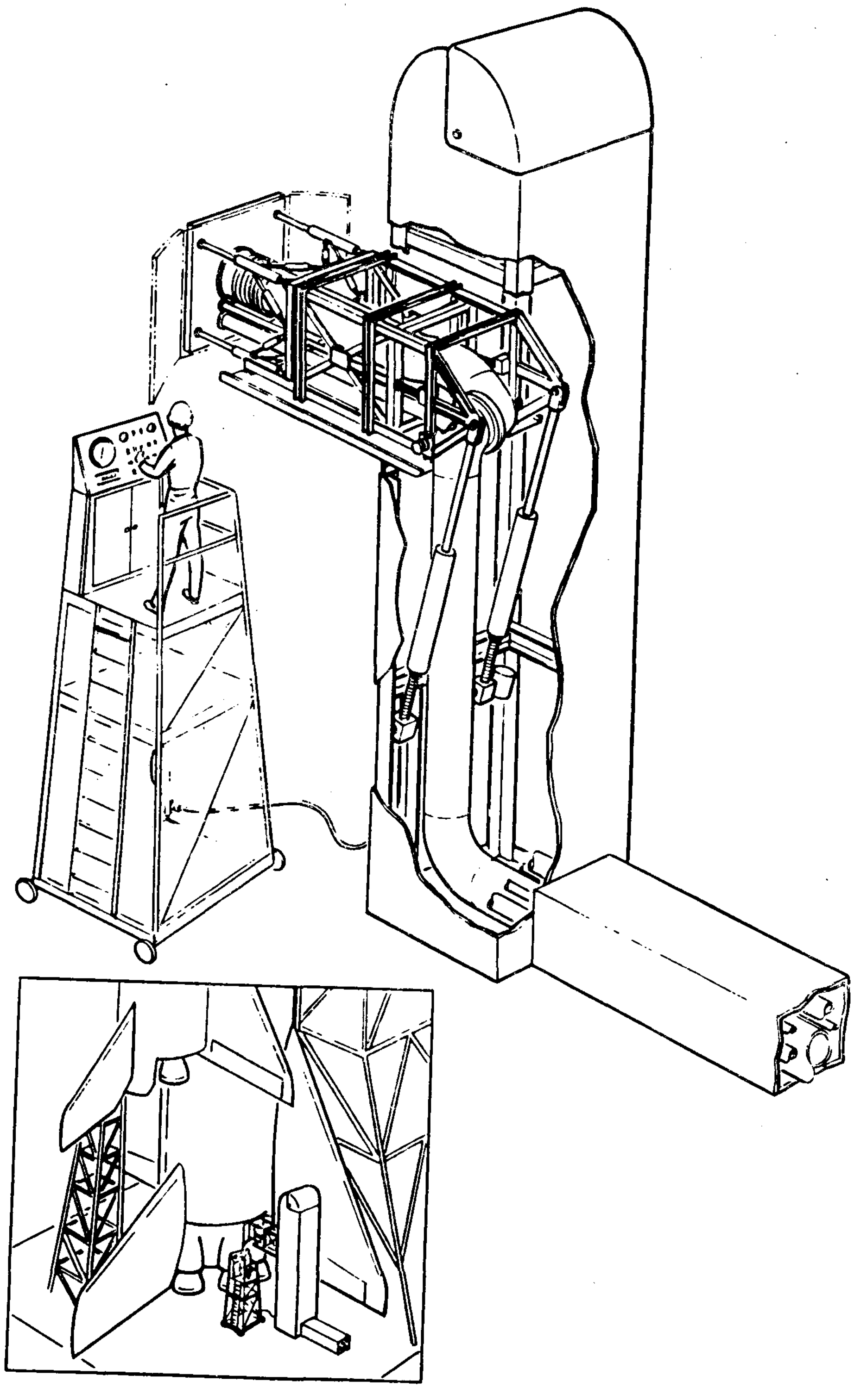

Figure 4-41. Booster Umbilical Handling Concept No. 3, Tail Service Mast (TSM) Type

Table 4-1. Booster Riseoff Umbilical Carrier Concepts

Service	Size (in.)	Type	Operational Pressure (psig)
Concept A			
LH_2 Fill and Drain	10	Slip	90
JP-5 Fill and Drain	3	Ball and Cone	150
GH_2 Fill	1	Slip	1000
GHe Fill	1	Slip	3700
GN_2 Purge	4	Slip	150
Electrical	Rectangular Connector		
Concept B			
LH_2 Fill and Drain	10	Pressure Balance	90
JP-5 Fill and Drain	3	Ball and Cone	150
GH_2 Fill	1	Pressure Balance	1000
GHe Fill	1	Pressure Balance	3700
GN_2 Purge	4	Slip	150
Electrical	Rectangular Connector		
Concept C			
LH_2 Fill and Drain	10	Ball and Cone	90
JP-5 Fill and Drain	3	Ball and Cone	150
GH_2 Fill	1	Pressure Balance	1000
GHe Fill	1	Pressure Balance	3700
GN_2 Purge	4	Slip	150
Electrical	No.40	MS	4 Required

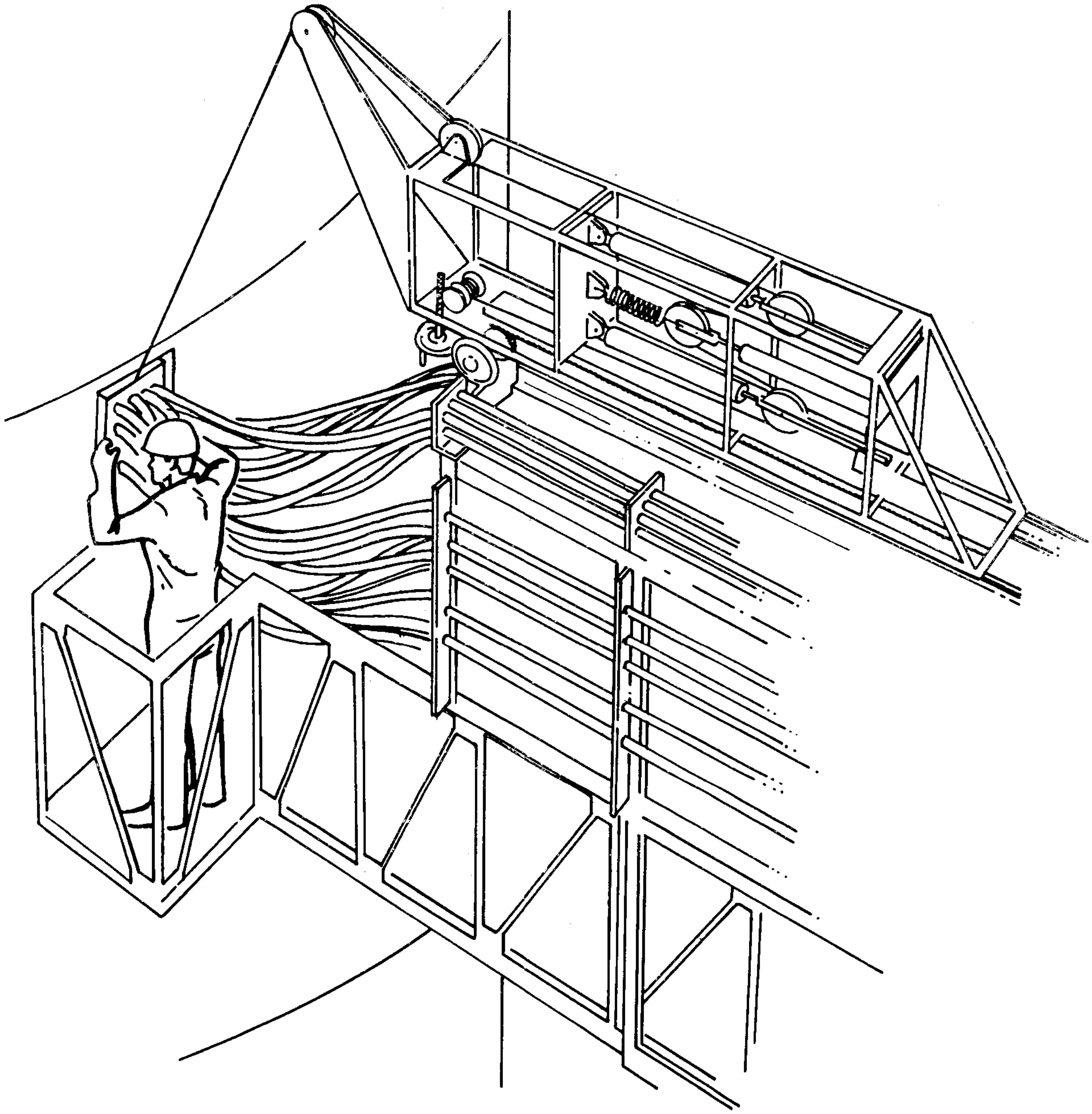

Figure 4-42. Orbiter Umbilical Handling Concept No. 1, Retractable Boom

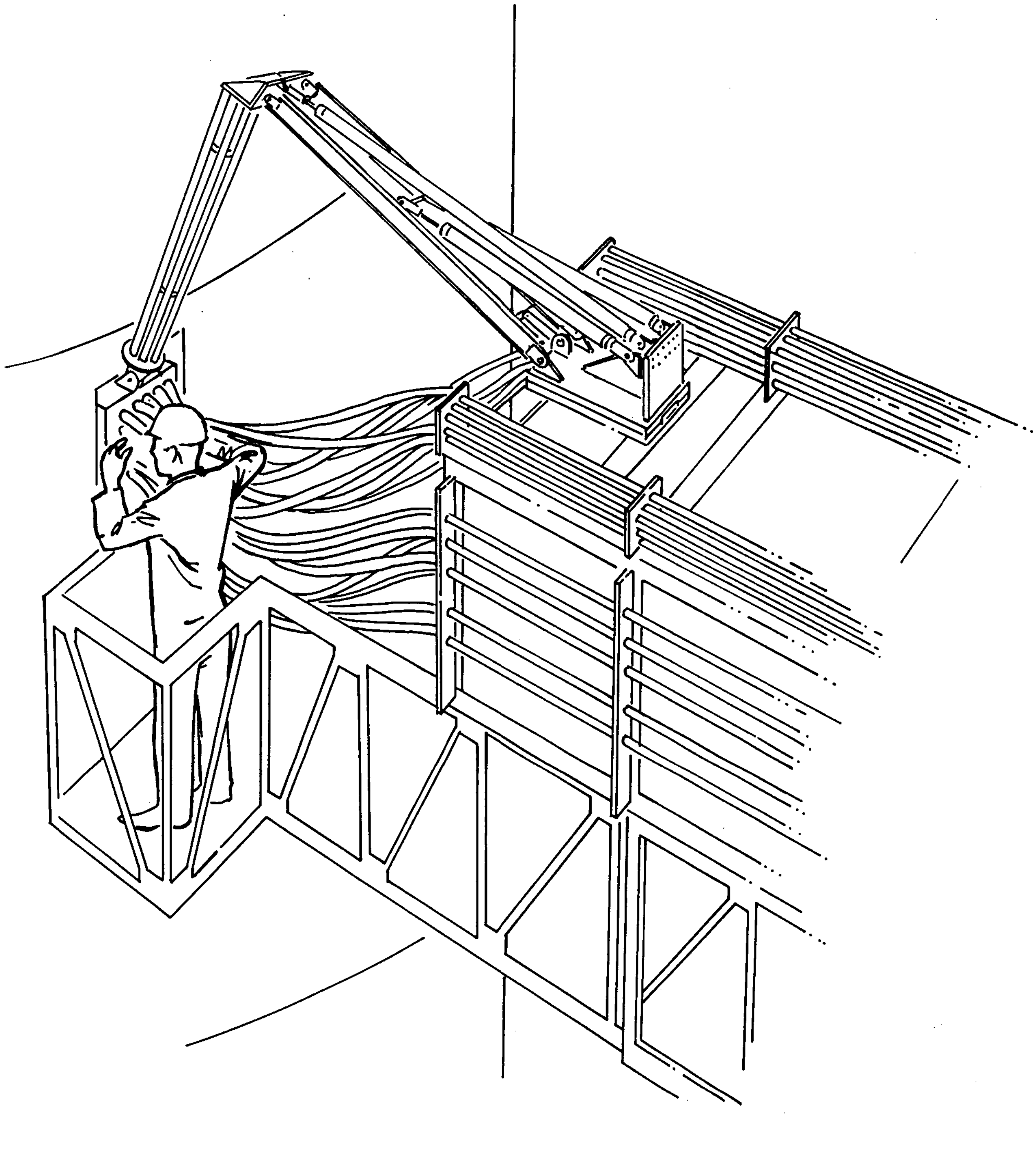

Figure 4-43. Orbiter Umbilical Handling Concept No. 2, Counterbalanced Boom

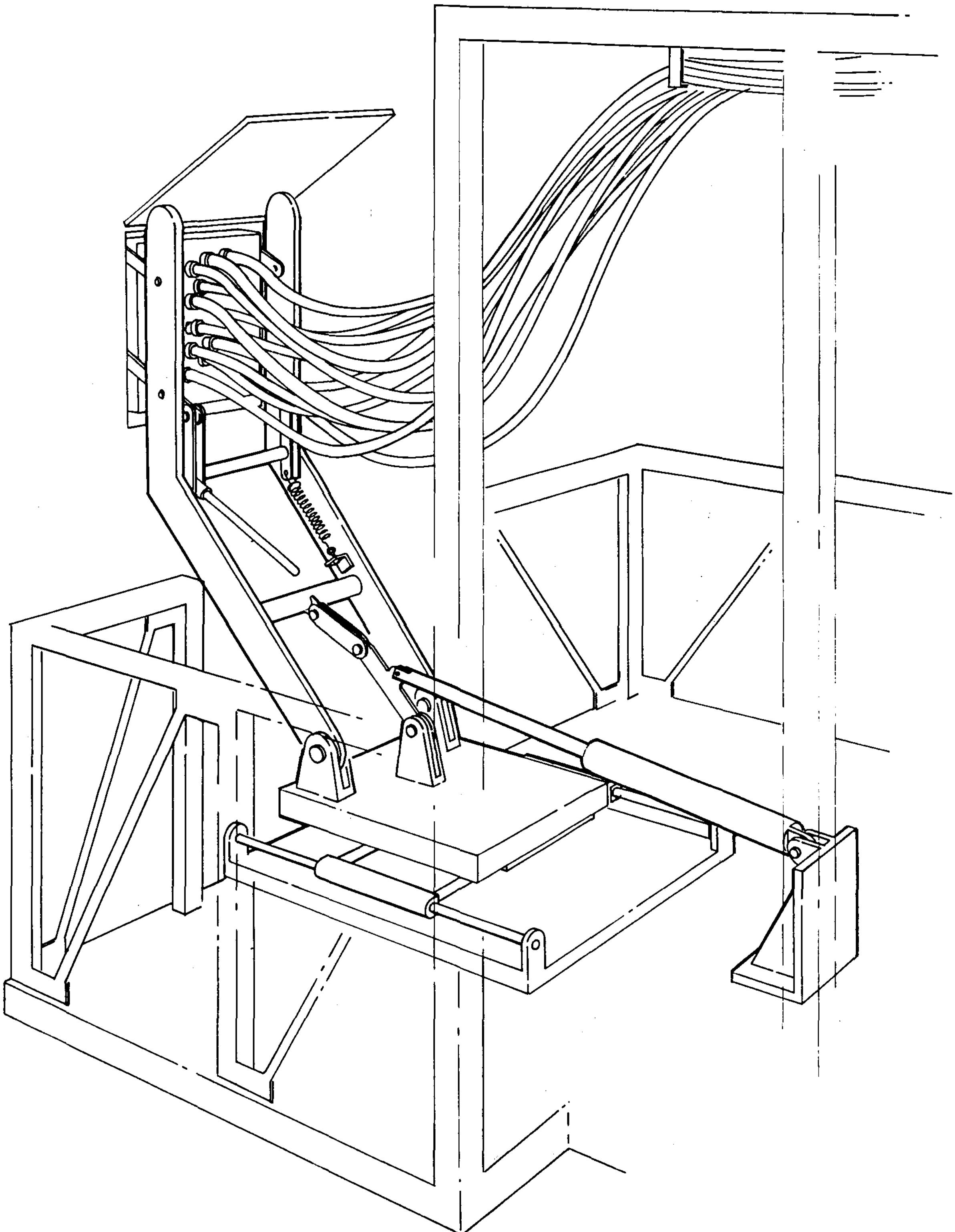

Figure 4-44. Orbiter Umbilical Handling Concept No. 3, Platform Mounted Retracting Arm

4.1 BOOSTER UMBILICAL HANDLING CONCEPT NO. 1, FIXED ELEVATION

This handling concept is characterized primarily by the design features incorporated to accommodate relative motion of the vehicle umbilical carrier (Figure 4-39). The ground carrier is allowed to move horizontally in any direction to track the vehicle carrier motion while it is fixed in elevation. The coupling design, therefore, must be capable of accommodating the vertical relative motion of the vehicle carrier. The amount of vertical relative motion will influence the choice of the coupling concept.

The slip coupling, of course, is capable of accepting the largest vertical excursions. It has been used with success on several vehicle programs. The ball and cone coupling has some advantages over the slip coupling, but it only has limited vertical motion capability, depending on the design of bellows and/or springs.

Another important feature of Concept No. 1 is the use of a screw jack elevating mechanism that provides a rapid engagement or connection capability for the ground carrier. It allows the ground carrier to be lowered out of the way during booster erection on the launcher. This concept will also have provisions to cover the ground carrier and couplings with a blast shield for protection from vehicle engine exhaust blast.

4.2 BOOSTER UMBILICAL HANDLING CONCEPT NO. 2 SPRING MOUNTED - LOCKED TO VEHICLE

The characteristic difference of Concept Number 2 (Figure 4-40) from Concept Number 1 is that the ground carrier tracks the vertical motion of the vehicle carrier as well as the horizontal motion. This, of course, allows a greater selection of coupling types because the design only has to accommodate tolerances and not relative motion. The ball and cone coupling can be used with the only disadvantage being the amount of separation loads generated by the thrust bellows.

The thrust loads from the fluid pressure may be reacted by the spring loads. If this loading produces a structural penalty on the vehicle, then the coupling loads may be reacted internally by locking the ground carrier to the vehicle carrier. The inherent reliability of the unlocked rise off disconnects may be retained by unlocking the locks after the pressure has been reduced and prior to engine start or vehicle release.

4.3 BOOSTER UMBILICAL HANDLING CONCEPT NO. 3 TAIL SERVICE MAST (TSM) TYPE

Concept No. 3 is characterized by the horizontal release direction of the couplings (Figure 4-41). Because the disconnects must be in-flight (required for on-pad abort) and because they must be unlocked and ejected laterally from the vehicle after liftoff, the carrier lock(s) must have primary, secondary, and tertiary release modes (fail operational/fail operational).

Because there is no relative motion between the ground and vehicle carriers, the choice of couplings is not limited thereby.

Included as part of the Concept No. 3 is the articulation necessary to retract the mast out of the way during booster erection. Provisions are incorporated for local manual control of the mechanisms to allow rapid engagement of the ground carrier to the vehicle carrier. The retraction of the mast also provides protection of the ground system from vehicle engine exhaust blast.

This concept is advantageous when space limitations preclude the use of either of the riseoff concepts (Concept Numbers 1 and 2).

4.4 ORBITER UMBILICAL HANDLING CONCEPT NO. 1, RETRACTABLE BOOM

Concept No. 1 for handling the orbiter umbilical carrier is comprised of a roller-mounted retractable boom atop the service arm. The umbilical carrier is supported from the boom by a lanyard with the boom extended for umbilical carrier installation. The umbilical carrier is released and ejected from the vehicle pneumatically. Upon release signal, the lanyard is retracted by pneumatic cylinders mounted on the boom. Extension and retraction of the boom is accomplished manually with a rack and pinion and hand wheel. Adjustment of the lanyard for supporting the umbilical carrier during mating is accomplished manually with a hand wheel driving a worm gear reel.

4.5 ORBITER UMBILICAL HANDLING CONCEPT NO. 2, COUNTERBALANCED BOOM

Concept No. 2 for handling the orbiter umbilical carrier consists of a spring counter-balanced boom mounted atop the service arm. The umbilical carrier is attached to a the boom by a limited motion universal coupling thus providing stability to the umbilical housing during installation and retraction.

The counterbalance springs are adjusted to support the weight of the umbilical housing thus providing ease of handling during installation and without imposing a significant load to the vehicle structure.

The umbilical carrier is pneumatically ejected prior to vehicle liftoff. The signal provided for the ejection of the carrier also provides the signal to pneumatically pressurize the retraction cylinder on the boom. When the retraction is completed the service arm can then be retracted to the tower and secured for liftoff.

4.6 ORBITER UMBILICAL HANDLING CONCEPT NO. 3, PLATFORM MOUNTED RETRACTING ARM

Concept No. 3 for handling the orbiter umbilical carrier consists of a platform mounted retracting arm with a floating base to allow tracking of vehicle motions.

The umbilical carrier is mounted on links from the retracting arm with a manual positioning handle for vertical alignment during connect. Disconnect and ejection of the carrier from the vehicle is by pneumatic actuation. The floating base is mounted on parallel guide rods with ball bushings for friction free motion in a horizontal plane. Retraction of the arm is accomplished by a pneumatic cylinder actuated by the carrier release signal. An alternate method of mounting the retract cylinder positions the cylinder below the floating base and detaches the cylinder rod from the base so that the cylinder rod does not have to travel with the vehicle motions. As the cylinder is actuated it pushes the base away from the vehicle and a link attached to the retracting arm causes the arm to pivot vertically and retract as the base continues moving.

SECTION 5

CONCEPT EVALUATION AND TRADEOFF ANALYSIS

Figures 5-1 and 5-2 are block diagrams that illustrate the flow for concept selection. It is recognized that more combinations are possible than shown, however, those shown are considered the most compatible combinations. The portion of the block diagram showing the selected electrical connector flow applies also to the selection of fluid connectors as well as to locking and release devices.

5.1 CRYOGENIC COUPLINGS (UNWEIGHTED)

Relative ranking numbers are shown in Table 5-1 for each parameter for the concepts under consideration. Each concept provides a vent port between the dual seals for vent or drain and monitoring of leakage past the primary seal.

5.2 CRYOGENIC COUPLINGS (WEIGHTED)

The ball and cone coupling with bellows and dual ring seal is ranked the highest due to its successful usage history for both LO_2 and LH_2, and its maintenance characteristics. (See Table 5-2).

5.3 HIGH PRESSURE PNEUMATIC AND HYDRAULIC COUPLINGS (UNWEIGHTED)

Relative ranking numbers are shown in Table 5-3 for each parameter for the concepts under consideration.

5.4 HIGH PRESSURE PNEUMATIC AND HYDRAULIC COUPLINGS (WEIGHTED)

The slip coupling with O-ring seals attained the highest ranking due to its successful usage history and general simplicity. (See Table 5-4.)

5.5 LOW PRESSURE PNEUMATIC, H_2O GLYCOL, AND JP-5 COUPLINGS (UNWEIGHTED)

Relative ranking numbers are shown in Table 5-5 for each evaluation parameter for the coupling concepts under consideration. Couplings with dual seals incorporate a vent port between the seals for vent or drain and monitoring of leakage past the primary seal. The slip coupling with O-rings is not suitable for cold gas venting.

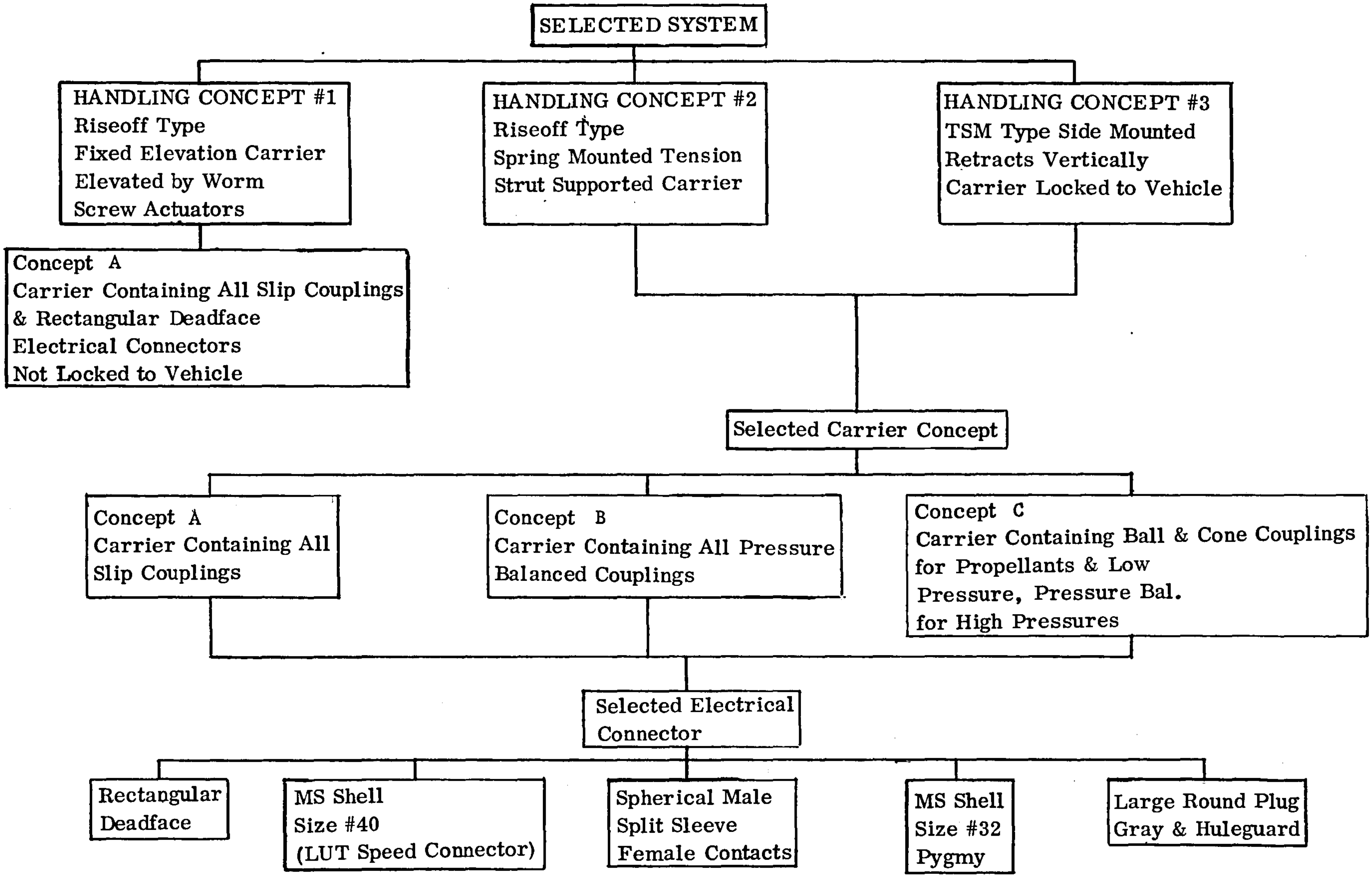

Figure 5-1. Booster Umbilical System Selection

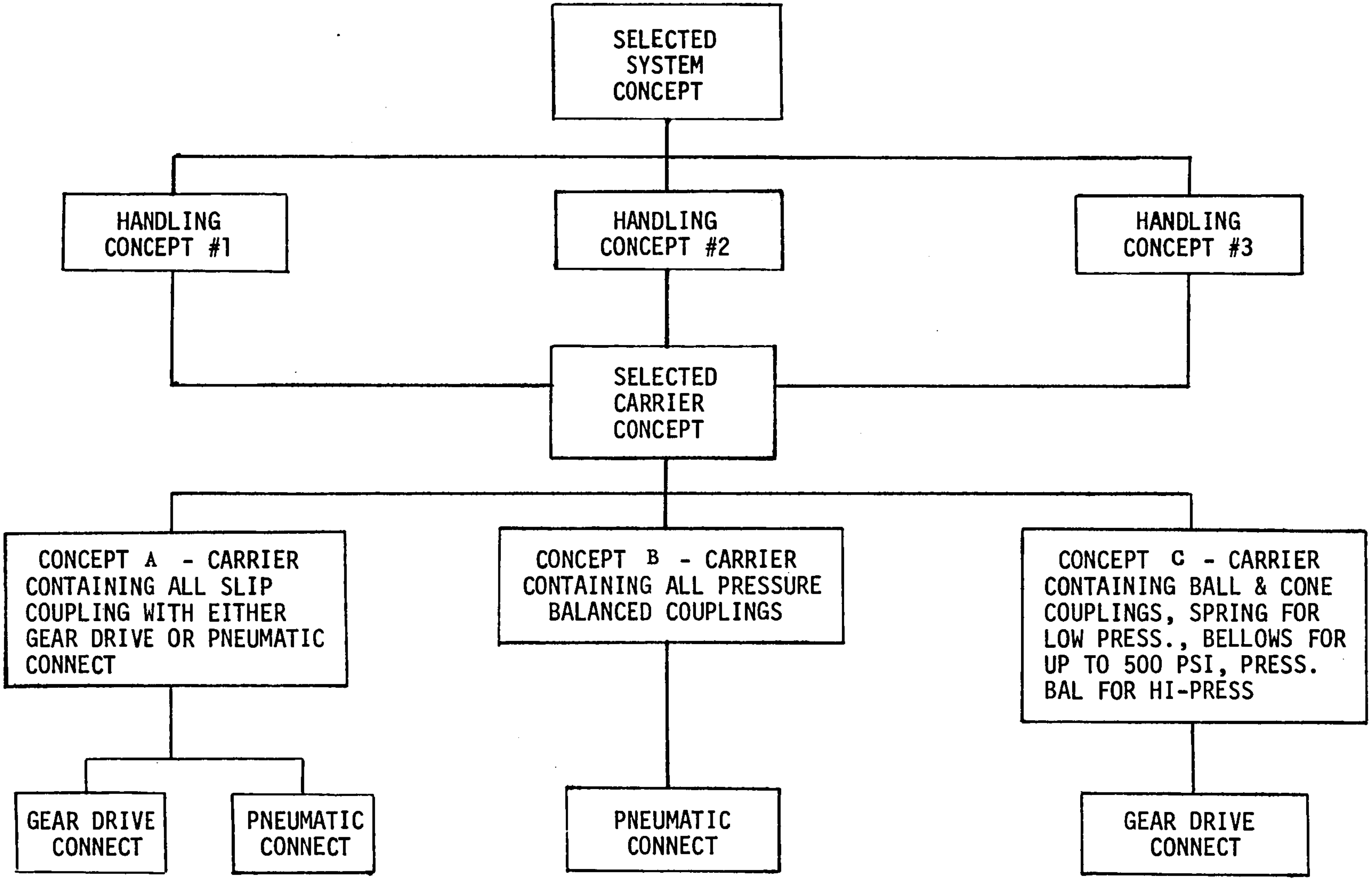

Figure 5.2. Orbiter Umbilical System Selection

Table 5-1. Cryogenic Couplings (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Ball & Cone with Bellows Dual Ring Seal	Ball & Cone-Bellows Primary-Ring Seal Second.-SF Lip Seal	Slip-Dual SF Lip Seal	Slip Prim.-Chevron Second.-SF Lip	Press. Bal. Dual Lip Seals	Semi-Press. Bal Conical-Dual SF Lip Seals
		TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)							
		VERIFICATION OF CONNECT		9	9	10	9	6	5
		ALIGNMENT REQUIREMENTS		10	9	8	7	7	9
		ADJUSTMENT REQUIREMENTS		8	8	9	5	6	5
CONNECT AND VERIFY	25%	CONNECT FORCE REQUIRED		6	7	8	9	9	10
		POSSIBILITY OF DAMAGE TO COMPONENTS		10	9	8	8	7	6
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)							
		PERSONNEL (CREW) REQUIRED							
		SAFETY (PERSONNEL)							
		EASE OF REPLACEMENT		10	9	9	8	8	7
		OPERATIONAL LIFE (WEAR RESISTANCE)		9	8	8	7	6	5
		ACCESSIBILITY FOR MAINTENANCE		9	9	9	8	7	7
MAINTAINABILITY	30%	EASE OF COMPONENT REFURBISHMENT		9	7	6	6	6	6
		LUBRICATION REQUIRED							
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)							
		SIZE		7	9	9	8	4	5
		CONFIDENCE IN DESIGN (EXPERIENCE)		9	8	8	6	7	6
		REDUNDANCY PROVIDED							
		FAILURE TO CONNECT		10	9	9	9	7	7
		FAILURE TO DISCONNECT		10	9	8	7	7	6
RELIABILITY	35%	FAILURE TO OPEN							
		FAILURE TO CLOSE							
		INADVERTENT CLOSURE							
		CONTAMINATION TRAPS							
		NUMBER OF PARTS		10	9	9	7	7	6
		COST		6	7	8	8	4	7
		WEIGHT (VEHICLE)		8	10	10	6	4	5
COST	10%	LOAD IMPOSED ON VEHICLE		3	5	6	5	10	8
		SIZE							
		WEIGHT (GROUND)							
	100%	TOTAL							

Table 5-2. Cryogenic Couplings (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Ball & Cone with Bellows Dual Ring Seal	Ball & Cone-Bellows Primary-Ring Seal Second.-SF Lip Seal	Slip-Dual SF Lip Seal	Slip Prim.-Chevron Second.-SF Lip	Press. Bal. Dual Lip Seals	Semi-Press. Bal Conical-Dual SF Lip Seals
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)							
		VERIFICATION OF CONNECT	7	63	63	70	63	42	35
		ALIGNMENT REQUIREMENTS	5	50	45	40	35	35	45
		ADJUSTMENT REQUIREMENTS	5	40	40	45	25	30	25
		CONNECT FORCE REQUIRED	3	18	21	24	27	27	10
		POSSIBILITY OF DAMAGE TO COMPONENTS	5	50	45	40	40	35	30
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)							
		PERSONNEL (CREW) REQUIRED							
		SAFETY (PERSONNEL)							
MAINTAINABILITY	30%	EASE OF REPLACEMENT	8	80	72	72	64	64	56
		OPERATIONAL LIFE (WEAR RESISTANCE)	3	27	24	24	21	18	15
		ACCESSIBILITY FOR MAINTENANCE	7	63	63	63	56	49	49
		EASE OF COMPONENT REFURBISHMENT	9	81	63	54	54	54	54
		LUBRICATION REQUIRED							
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)							
		SIZE	3	21	27	27	24	12	15
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	15	135	120	120	90	105	90
		REDUNDANCY PROVIDED							
		FAILURE TO CONNECT	5	50	45	45	45	35	35
		FAILURE TO DISCONNECT	10	100	90	80	70	70	60
		FAILURE TO OPEN							
		FAILURE TO CLOSE							
		INADVERTENT CLOSURE							
		CONTAMINATION TRAPS							
		NUMBER OF PARTS	5	50	45	45	35	35	30
COST	10%	COST	5	30	35	40	40	20	35
		WEIGHT (VEHICLE)	3	24	30	30	18	12	15
		LOAD IMPOSED ON VEHICLE	2	6	10	12	10	20	16
		SIZE							
		WEIGHT (GROUND)							
	100%	TOTAL		888	838	831	717	663	615

Table 5-3. High Pressure Pneumatic and Hydraulic Couplings (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Slip-Dual SF Lip Seal	Slip Prim.-Chevron Second.-SF Lip	Press. Bal. Dual Lip Seals	Slip Dual O-Ring
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)					
		VERIFICATION OF CONNECT		10	7	6	10
		ALIGNMENT REQUIREMENTS		9	8	5	10
		ADJUSTMENT REQUIREMENTS		10	5	6	10
		CONNECT FORCE REQUIRED		9	5	8	10
		POSSIBILITY OF DAMAGE TO COMPONENTS		8	7	8	9
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD. ELECT)					
		PERSONNEL (CREW) REQUIRED					
		SAFETY (PERSONNEL)					
MAINTAINABILITY	30%	EASE OF REPLACEMENT		8	6	7	10
		OPERATIONAL LIFE (WEAR RESISTANCE)		8	6	6	9
		ACCESSIBILITY FOR MAINTENANCE		9	6	7	10
		EASE OF COMPONENT REFURBISHMENT		8	4	6	10
		LUBRICATION REQUIRED					
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)					
		SIZE		7	7	5	10
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)		5	6	8	10
		REDUNDANCY PROVIDED					
		FAILURE TO CONNECT		9	8	6	10
		FAILURE TO DISCONNECT		8	6	7	10
		FAILURE TO OPEN					
		FAILURE TO CLOSE					
		INADVERTENT CLOSURE					
		CONTAMINATION TRAPS					
		NUMBER OF PARTS		7	6	8	10
COST	10%	COST		8	8	6	10
		WEIGHT (VEHICLE)		10	10	7	10
		LOAD IMPOSED ON VEHICLE		6	6	10	6
		SIZE					
		WEIGHT (GROUND)					
	100%	TOTAL					

Table 5-4. High Pressure Pneumatic and Hydraulic Couplings (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Slip-Dual SF Lip Seal	Slip Prim.-Chevron Second.-SF Lip	Press. Bal. Dual Lip Seals	Slip Dual O-Ring
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)					
		VERIFICATION OF CONNECT	7	70	49	42	70
		ALIGNMENT REQUIREMENTS	5	45	40	25	50
		ADJUSTMENT REQUIREMENTS	5	50	25	30	50
		CONNECT FORCE REQUIRED	3	27	15	24	30
		POSSIBILITY OF DAMAGE TO COMPONENTS	5	40	35	40	45
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)					
		PERSONNEL (CREW) REQUIRED					
		SAFETY (PERSONNEL)					
MAINTAINABILITY	30%	EASE OF REPLACEMENT	6	64	48	56	80
		OPERATIONAL LIFE (WEAR RESISTANCE)	3	24	18	18	27
		ACCESSIBILITY FOR MAINTENANCE	7	63	42	49	70
		EASE OF COMPONENT REFURBISHMENT	9	72	36	54	90
		LUBRICATION REQUIRED					
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)					
		SIZE	3	21	21	15	30
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	15	75	90	120	150
		REDUNDANCY PROVIDED					
		FAILURE TO CONNECT	5	45	40	30	50
		FAILURE TO DISCONNECT	10	80	60	70	100
		FAILURE TO OPEN					
		FAILURE TO CLOSE					
		INADVERTENT CLOSURE					
		CONTAMINATION TRAPS					
		NUMBER OF PARTS	5	35	30	40	50
COST	10%	COST	5	40	40	30	50
		WEIGHT (VEHICLE)	3	30	30	21	30
		LOAD IMPOSED ON VEHICLE	2	12	12	20	12
		SIZE					
		WEIGHT (GROUND)					
	100%	TOTAL		793	631	684	984

Table 5-5. Low Pressure Pneumatic, H_2O Glycol, and JP-5 Couplings (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Ball & Cone with Bellows Dual Ring Seal	Ball & Cone-Bellows Primary-Ring Seal Second.-SF Lip Seal	Slip-Dual SF Lip Seal	Slip Prim.-Chevron Second.-SF Lip	Ball & Cone with Spring, Ring Seal	Slip Dual O-Ring
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)							
		VERIFICATION OF CONNECT		10	10	10	9	8	8
		ALIGNMENT REQUIREMENTS		10	8	7	7	10	8
		ADJUSTMENT REQUIREMENTS		10	10	9	8	7	9
		CONNECT FORCE REQUIRED		9	9	8	6	7	8
		POSSIBILITY OF DAMAGE TO COMPONENTS		7	7	9	8	9	10
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)							
		PERSONNEL (CREW) REQUIRED							
		SAFETY (PERSONNEL)							
MAINTAINABILITY	30%	EASE OF REPLACEMENT		9	7	9	6	10	10
		OPERATIONAL LIFE (WEAR RESISTANCE)		8	8	9	9	10	10
		ACCESSIBILITY FOR MAINTENANCE		8	6	7	6	10	10
		EASE OF COMPONENT REFURBISHMENT		10	7	6	5	10	10
		LUBRICATION REQUIRED							
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)							
		SIZE		7	7	9	9	8	10
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)		10	7	6	5	9	10
		REDUNDANCY PROVIDED							
		FAILURE TO CONNECT		9	7	7	5	10	8
		FAILURE TO DISCONNECT		10	9	8	6	10	9
		FAILURE TO OPEN							
		FAILURE TO CLOSE							
		INADVERTENT CLOSURE							
		CONTAMINATION TRAPS							
		NUMBER OF PARTS		9	7	6	5	8	10
COST	10%	COST		8	7	7	6	9	10
		WEIGHT (VEHICLE)		8	8	10	10	9	10
		LOAD IMPOSED ON VEHICLE		7	7	10	9	9	10
		SIZE							
		WEIGHT (GROUND)							
	100%	TOTAL							

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5.6 LOW PRESSURE PNEUMATIC, H_2O GLYCOL, AND JP-5 COUPLINGS (WEIGHTED)

The slip coupling with O-rings attained the highest ranking due to its overall simplicity and history of successful usage. It is not suitable, however, for cold gases. The ball and cone coupling with a spring and single ring seal is suitable for cold gases, but the ball and cone coupling with dual ring seals is a better choice for hazardous cold gases. (See Table 5-6).

5.7 LOCKING AND RELEASE DEVICE EVALUATION (UNWEIGHTED)

Each of the devices under consideration incorporates a pneumatic actuation device as an integral part with the exception of the hook latch which uses an external cylinder. Again, individual differences in the assigned relative ranking numbers are not great, however, the sum total after applying the weighting factors on the matrix presented in Table 5-7 shows greater differences in the relative merits of each.

5.8 LOCKING AND RELEASE DEVICE EVALUATION (WEIGHTED)

The collet locking and release device ranked the highest with the 4-ball male locking device next. The primary factors that cause the collet to be the higher ranked are: better load distribtuon, less wear due to brinneling, and ease of holding critical tolerances during fabrication. The self-cocking feature is also more easily incorporated into the collet device thus facilitating ease of connection. (See Table 5-8).

While it is recognized that the 4-ball male locking device is widely used on Saturn 5 - Apollo, it is recognized that collet locking devices have also been used to a considerable extent. Hardware experience on Convair Aerospace's many and varied programs has resulted in a basic distrust in the use of ball locking devices. Component failures have resulted in impact ranging all the way from nuisance items to the actual loss of an Atlas-Centaur vehicle.

The relative ranking numbers shown on the matrices represent, to a certain extent, a subjective evaluation. The numbers shown essentially reflect the Convair Aerospace attitude regarding ball locking devices, beginning at the higher levels of engineering management.

5.9 ELECTRICAL CONNECTOR EVALUATION (UNWEIGHTED)

The relative ranking numbers appearing for each parameter in columns for each type connector under consideration are shown in Table 5-9. In order to evaluate the connectors on a common baseline, the number of connectors required to provide a minimum of 12 each No. 1/0 contacts and 120 each No. 16 contacts is identified.

Table 5-6. Low Pressure Pneumatic, H_2O Glycol, and JP-5 Couplings (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Ball & Cone with Bellows Dual Ring Seal	Ball & Cone-Bellows Primary-Ring Seal Second.-SF Lip Seal	Slip-Dual SF Lip Seal	Slip Prim.-Chevron Second.-SF Lip	Ball & Cone with Spring, Ring Seal	Slip Dual O-Ring
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)							
		VERIFICATION OF CONNECT	7	70	70	70	63	56	56
		ALIGNMENT REQUIREMENTS	5	50	40	35	35	50	40
		ADJUSTMENT REQUIREMENTS	5	50	50	45	40	35	45
		CONNECT FORCE REQUIRED	3	27	27	24	18	21	24
		POSSIBILITY OF DAMAGE TO COMPONENTS	5	35	35	45	40	45	50
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD. ELECT)							
		PERSONNEL (CREW) REQUIRED							
		SAFETY (PERSONNEL)							
MAINTAINABILITY	30%	EASE OF REPLACEMENT	8	72	56	72	48	80	80
		OPERATIONAL LIFE (WEAR RESISTANCE)	3	24	24	27	27	30	30
		ACCESSIBILITY FOR MAINTENANCE	7	56	42	49	42	70	70
		EASE OF COMPONENT REFURBISHMENT	9	90	63	54	45	90	90
		LUBRICATION REQUIRED							
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)							
		SIZE	3	21	21	27	27	24	30
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	15	150	105	90	75	135	150
		REDUNDANCY PROVIDED							
		FAILURE TO CONNECT	5	45	35	35	25	50	40
		FAILURE TO DISCONNECT	10	100	90	80	60	100	90
		FAILURE TO OPEN							
		FAILURE TO CLOSE							
		INADVERTENT CLOSURE							
		CONTAMINATION TRAPS							
		NUMBER OF PARTS	5	45	35	30	25	40	50
COST	10%	COST	5	40	35	35	30	45	50
		WEIGHT (VEHICLE)	3	24	24	30	30	27	30
		LOAD IMPOSED ON VEHICLE	2	14	14	20	18	18	20
		SIZE							
		WEIGHT (GROUND)							
	100%	TOTAL		913	766	768	648	916	945

Table 5-7. Locking and Release Device (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	4-Ball Lock Male	Toggle Lock	Finger Lock	Hook Latch	Collet Lock	Ball Lock Female	Spring Latch
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)								
		VERIFICATION OF CONNECT		10	8	8	10	10	9	9
		ALIGNMENT REQUIREMENTS		10	9	8	8	10	7	6
		ADJUSTMENT REQUIREMENTS		9	8	8	7	9	9	7
		CONNECT FORCE REQUIRED								
		POSSIBILITY OF DAMAGE TO COMPONENTS		10	8	8	10	10	8	7
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)								
		PERSONNEL (CREW) REQUIRED								
		SAFETY (PERSONNEL)		9	7	7	9	10	8	7
MAINTAINABILITY	30%	EASE OF REPLACEMENT		10	10	8	7	10	8	7
		OPERATIONAL LIFE (WEAR RESISTANCE)		8	8	8	9	10	7	7
		ACCESSIBILITY FOR MAINTENANCE								
		EASE OF COMPONENT REFURBISHMENT		10	8	7	8	9	7	7
		LUBRICATION REQUIRED		9	7	7	10	9	8	7
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)								
		SIZE		8	7	7	6	9	7	6
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)		9	8	8	8	10	7	5
		REDUNDANCY PROVIDED								
		FAILURE TO CONNECT		10	8	8	10	10	9	6
		FAILURE TO DISCONNECT		9	8	8	9	10	8	5
		FAILURE TO OPEN								
		FAILURE TO CLOSE								
		INADVERTENT CLOSURE								
		CONTAMINATION TRAPS								
		NUMBER OF PARTS								
COST	10%	COST		9	7	7	10	8	7	7
		WEIGHT (VEHICLE)		9	8	8	7	10	8	8
		LOAD IMPOSED ON VEHICLE								
		SIZE								
		WEIGHT (GROUND)								
	100%	TOTAL								

Table 5-8. Locking and Release Device (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	4-Ball Lock Male	Toggle Lock	Finger Lock	Hook Latch	Collet Lock	Ball Lock Female	Spring Latch
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)								
		VERIFICATION OF CONNECT	5	50	40	40	50	50	45	45
		ALIGNMENT REQUIREMENTS	5	50	45	40	40	50	35	30
		ADJUSTMENT REQUIREMENTS	5	45	40	40	35	45	45	35
		CONNECT FORCE REQUIRED								
		POSSIBILITY OF DAMAGE TO COMPONENTS	5	50	40	40	50	50	40	35
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU. HYD, ELECT)								
		PERSONNEL (CREW) REQUIRED								
		SAFETY (PERSONNEL)	5	45	35	35	45	50	40	35
MAINTAINABILITY	30%	EASE OF REPLACEMENT	7	70	70	56	49	70	56	49
		OPERATIONAL LIFE (WEAR RESISTANCE)	5	40	40	40	45	50	35	35
		ACCESSIBILITY FOR MAINTENANCE								
		EASE OF COMPONENT REFURBISHMENT	8	80	64	56	64	72	56	56
		LUBRICATION REQUIRED	5	45	35	35	50	45	40	35
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)								
		SIZE	5	40	35	35	30	45	35	30
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	20	180	160	160	160	200	140	100
		REDUNDANCY PROVIDED								
		FAILURE TO CONNECT	5	50	40	40	50	50	45	30
		FAILURE TO DISCONNECT	10	90	80	80	90	100	80	50
		FAILURE TO OPEN								
		FAILURE TO CLOSE								
		INADVERTENT CLOSURE								
		CONTAMINATION TRAPS								
		NUMBER OF PARTS								
COST	10%	COST	3	27	21	21	30	24	21	21
		WEIGHT (VEHICLE)	7	63	56	56	49	70	56	56
		LOAD IMPOSED ON VEHICLE								
		SIZE								
		WEIGHT (GROUND)								
	100%	TOTAL		925	801	774	837	971	769	642

Table 5-9. Electrical Connector (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Rectangular Deadface Connector (Cannon)	MS Shell Size #40 (Cannon)	Spherical Male, Split Sleeve Female Contacts	MS Shell #32 Pygmy	Large Round Plug (Gray & Huleguard)
		TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)						
		VERIFICATION OF CONNECT		9	6	9	4	9
		ALIGNMENT REQUIREMENTS		9	6	10	4	7
		ADJUSTMENT REQUIREMENTS						
CONNECT AND VERIFY	25%	CONNECT FORCE REQUIRED		8	9	10	9	8
		POSSIBILITY OF DAMAGE TO COMPONENTS		8	6	9	4	7
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD. ELECT)						
		PERSONNEL (CREW) REQUIRED						
		SAFETY (PERSONNEL)						
		EASE OF REPLACEMENT		9	5	7	6	7
		OPERATIONAL LIFE (WEAR RESISTANCE)		8	6	9	6	7
		ACCESSIBILITY FOR MAINTENANCE						
MAINTAINABILITY	30%	EASE OF COMPONENT REFURBISHMENT						
		LUBRICATION REQUIRED						
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)		10	2	9	2	6
		SIZE		2 Req'd 9	5 Req'd 8	2 Req'd 7	6 Req'd10	2 Req'd 7
		CONFIDENCE IN DESIGN (EXPERIENCE)		9	9	5	6	6
		REDUNDANCY PROVIDED						
		FAILURE TO CONNECT		8	4	9	4	7
		FAILURE TO DISCONNECT		9	8	10	8	8
RELIABILITY	35%	FAILURE TO OPEN						
		FAILURE TO CLOSE						
		INADVERTENT CLOSURE						
		CONTAMINATION TRAPS						
		NUMBER OF PARTS						
		COST		9	8	7	10	7
		WEIGHT (VEHICLE)		9	8	7	10	7
COST	10%	LOAD IMPOSED ON VEHICLE						
		SIZE						
		WEIGHT (GROUND)						
	100%	TOTAL						

5.10 ELECTRICAL CONNECTOR EVALUATION (WEIGHTED)

A weighting factor has been applied to the relative ranking numbers assigned for each parameter shown in Table 5-10. Those parameters that have more bearing on the selection of a final concept carry the highest weighting factor.

Primary factor influencing the higher ranking of the rectangular deadface connector are: lower possibility of inflight damage, fewer required, each connector contains aligning pins, and ease of replacement of the deadface panel. Confidence in design for both the rectangular deadface and MS shell size No. 40 connectors ranked high since the former is used on Atlas, Polaris, and Poseidon and the latter on Saturn and previously on Jupiter.

5.11 DEBRIS PROTECTION (UNWEIGHTED)

The relative ranking numbers for those parameters that affect a decision on selection of the most attractive debris protection method are shown in Table 5-11. A summation with weighting factors applied is shown in Table 5-12.

5.12 DEBRIS PROTECTION (WEIGHTED)

The internally actuated poppets attained the highest relative ranking primarily due to confidence in design based on past experience. Externally actuated devices rank lowest due to additional actuation systems required. (See Table 5-12).

5.13 DEBRIS PROTECTION METHOD COMPATIBILITY

Table 5-13 is a chart that identifies the debris protection methods that are compatible with each of the couplings under consideration. An "X" indicates design compatibility while a blank indicates that the closure is not compatible with a given coupling.

5.14 BOOSTER UMBILICAL CARRIERS (UNWEIGHTED)

Table 5-14 shows the relative ranking numbers for each parameter for the concepts under consideration.

5.15 BOOSTER UMBILICAL CARRIERS (WEIGHTED)

Concept A attained the highest ranking although it ranked only 13 points above Concept C. (See Table 5-15). Both Concepts A and C are appreciably higher than Concept B. Factors contributing to the higher ranking of Concept A are: overall simplicity, lower cost, easier component refurbishment, lower connect force required, and lower loads imposed on the vehicle.

5.16 BOOSTER UMBILICAL HANDLING CONCEPTS (UNWEIGHTED)

Relative ranking numbers for each parameter for the concepts under consideration are shown in Table 5-16.

Table 5-10. Electrical Connector (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Rectangular Deadface Connector (Cannon)	MS Shell Size #40 (Cannon)	Spherical Male, Split Sleeve Female Contacts	MS Shell #32 Pygmy	Large Round Plug (Gray & Huleguard)
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)						
		VERIFICATION OF CONNECT	10	90	60	90	40	90
		ALIGNMENT REQUIREMENTS	5	45	30	50	20	35
		ADJUSTMENT REQUIREMENTS						
		CONNECT FORCE REQUIRED	5	40	45	50	45	40
		POSSIBILITY OF DAMAGE TO COMPONENTS	5	40	30	45	20	35
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)						
		PERSONNEL (CREW) REQUIRED						
		SAFETY (PERSONNEL)						
MAINTAINABILITY	30%	EASE OF REPLACEMENT	10	90	50	70	60	70
		OPERATIONAL LIFE (WEAR RESISTANCE)	10	80	60	90	60	70
		ACCESSIBILITY FOR MAINTENANCE						
		EASE OF COMPONENT REFURBISHMENT						
		LUBRICATION REQUIRED						
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)	5	50	10	45	10	30
		SIZE	5	45	40	35	50	35
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	20	180	180	100	120	120
		REDUNDANCY PROVIDED						
		FAILURE TO CONNECT	5	40	20	45	20	35
		FAILURE TO DISCONNECT	10	90	80	100	80	80
		FAILURE TO OPEN						
		FAILURE TO CLOSE						
		INADVERTENT CLOSURE						
		CONTAMINATION TRAPS						
		NUMBER OF PARTS						
COST	10%	COST	8	64	72	56	80	56
		WEIGHT (VEHICLE)	2	18	16	14	20	14
		LOAD IMPOSED ON VEHICLE						
		SIZE						
		WEIGHT (GROUND)						
	100%	TOTAL		872	693	790	625	710

Table 5-11. Debris Protection (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Poppets Internally Actuated	Butterfly Valves Internally Actuated	Butterfly Valves Externally Actuated	Swing Check Internally Actuated	Split Butterfly Check Internally Actuated	Flex Cone & Poppet Internally Actuated	Check Valve Adjacent to Coupling	Shut-Off Valve Adjacent to Coupling	Shut-Off Valve Adjacent to Flex Line (Ground)	Sleeve, Pressure Balanced Coupling Only
		TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)											
		VERIFICATION OF CONNECT		9	7	9	5	3	2	3	10	10	5
		ALIGNMENT REQUIREMENTS		8	8	5	5	3	5	10	10	10	5
		ADJUSTMENT REQUIREMENTS											
CONNECT AND VERIFY	25%	CONNECT FORCE REQUIRED		8	9	10	8	8	9	10	10	10	8
		POSSIBILITY OF DAMAGE TO COMPONENTS											
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)		10	10	5	10	10	10	9	3	3	10
		PERSONNEL (CREW) REQUIRED											
		SAFETY (PERSONNEL)											
		EASE OF REPLACEMENT		9	9	8	9	8	8	9	8	8	7
		OPERATIONAL LIFE (WEAR RESISTANCE)											
		ACCESSIBILITY FOR MAINTENANCE											
MAINTAINABILITY	30%	EASE OF COMPONENT REFURBISHMENT		9	8	7	8	8	7	6	6	5	6
		LUBRICATION REQUIRED		8	8	7	9	9	10	8	7	6	8
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)											
		SIZE											
		CONFIDENCE IN DESIGN (EXPERIENCE)		10	7	6	5	5	1	5	9	9	5
		REDUNDANCY PROVIDED											
		FAILURE TO CONNECT											
		FAILURE TO DISCONNECT											
RELIABILITY	35%	FAILURE TO OPEN		9	9	8	9	9	10	8	7	7	9
		FAILURE TO CLOSE		8	8	9	8	6	5	9	8	8	8
		INADVERTENT CLOSURE		10	10	8	10	10	10	8	6	6	10
		CONTAMINATION TRAPS		9	9	8	9	9	9	8	8	8	6
		NUMBER OF PARTS		9	9	8	9	8	6	8	7	7	9
		COST		9	9	5	9	8	6	6	5	5	8
		WEIGHT (VEHICLE)											
COST	10%	LOAD IMPOSED ON VEHICLE											
		SIZE		6	9	9	8	9	8	10	10	10	9
		WEIGHT (GROUND)		7	9	4	7	8	9	5	3	3	9
	100%	TOTAL											

Table 5-12. Debris Protection (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	Poppets Internally Actuated	Butterfly Valves Internally Actuated	Butterfly Valves Externally Actuated	Swing Check Internally Actuated	Split Butterfly Check Internally Actuated	Flex Cone & Poppet Internally Actuated	* Check Valve Adjacent to Coupling	Shut-Off Valve Adjacent to Coupling	Shut-Off Valve Adjacent to Flex Line (Ground)	Sleeve, Pressure Balanced Coupling Only
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)											
		VERIFICATION OF CONNECT	10	90	70	90	50	30	20	30	100	100	50
		ALIGNMENT REQUIREMENTS	5	40	40	25	25	15	25	50	50	50	5
		ADJUSTMENT REQUIREMENTS											
		CONNECT FORCE REQUIRED	5	40	45	50	40	40	45	50	50	50	40
		POSSIBILITY OF DAMAGE TO COMPONENTS											
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)	5	50	50	25	50	50	50	45	15	15	50
		PERSONNEL (CREW) REQUIRED											
		SAFETY (PERSONNEL)											
MAINTAINABILITY	30%	EASE OF REPLACEMENT	10	90	90	80	90	80	80	90	80	80	70
		OPERATIONAL LIFE (WEAR RESISTANCE)											
		ACCESSIBILITY FOR MAINTENANCE											
		EASE OF COMPONENT REFURBISHMENT	10	90	80	70	80	80	70	60	60	50	60
		LUBRICATION REQUIRED	10	80	80	70	90	90	100	80	70	60	80
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)											
		SIZE											
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	15	150	105	90	75	75	15	75	135	135	75
		REDUNDANCY PROVIDED											
		FAILURE TO CONNECT											
		FAILURE TO DISCONNECT											
		FAILURE TO OPEN	4	36	36	32	36	36	40	32	28	28	36
		FAILURE TO CLOSE	3	24	24	27	24	18	15	27	24	24	24
		INADVERTENT CLOSURE	10	100	100	80	100	100	100	80	60	60	100
		CONTAMINATION TRAPS	1	9	9	8	9	9	9	8	8	8	6
		NUMBER OF PARTS	2	18	18	16	18	16	12	16	14	14	9
COST	10%	COST	5	45	45	25	45	40	30	30	25	25	40
		WEIGHT (VEHICLE)											
		LOAD IMPOSED ON VEHICLE											
		SIZE	2	12	18	18	16	18	16	20	20	20	18
		WEIGHT (GROUND)	3	21	27	12	21	24	27	15	9	9	27
	100%	TOTAL	100	895	837	718	769	721	654	708	748	728	690

*Not suitable for drain or vent

Table 5-13. Debris Protection Method Compatibility

CLOSURE METHODS	COUPLING TYPES							
	Ball & Cone with Bellows Dual Ring Seal	Ball & Cone With Bellows Prim.-Ring Seal Sec.-SF Lip Seal	Slip-Dual SF LipSeal	Slip-Prim. Chevron & Sec.SF Lip	Press.Bal. Dual Lip Seals	Press.Bal.Conical Dual SF Lip Seals	Ball&Cone witn Spring, Ring Seal	Slip O-Ring
Sleeve - Press. Bal. Cplngs. Only					X			
Shutoff Valve Adj.to Flex Line (Ground)	X	X	X	X	X	X	X	X
Shutoff Valve Adj.to Coupling	X	X	X	X	X	X	X	X
Check Valve Adj.to Coupling*	X	X	X	X	X	X	X	X
Flex Cone & Poppet Internally Actuated			X	X		X		
Split Butterfly Check Internally Actuated	X	X	X	X				
Swing Check Internally Actuated			X	X				
Butterfly Valves Externally Actuated	X	X	X	X				
Butterfly Valves Internally Actuated	X	X	X	X				
Poppets Internally Actuated	X	X	X	X			X	X

* Not suitable for drain or vent

Table 5-14. Booster Umbilical Carriers (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT A Carrier Containing All Slip Couplings	CONCEPT B Carrier Containing All Press. Balanced Couplings	CONCEPT C Ball & Cone Couplings with Springs for Low Press., Bellows for Medium Press., Press. Balanced Couplings for Over 500 psig.
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)				
		VERIFICATION OF CONNECT		9	8	9
		ALIGNMENT REQUIREMENTS		6	6	10
		ADJUSTMENT REQUIREMENTS		10	6	9
		CONNECT FORCE REQUIRED		10	8	6
		POSSIBILITY OF DAMAGE TO COMPONENTS		7	5	10
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU. HYD, ELECT)				
		PERSONNEL (CREW) REQUIRED		9	9	10
		SAFETY (PERSONNEL)		9	9	9
MAINTAINABILITY	30%	EASE OF REPLACEMENT		8	8	10
		OPERATIONAL LIFE (WEAR RESISTANCE)				
		ACCESSIBILITY FOR MAINTENANCE				
		EASE OF COMPONENT REFURBISHMENT		10	9	6
		LUBRICATION REQUIRED		10	9	9
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)				
		SIZE		10	8	9
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)		9	8	10
		REDUNDANCY PROVIDED				
		FAILURE TO CONNECT		10	6	9
		FAILURE TO DISCONNECT		9	8	10
		FAILURE TO OPEN				
		FAILURE TO CLOSE				
		INADVERTENT CLOSURE				
		CONTAMINATION TRAPS				
		NUMBER OF PARTS				
COST	10%	COST		9	6	5
		WEIGHT (VEHICLE)		9	6	10
		LOAD IMPOSED ON VEHICLE		8	10	5
		SIZE				
		WEIGHT (GROUND)		10	9	8
	100%	TOTAL				

Table 5-15. Booster Umbilical Carriers (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT A Carrier Containing All Slip Couplings	CONCEPT B Carrier Containing All Press. Balanced Couplings	CONCEPT C Ball & Cone Couplings with Springs for Low Press., Bellows for Medium Press., Press. Balanced Couplings for Over 500 psig.
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)				
		VERIFICATION OF CONNECT	3	27	24	27
		ALIGNMENT REQUIREMENTS	5	30	30	50
		ADJUSTMENT REQUIREMENTS	5	50	30	45
		CONNECT FORCE REQUIRED	2	20	16	12
		POSSIBILITY OF DAMAGE TO COMPONENTS	2	14	10	20
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)				
		PERSONNEL (CREW) REQUIRED	5	45	45	50
		SAFETY (PERSONNEL)	3	27	27	27
MAINTAINABILITY	30%	EASE OF REPLACEMENT	10	80	80	100
		OPERATIONAL LIFE (WEAR RESISTANCE)				
		ACCESSIBILITY FOR MAINTENANCE				
		EASE OF COMPONENT REFURBISHMENT	10	100	90	60
		LUBRICATION REQUIRED	5	50	45	45
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)				
		SIZE	5	50	40	45
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	20	180	160	200
		REDUNDANCY PROVIDED				
		FAILURE TO CONNECT	5	50	30	45
		FAILURE TO DISCONNECT	10	90	80	100
		FAILURE TO OPEN				
		FAILURE TO CLOSE				
		INADVERTENT CLOSURE				
		CONTAMINATION TRAPS				
		NUMBER OF PARTS				
COST	10%	COST	5	45	30	25
		WEIGHT (VEHICLE)	2	18	12	20
		LOAD IMPOSED ON VEHICLE	2	16	20	10
		SIZE				
		WEIGHT (GROUND)	1	10	9	8
	100%	TOTAL		902	778	889

Table 5-16. Booster Umbilical Handling Concepts (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT #1 Fixed Elevation	CONCEPT #2 Spring Mounted Locked to Vehicle	CONCEPT #3 TSM Type
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)	5	9	10	8
		VERIFICATION OF CONNECT				
		ALIGNMENT REQUIREMENTS				
		ADJUSTMENT REQUIREMENTS	4	8	10	5
		CONNECT FORCE REQUIRED				
		POSSIBILITY OF DAMAGE TO COMPONENTS	3	9	10	6
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)	5	9	9	6
		PERSONNEL (CREW) REQUIRED	5	9	10	4
		SAFETY (PERSONNEL)	3	10	8	7
MAINTAINABILITY	30%	EASE OF REPLACEMENT	10	9	8	10
		OPERATIONAL LIFE (WEAR RESISTANCE)				
		ACCESSIBILITY FOR MAINTENANCE	10	8	8	6
		EASE OF COMPONENT REFURBISHMENT	7	9	9	6
		LUBRICATION REQUIRED				
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)				
		SIZE	3	8	8	4
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	15	10	9	8
		REDUNDANCY PROVIDED				
		FAILURE TO CONNECT	7	9	10	7
		FAILURE TO DISCONNECT	10	10	9	6
		FAILURE TO OPEN				
		FAILURE TO CLOSE				
		INADVERTENT CLOSURE				
		CONTAMINATION TRAPS				
		NUMBER OF PARTS	3	10	8	6
COST	10%	COST	5	9	9	4
		WEIGHT (VEHICLE)	2	8	9	10
		LOAD IMPOSED ON VEHICLE	2	10	6	9
		SIZE				
		WEIGHT (GROUND)	1	10	9	6
	100%	TOTAL				

Concept No. 1 utilizes a carrier with slip couplings mounted at a fixed elevation with a preset clearance between the carrier and the vehicle. Vehicle deflections are permitted by changes in the clearance with overtravel provided by the couplings.

Concept No. 2 utilizes a carrier that is locked to the vehicle until completion of fluid transfer. Prior to engine ignition, the latches are released and verification received. In the event of an on-pad abort, the latches are re-engaged for subsequent propellant drain.

Concept No. 3 is similar to the presently utilized Saturn V Tail Service Mast. The carrier is locked to the vehicle and incorporates primary, secondary, and tertiary release modes. Retract cylinders are pre-pressurized to provide sufficient carrier retraction to clear the vehicle in the event that boom retraction does not occur.

5.17 BOOSTER UMBILICAL HANDLING CONCEPTS (WEIGHTED)

Concept No. 1, Fixed Elevation, attained the highest ranking due mostly to higher grades for the reliability parameters. (See Table 5-17).

Concept No. 3 ranked the lowest due to system complexity, adjustment requirements, additional systems required, additional personnel required, maintenance requirements, and overall reliability.

5.18 ORBITER UMBILICAL CARRIERS (UNWEIGHTED)

This matrix shows the relative ranking numbers assigned for each parameter for the various concepts under consideration. More combinations are possible than those shown, however, those shown are considered the most compatible without undue duplication. (See Table 5-18).

5.19 ORBITER UMBILICAL CARRIERS (WEIGHTED)

Concept C attained the highest relative ranking primarily due to past successful experience with ball and cone couplings and their inherent capability of self-alignment while requiring minimum engagement. The gear drive method of connection requires a minimum of additional tools and/or equipment and provides positive alignment during the connection and engagement cycle. The collet locking and release device has a proven history of reliable operation with little wear and minimum refurbishment. Concept C with the 4-ball male locking and release device and Concept A utilizing the gear drive connect are still considered acceptable but do not incorporate as many desirable features as Concept C with the collet. (See Table 5-19).

Table 5-17. Booster Umbilical Handling Concepts (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT #1 Fixed Elevation	CONCEPT #2 Spring Mounted Locked to Vehicle	CONCEPT #3 TSM Type
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)		45	50	40
		VERIFICATION OF CONNECT				
		ALIGNMENT REQUIREMENTS				
		ADJUSTMENT REQUIREMENTS		32	40	20
		CONNECT FORCE REQUIRED				
		POSSIBILITY OF DAMAGE TO COMPONENTS		27	30	18
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD. ELECT)		45	45	30
		PERSONNEL (CREW) REQUIRED		45	50	20
		SAFETY (PERSONNEL)		30	24	21
MAINTAINABILITY	30%	EASE OF REPLACEMENT		90	80	100
		OPERATIONAL LIFE (WEAR RESISTANCE)				
		ACCESSIBILITY FOR MAINTENANCE		80	80	60
		EASE OF COMPONENT REFURBISHMENT		63	63	42
		LUBRICATION REQUIRED				
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)				
		SIZE		24	24	12
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)		150	135	120
		REDUNDANCY PROVIDED				
		FAILURE TO CONNECT		63	70	49
		FAILURE TO DISCONNECT		100	90	60
		FAILURE TO OPEN				
		FAILURE TO CLOSE				
		INADVERTENT CLOSURE				
		CONTAMINATION TRAPS				
		NUMBER OF PARTS		30	24	18
COST	10%	COST		45	45	20
		WEIGHT (VEHICLE)		16	18	20
		LOAD IMPOSED ON VEHICLE		20	12	18
		SIZE				
		WEIGHT (GROUND)		10	9	6
	100%	TOTAL		915	889	674

Table 5-18. Orbiter Umbilical Carriers (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT A Carrier Containing All Slip Couplings Collet Lock & Release		CONCEPT B Carrier Containing All Press. Balanced Couplings. Pneu Connect w/Ball Lock.	CONCEPT C Ball & Cone Couplings with Springs for Low Press., Bellows for Medium Press., Press. Balanced Couplings for Over 500 psig.	
				Gear Drive Connect	Pneumatic Connect		Gear Drive for Connect Ball Lock	Gear Drive for Connect Collet
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)		10	6	6	10	10
		VERIFICATION OF CONNECT		9	9	8	10	10
		ALIGNMENT REQUIREMENTS		6	6	5	10	10
		ADJUSTMENT REQUIREMENTS		9	6	6	9	9
		CONNECT FORCE REQUIRED		10	10	8	6	6
		POSSIBILITY OF DAMAGE TO COMPONENTS		8	4	4	9	9
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD. ELECT)		9	6	6	9	9
		PERSONNEL (CREW) REQUIRED		10	5	5	8	10
		SAFETY (PERSONNEL)		10	8	8	8	8
MAINTAINABILITY	30%	EASE OF REPLACEMENT		7	8	8	7	7
		OPERATIONAL LIFE (WEAR RESISTANCE)						
		ACCESSIBILITY FOR MAINTENANCE						
		EASE OF COMPONENT REFURBISHMENT		6	8	8	7	7
		LUBRICATION REQUIRED		8	7	7	8	8
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)						
		SIZE		8	10	7	8	8
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)		8	6	6	9	10
		REDUNDANCY PROVIDED						
		FAILURE TO CONNECT						
		FAILURE TO DISCONNECT		9	7	7	9	10
		FAILURE TO OPEN						
		FAILURE TO CLOSE						
		INADVERTENT CLOSURE						
		CONTAMINATION TRAPS						
		NUMBER OF PARTS						
COST	10%	COST		8	9	4	7	7
		WEIGHT (VEHICLE)		9	10	7	8	8
		LOAD IMPOSED ON VEHICLE						
		SIZE						
		WEIGHT (GROUND)						
	100%	TOTAL						

Table 5-19. Orbiter Umbilical Carriers (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT A Carrier Containing All Slip Couplings Collet Lock & Release: Gear Drive Connect	CONCEPT A: Pneumatic Connect	CONCEPT B Carrier Containing All Press. Balanced Couplings. Pneu Connect w/Ball Lock.	CONCEPT C Ball & Cone Couplings with Springs for Low Press., Bellows for Medium Press., Press. Balanced Couplings for Over 500 psig. Gear Drive for Connect: Ball Lock	CONCEPT C Gear Drive for Connect: Collet
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)	5	50	30	30	50	50
		VERIFICATION OF CONNECT	3	27	27	24	30	30
		ALIGNMENT REQUIREMENTS	2	12	12	10	20	20
		ADJUSTMENT REQUIREMENTS	2	18	12	12	18	18
		CONNECT FORCE REQUIRED	2	20	20	16	12	12
		POSSIBILITY OF DAMAGE TO COMPONENTS	2	16	8	8	18	18
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)	2	18	12	12	18	18
		PERSONNEL (CREW) REQUIRED	5	50	25	25	40	50
		SAFETY (PERSONNEL)	2	20	16	16	16	16
MAINTAINABILITY	30%	EASE OF REPLACEMENT	10	70	80	80	70	70
		OPERATIONAL LIFE (WEAR RESISTANCE)						
		ACCESSIBILITY FOR MAINTENANCE						
		EASE OF COMPONENT REFURBISHMENT	10	60	80	80	70	70
		LUBRICATION REQUIRED	5	40	35	35	40	40
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)						
		SIZE	5	40	50	35	40	40
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	20	160	120	120	180	200
		REDUNDANCY PROVIDED						
		FAILURE TO CONNECT						
		FAILURE TO DISCONNECT	15	135	105	105	135	150
		FAILURE TO OPEN						
		FAILURE TO CLOSE						
		INADVERTENT CLOSURE						
		CONTAMINATION TRAPS						
		NUMBER OF PARTS						
COST	10%	COST	7	56	63	28	49	49
		WEIGHT (VEHICLE)	3	27	30	21	24	24
		LOAD IMPOSED ON VEHICLE						
		SIZE						
		WEIGHT (GROUND)						
	100%	TOTAL		819	725	657	830	875

5.20 ORBITER UMBILICAL HANDLING CONCEPTS (UNWEIGHTED)

The relative ranking numbers for each parameter for the concepts under consideration are shown in Table 5-20. The summation of ranking numbers with weighting factors applied is shown on the following matrix.

5.21 ORBITER UMBILICAL HANDLING CONCEPTS (WEIGHTED)

The highest ranking was attained by Concept No. 2, the counterbalanced boom. This concept ranked considerably higher than the next highest due to its overall simplicity. (See Tab 5-21).

5.22 HANDLING SYSTEM/COMPONENT COMPATIBILITY

Table 5-22 identifies the components that are compatible with each of the umbilical carrier handling concepts. An "X" indicates design compatibility while a blank indicates that the component is not compatible with a given handling system.

Table 5-20. Orbiter Umbilical Handling Concepts (Unweighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT #1 Retractable Boom		CONCEPT #2 Counter Balanced Boom	CONCEPT #3 Platform Mounted Retracting Arm	
				Twin Cyl	Single Cyl		Attached Cyl	Free Cyl
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)		8	8	10	7	7
		VERIFICATION OF CONNECT						
		ALIGNMENT REQUIREMENTS						
		ADJUSTMENT REQUIREMENTS		7	7	9	6	6
		CONNECT FORCE REQUIRED						
		POSSIBILITY OF DAMAGE TO COMPONENTS		6	6	8	9	9
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)		6	7	9	7	7
		PERSONNEL (CREW) REQUIRED		6	6	8	8	8
		SAFETY (PERSONNEL)		7	7	9	8	8
MAINTAINABILITY	30%	EASE OF REPLACEMENT		4	4	8	10	10
		OPERATIONAL LIFE (WEAR RESISTANCE)						
		ACCESSIBILITY FOR MAINTENANCE		6	6	7	10	9
		EASE OF COMPONENT REFURBISHMENT		8	9	10	6	6
		LUBRICATION REQUIRED						
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)						
		SIZE		7	6	10	8	9
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)		9	9	7	4	6
		REDUNDANCY PROVIDED		10	5	10	8	8
		FAILURE TO CONNECT						
		FAILURE TO DISCONNECT		9	6	10	5	5
		FAILURE TO OPEN						
		FAILURE TO CLOSE						
		INADVERTENT CLOSURE						
		CONTAMINATION TRAPS						
		NUMBER OF PARTS						
COST	10%	COST		8	9	10	7	7
		WEIGHT (VEHICLE)						
		LOAD IMPOSED ON VEHICLE		10	10	8	6	7
		SIZE						
		WEIGHT (GROUND)		6	6	10	8	8
	100%	TOTAL						

Table 5-21. Orbiter Umbilical Handling Concepts (Weighted)

MAJOR PARAMETER	WT	SUB-PARAMETER	WT	CONCEPT #1 Retractable Boom		CONCEPT #2 Counter Balanced Boom	CONCEPT #3 Platform Mounted Retracting Arm	
				Twin Cyl	Single Cyl		Attached Cyl	Free Cyl
CONNECT AND VERIFY	25%	TIME REQ'D TO CONNECT UMBILICAL (INCLUDING PREP)	5	40	40	50	35	35
		VERIFICATION OF CONNECT						
		ALIGNMENT REQUIREMENTS						
		ADJUSTMENT REQUIREMENTS	5	35	35	45	30	30
		CONNECT FORCE REQUIRED						
		POSSIBILITY OF DAMAGE TO COMPONENTS	3	18	18	24	27	27
		ADDITIONAL SYS REQ'D FOR CONNECT (PNEU, HYD, ELECT)	4	24	28	36	28	28
		PERSONNEL (CREW) REQUIRED	5	30	30	40	40	40
		SAFETY (PERSONNEL)	3	21	21	27	24	24
MAINTAINABILITY	30%	EASE OF REPLACEMENT	5	20	20	40	50	50
		OPERATIONAL LIFE (WEAR RESISTANCE)						
		ACCESSIBILITY FOR MAINTENANCE	10	60	60	70	100	90
		EASE OF COMPONENT REFURBISHMENT	10	80	90	100	60	60
		LUBRICATION REQUIRED						
		TEMPERATURE RANGE (POSSIBILITY INFLIGHT DAM)						
		SIZE	5	35	30	50	40	45
RELIABILITY	35%	CONFIDENCE IN DESIGN (EXPERIENCE)	15	135	135	105	60	90
		REDUNDANCY PROVIDED	10	100	50	100	80	80
		FAILURE TO CONNECT						
		FAILURE TO DISCONNECT	10	90	60	100	50	50
		FAILURE TO OPEN						
		FAILURE TO CLOSE						
		INADVERTENT CLOSURE						
		CONTAMINATION TRAPS						
		NUMBER OF PARTS						
COST	10%	COST	5	40	45	50	35	35
		WEIGHT (VEHICLE)						
		LOAD IMPOSED ON VEHICLE	4	40	40	32	24	28
		SIZE						
		WEIGHT (GROUND)	1	6	6	10	8	8
	100%	TOTAL	100	774	708	879	691	720

Table 5-22. Handling System / Component Compatibility

TYPE	COMPONENTS	ORBITER #1	ORBITER #2	ORBITER #3	BOOSTER #1	BOOSTER #2	BOOSTER #3
Carriers	Concept A Carrier Containing Slip Couplings	X	X	X	X	X	
	Concept B Carrier Containing Pressure Balanced Couplings	X	X	X		X	X
	Concept C Carrier Containing Ball & Cone Couplings	X	X	X	X	X	X
Electrical Connectors	Rectangular Deadface Connector				X	X	X
	MS Shell Size #40				X	X	X
	Spherical Male, Split Sleeve Female Contacts				X	X	X
	MS Shell Size #32 Pygmy				X	X	X
	Large Round Plug (Gray & Huleguard)				X	X	X
Locking Devices	4 Ball Lock Male	X	X	X		X	X
	Toggle Lock	X	X	X		X	X
	Finger Lock	X	X	X		X	X
	Hook Latch					X	X
	Collet Lock	X	X	X		X	X
	Ball Lock, Female	X	X	X		X	X
	Spring Latch	X	X	X		X	X
Couplings	Ball & Cone with Bellows, Dual Ring Seal	X	X	X	X	X	X
	Ball & Cone with Bellows, Prim. Ring Seal, Sec. SF Lip Seal	X	X	X	X	X	X
	Slip-Dual SF Lip Seal	X	X	X	X	X	X
	Slip-Prim. Chevron, Sec. SF Lip Seal	X	X	X	X	X	X
	Pressure Balanced-Dual Lip Seals	X	X	X		X	X
	Pressure Balanced-Conical with Dual SF Lip Seals	X	X	X		X	X
	Ball & Cone with Spring, Single Ring Seal	X	X	X	X	X	X
	Slip-Single O-Ring	X	X	X	X	X	X

SECTION 6

SELECTED CONCEPT REQUIREMENTS DEFINITION

Table 6-1 contains a summary of the various weighted evaluation factors from the tradeoff matrices in Section 5. The single asterisk * indicates the various concepts selected to be included into the space shuttle booster fuel riseoff disconnect panel conceptual design and the double asterisk ** indicates the various concepts selected to be incorporated into the orbiter umbilical conceptual design. The following paragraphs present a brief specification outline for the selected concept. Note that it has been described primarily for a space shuttle B9U booster and 161C orbiter configuration and has not been updated to agree with the most current space shuttle configurations.

6.1 SELECTED BOOSTER CONCEPT DEFINITION

The following paragraphs give a description of the salient features of the selected booster umbilical concept. Appendix A lists the drawings which have been prepared to detail this concept. Note that these drawings have been prepared to design a prototype of the concept for testing the handling and verification concepts only. As such, the design is not directly useable for a vehicle design but must be adapted to the specific application desired.

6.1.1 HANDLING CONCEPT. Selected for definition is Concept No. 1 which is a riseoff type with a fixed elevation carrier, and elevated by worm screw actuators.

Table 6-1. Weighted Evaluation Summary of Tradeoff Matrices

Alternate Concepts	Weighted Evaluation Factor
CRYOGENIC COUPLINGS	
Ball and cone with bellows and dual ring seal	888**
Ball and cone with bellows, primary-ring seal and secondary-self forming (SF) lip seal	838
Slip with Dual SF lip seal	831*
Slip with primary-chevron secondary-SF lip seal	717
Pressure balanced-dual lip seals	663
Semi pressure balanced (conical) dual SF lip seals	615

Table 6-1. Weighted Evaluation Summary of Tradeoff Matrices, Continued

Alternate Concepts	Weighted Evaluation Factor
HIGH PRESSURE PNEUMATIC AND HYDRAULIC COUPLINGS	
Slip with dual SF lip seal	793
Slip with primary-chevron secondary-SF lip seal	631
Pressure balanced-dual lip seals	684
Slip with dual O-ring seals	984* **
LOW PRESSURE PNEUMATIC, H_2O, GLYCOL AND J-P COUPLINGS	
Ball and cone with bellows and dual ring seal	913
Ball and cone with bellows, pri-ring seal secondary-SF lip seal	766
Slip with dual SF lip seal	738
Slip with primary-chevron secondary SF lip seal	648
Ball and cone with spring, ring seal	916**
Slip with dual O-ring seals	945*
LOCKING AND RELEASE DEVICE	
4-ball lock, male	925
Toggle lock	801
Finger lock	774
Hook latch	837
Collet lock	971**
Ball lock, female	769
Spring latch	642
ELECTRICAL CONNECTOR	
Rectangular Deadface Connector (Cannon)	872*
MS Shell Size No. 40 (Cannon)	693

Table 6-1. Weighted Evaluation Summary of Tradeoff Matrices, Continued

Alternate Concepts	Weighted Evaluation Factor
Spherical Male, Split Sleeve Female Contacts	790
MS Shell Size No. 32 (Pygmy)	625
Large Round Plug (Gray and Huleguard)	710
DEBRIS PROTECTION	
Poppets, internally actuated	895* **
Butterfly valves, internally actuated	837
Butterfly valves, externally actuated	718
Swing check, internally actuated	769
Split butterfly check, internally actuated	721
Flex cone and poppet, internally actuated	654
Check valve adjacent to coupling	708
Shut-off valve adjacent to coupling	748
Shut-off valve adjacent to flex line (ground)	728
Sleeve, pressure balanced coupling only	690
BOOSTER UMBILICAL CARRIERS	
Concept A - All slip couplings	902*
Concept B - All pressure-balanced couplings	778
Concept C - Ball and cone couplings with springs for low press, bellows for medium press and pressure-balanced couplings for over 500 psig	889
BOOSTER UMBILICAL HANDLING CONCEPTS	
Concept 1 - Fixed elevation	915*
Concept 2 - Spring mounted locked to vehicle	889
Concept 3 - Tail service mast type	674

Table 6-1. Weighted Evaluation Summary of Tradeoff Matrices, Continued

Alternate Concepts	Weighted Evaluation Factor
ORBITER UMBILICAL CARRIERS	
CONCEPT A - All slip couplings - collet lock	
Gear drive connect	819
Pneumatic connect	725
CONCEPT B - All pressure balanced couplings, pneumatic connect, ball lock	657
CONCEPT C - Ball and cone coupling with springs for low press and bellows for medium press, pressure balanced for over 500 psig gear drive for connect	
Ball lock	830
Collet	875**
ORBITER UMBILICAL HANDLING CONCEPTS	
CONCEPT 1 - Retractable boom	
Twin cylinder	774
Single cylinder	708
CONCEPT 2 - Counter-balanced Boom	879**
CONCEPT 3 - Platform mounted retracting arm	
Attached cylinder	691
Free cylinder	720

This booster fuel umbilical disconnect concept is characterized primarily by the direction of disconnect motion, the method of accommodating vehicle relative motion, and the method of accommodating the loads generated by the fluid system pressures.

The umbilical couplings (for fluid and electrical services) are disconnected vertically in the direction of flight and as a direct result of vehicle motion. The ground half will remain at a fixed elevation and the vehicle half will rise with the vehicle and separate during liftoff.

During the extended time interval after the umbilical couplings have been mated until the vehicle is launched, the vehicle half of the couplings will be subjected to relative motion with respect to the fixed portion of the launcher. This motion has been established arbitrarily as ± 2 inches horizontally in any direction from the nominal position and ± 1 inch vertically from the nominal position. The horizontal motion will be accommodated by allowing the ground half of the coupling to move horizontally to track the vehicle. The relative motion between the ground half of the couplings and the fixed ground system will be accommodated by flex joints, flex hoses, or electrical cables.

For the fluid and gas couplings, the vertical relative motion of the vehicle half is accommodated by a sliding seal between the coupling halves. While the vehicle half is allowed to move up and down due to vehicle motion, the ground half will remain at a fixed elevation. For the electrical couplings, the vertical relative motion of the vehicle half will be accommodated by spring-loading the ground half of the coupling against the vehicle half. The spring load must be large enough to overcome the dynamic loading due to engine generated noise and vibration.

The pressures internal to the fluid and gas couplings generate a force on the piston area of the sliding seal and tend to force the two coupling halves apart. Upward motion of the vehicle half is to be restrained by the vehicle mass and structure. Downward motion of the ground half is to be restrained by structural supports from the ground. None of the vertical upward load on the vehicle is to be restrained by locks adjacent to the coupling(s) or carrier in order to alleviate vehicle structural loading. Incorporation of load relief locking devices would introduce an additional failure mode during launch.

6.1.2 CARRIER CONCEPT. Concept A is a carrier containing all slip couplings and rectangular deadface electrical connectors, not locked to the vehicle. This carrier concept is essentially inherent in the handling concept as described in paragraph 6.1.1.

Freedom of lateral motion for the ground carrier will be provided by four parallel compression struts. The nominal position of the carrier will be maintained by four tension type springs.

The ground carrier shall incorporate alignment pins that will engage with mating funnel fittings on the vehicle carrier. These alignment pins will reorient the ground carrier to align with the initial laterzl mislocation of the vehicle. The design of the pins shall be such as to assure that the ground carrier is aligned with the vehicle carrier to within ± 0.050 inch prior to the point in the vertical travel that any of the vertical couplings start to engage. Each of the couplings shall incorporate self-alignment provisions and shall be mounted in the ground carrier to ensure proper engagement from an initial misalignment of ± 0.050 inches laterally and ± 1 degree angular misalignment. The electrical connectors must also provide for rotational misalignment.

6.1.3 SCREW JACK ELEVATING MECHANISM. The screw jack elevating mechanism serves the following purposes:

a. It allows the ground halves of the couplings (mounted in the ground carrier) to be retracted, or lowered, out of the way during the time that the booster is being installed on the launch support pedestals. A nominal 12 inches of motion has been assumed.

b. It allows the ground halves of the couplings (all at the same time) to be rapidly engaged, or raised, under power and local manual control.

c. It provides the support for the ground carrier and couplings to maintain them at the proper fixed elevation during vehicle relative motion and during the loading applied by the fluid and gas pressures internal to the slip couplings.

6.1.4 PROTECTIVE BLAST DOOR (GROUND). This door (or doors) will be actuated by a ground pneumatic system after the vehicle has risen to an altitude sufficient to provide clearance for door movement. The door(s) outer surface will have sufficient structural and thermal integrity to withstand the direct impingement of the engine exhaust during the launch transient. The door(s) must be closed completely before the vehicle has risen to an altitude sufficient for direct exhaust impingement on the umbilical couplings.

6.1.5 PROTECTIVE DOOR (VEHICLE). This door (or doors) will be actuated by a vehicle system after the vehicle has risen to an altitude sufficient to provide clearance for door movement. The door(s) will have sufficient structural and thermal integrity to withstand the environment to be encountered during the vehicle flight and recovery.

6.1.6 CRYOGENIC COUPLINGS. The single cryogenic coupling in this panel will be nominal 10-inch size liquid hydrogen coupling and will have a 90 psig operating pressure. It will be a slip coupling having a sliding seal piston area of approximately 50 square inches (8-inch diameter). It will have dual self-forming lip seals similar to the Atlas 11 inch liquid oxygen staging disconnect. It will have a tertiary seal to contain a gaseous helium purge adjacent to the dual seals. This helium purge will prevent cryopumping and ice buildup on the sliding seal surface.

This coupling will be vacuum-jacketed and will not require the application of additional insulation after is is connected. The volume between the dual lip seals will be vented through a tubing connection on the ground side. This vent tubing will be monitored during verification of the connect phase when the coupling will be pressurized internally with gaseous helium or gaseous nitrogen. The acceptable amount of gas leaking out through the dual seal vent line will be established to provide a verification acceptance criteria. During actual liquid hydrogen transfer through this coupling, the volume between the dual seals will be vented to the gaseous hydrogen burn pond via a ground vent manifold system.

The coupling will also provide mounting provisions for an ultrasonic leak detector contact transducer. The acceptable amount of ultrasonic energy produced by a leaking seal during the verification phase will also be established. One, or both, verification acceptance systems may be used for connect verification. Neither one will be used during the propellant transfer operation.

While it is recognized that the tendency is normally toward more and more instrumentation of a launch operation, it is suggested that having too many measurements carries the risk of aborting due to erroneous indications as well as requiring considerable expense for maintenance. It is further suggested that a better approach for verifying couplings is to conduct a design evaluation and qualification test program of sufficient scope to justify confidence in the disconnects and carrier systems once it is verified that they have been properly engaged. With a design which conducts primary seal leakage to a safe disposal, and with confidence that the systems were properly engaged, neither ultrasonic nor telltale flow instrumentation should be required during the actual transfer operations.

Both halves of the disconnect will incorporate internal poppets for protection of the system from airborne debris during the launch, flight, and recovery operations. These debris poppets will be spring-loaded to the closed position and will be opened automatically by the engagement of the two coupling halves. The poppets will close automatically as the two couplings are separated.

The mounting provisions for the ground half of the coupling and the attached vacuum jacketed duct will allow some slight lateral and angular motion with respect to the ground carrier to assure that the coupling halves will align during engagement and disengagement. The vehicle half of the coupling will be rigidly attached to the vehicle carrier.

The ground carrier is mounted on a parallelogram linkage consisting of vertical compression struts. This linkage allows lateral freedom in any direction while keeping the ground carrier nominally parallel to the vehicle carrier. Because the compression struts move in an arc, the ground carrier is lowered very slightly as it is deflected from its neutral position. Before the ground carrier is driven up into engagement with the vehicle carrier it is spring loaded to the neutral position.

As the ground carrier is driven up to engagement, the first contact is made by the carrier alignment pins on the ground carrier(2) with the carrier alignment funnels on the vehicle carrier. If the vehicle carrier is located at the nominal position, then the pins will engage the centerline of the funnel without a camming action. If, however, the vehicle carrier has some initial misalignment (horizontal mislocation) then the pins (tapered) will contact the side of the funnel first. As the ground carrier continues being driven upward, the tapered pin is cammed sidewise by the funnel on the vehicle carrier to bring the tapered pin into alignment with the funnel centerline. As the ground carrier is cammed sidewise the centering springs are being deflected from the neutral position. The cylindrical portion of the tapered pins will enter the cylindrical portion of the funnel throat prior to the elevation required for any of the couplings to contact initially. Thus the 10 inch liquid hydrogen ground coupling half will be automatically course aligned with the vehicle half just prior to initial contact.

Initial contact of the ground coupling will be the tapered leading edge of the male ground half with the teflon funnel on the vehicle half. The camming action of the tapered leading edge and funnel will realign the ground half, as required, to provide proper coupling engagement as the carrier is driven upward to the neutral (or nominal) position. The ground coupling can slide sidewise slightly on either of the gimbal block bushings. The gimbal block bushings, in conjunction with the three gimbal joints in the liquid hydrogen vacuum-jacketed duct, will allow slight angular reorientation to assure that the cylindrical sections of the ground and vehicle halves of the couplings can engage and disengage without binding. The ground half of the coupling is spring-loaded to the neutral position prior to contact. The nature of the self forming lip seals is such as to be forgiving with respect to small out-of-roundness and centerline angular misalignment. There is ample metal-to-metal clearance and the lip seals are flexible.

6.1.7 HIGH PRESSURE PNEUMATIC COUPLINGS (GASEOUS HELIUM AND GASEOUS HYDROGEN). These couplings will be slip couplings and will have a 1-inch seal piston diameter. The gaseous helium disconnect will be rated for 3700 psig operating pressure and the gaseous hydrogen coupling will be rated for 1000 psig operating pressure.

Both couplings will incorporate dual O-ring seals. The volume between the dual seals will be vented through the ground side to provide a leakage telltale function during the verification phase (immediately after engagement). For the gaseous hydrogen coupling, the seal cavity vent line will be vented to the hydrogen burn pond vent manifold. For the gaseous helium coupling seal, cavity vent will be capped in order to force the secondary seal to act as a redundant seal rather than acting as a diverter to force a hazardous media (hydrogen) to leak into a safe disposal path. The gaseous helium dual O-ring seal cavities will be designed to avoid seal failure or damage due to high pressure gas trapped between the seals. The primary purpose of the back-up of the back-up seal in the helium slip coupling is to force the leak detection tracer gas to flow out through the measurement telltale. Since the helium leakage, if any, can be safely vented to the ambient surroundings of the coupling, a safe disposal vent is not required. Given these facts, then it is very easy to make the back-up seal act as a true redundant seal simply by putting a cap on the cavity vent line.

These couplings should not be cold enough to cryopump oxygen or nitrogen out of the ambient air, but frost or ice build-up may become a consideration. Ice scraper rings may be required.

Mounting provisions for an ultrasonic leak detector contact transducer will be incorporated into each coupling.

These couplings will incorporate debris poppets and alignment provisions as described for the cryogenic couplings.

6.1.8 FUEL (JP-5) COUPLING. This coupling will be a 3-inch slip coupling with dual O-ring and a 150 psig rating. The volume between the dual seals will be vented to the ground side as a leakage telltale during a verification and will be routed to a safe disposal accumulator during the JP-5 transfer operation.

This coupling will incorporate debris poppets, alignment mounting provisions and ultrasonic leak detector contact transducer mounting provisions as described for the cryogenic coupling.

6.1.9 VEHICLE CAVITY PURGE GN_2 COUPLING. This coupling will be a 4-inch diameter slip coupling with a single O-ring seal and will be rated for 150 psig. It will incorporate debris poppets, alignment mounting provisions, and ultrasonic leak detector contact transducer mounting provisions, same as described for the cryogenic coupling.

6.1.10 HYDRAULIC SYSTEM PRESSURE AND RETURN COUPLINGS. These couplings will be similar to the JP-5 coupling except they will be 2-inches in diameter and will be rated for 3000 psig operating pressure.

6.1.11 ELECTRICAL GROUND POWER CONNECTOR. Two separate 400 Hz, 3 phase power circuits will be routed through a single Cannon-type rectangular faced connector. This connector will be an adaption of the Atlas type connector to delete the solenoid-release spring-eject feature and make it suitable for use with a ground carrier. It will incorporate the springs necessary to keep it connected while accommodating the ± 1.0 inch of vertical relative motion.

The mounting provision to the carrier must allow for the ± 0.050 inch self alignment capability while only permitting a small amount (± 30 minutes) of angular travel. The alignment pins in the connector faceplate must provide the automated alignment laterally and rotationally as the ground carrier is raised into the nominal position.

Each of the two 3-phase circuits will consist of four No. 2-0 wires. The current through the connector will be carried by bussed No. 12 pins. Nine adjacent No. 12 pins will be bussed together to provide a No. 2-0 solder pot for the power cables.

The electrical disconnect back-shell and faceplate will be purged with a positive gaseous nitrogen pressure. The back-shell will incorporate Kellem grip strain relief.

6.1.12 DATA BUS ELECTRICAL CONNECTOR. The data bus electrical connector shall be separate from the electrical ground power connector. The minimum requirements are for a quantity of 12 Number 12 pins. This will be provided either by a shell size 40 MS series connector or by an additional rectangular connector. The MS series connector proposed for use incorporates shells specially modified for automatic alignment as the ground carrier is raised to the nominal position. The temperature rating of the insert material may prove to be too much of a handicap.

If the MS series is used, it will provide adequate spares. If the Cannon rectangular connector is used, it will provide more than adequate spares.

This connector will incorporate carrier mounting alignment provisions and gaseous nitrogen purge provisions as described for the electrical power connector.

6.2 SELECTED ORBITER CONCEPT DEFINITIONS

The following paragraphs give a description of the salient features of the selected orbiter integrated umbilical carrier concept. Appendix B lists the drawings which have been prepared to detail this concept. Note that these drawings have been prepared to design a prototype for testing of the handling and verification concepts only. As such, the design is not directly useable for a vehicle design but must be adapted to the specific application desired.

6.2.1 HANDLING CONCEPT. The handling concept selected for the orbiter umbilical carrier is the counterbalanced boom. In a manner similar to a desk lamp, the boom supporting the ground carrier is counterbalanced with springs to the extent necessary to take the dead weight of the carrier, couplings and hoses. With this boom properly adjusted, the carrier will seek the nominal installed position. The installing personnel will only have to overcome the friction brake on the main boom to engage the lower two spherical end guide pins. Further force will then be required to rotate the carrier on the lower guides until the collet lock is engaged. Positive visual indication of collet engagement is provided by the release pin when it is allowed to engage the expanding collet fingers.

Ease of handling of the carrier may be further enhanced by using a spring suspension support for the flex hoses at approximately mid-span. This will reduce the tendency of the carrier to tip away from the vehicle thereby reducing the effort required of the installing personnel. The design drawings do not reflect this suspension system as it would be easier to determine the requirements on a working prototype system.

Note that this handling concept does not require any auxiliary power or supporting systems to line up the ground carrier and engage the collet locking device. The task can very likely be done by one person, certainly by not more than two. When the release pin snaps into position there is no possible doubt that the lock has been properly engaged.

The counterbalanced boom also provides the forces necessary to retract the carrier from the vehicle after it has been released and ejected. The tip boom balancing cylinder (spring balanced) will be pressurized in the center with 750 psig GN_2 at the time of carrier release. The resulting thrust load will cause the tip boom to swing down and away from the vehicle.

At the same time, the main boom spring-loaded balancing cylinders (2) will be pressurized with 750 psig GN_2. These cylinders will cause the main boom to swing up and away from the vehicle. The combined action of the two booms will provide more than adequate clearance from the vehicle for the swing arm to rotate away from the vehicle path. Any one of the three cylinders will provide enough clearance for the swing arm to rotate.

A back-up system to the primary release kick-off and retract system is provided by a pneumatically-actuated lanyard. The direction of pull for the lanyard is directly away from the vehicle and slightly above the centerline of the ground umbilical carrier. The lanyard is attached to the collet locking mechanism release pin. If none of the primary release system is functional, the backup lanyard will:

1) pull the collet lock release pin, thus unlocking the lock,
2) perform the kick-off function of clearing the ground carrier from the vehicle carrier, and
3) retract the ground carrier far enough to provide clearance for rotating the swing-arm to its retracted position.

6.2.2 CARRIER CONCEPT. The selected concept is Concept C and is described as using ball and cone couplings with springs for low pressure and bellows for medium pressure and pressure-balanced slip couplings for pressures over 500 psig. It is further described as having a collet locking device and a gear drive for connection (pulling the carriers together after the collet is engaged).

The foremost features of this carrier concept are the gear-drive collet locking-device with the coupled gear drive guide pins. Prior to attempting to engage the ground carrier with the vehicle carrier, the collet lock and the four corner guide pins are extended from the face of the ground carrier 2 1/2 inches. It is verified that the collet is cocked and ready for engagement and that the release pin is extending from the rear of the locking device.

When the carrier is properly positioned with any two of the guide pins in their spherical seats, the carrier may be rotated around those two guide pins until the collet has entered the locking ring on the vehicle carrier. As soon as the collet is through the locking ring, the collet fingers will spread, allowing the spring loaded release pin to slide down between the fingers, locking the collet until the release pin is withdrawn.

At this point, none of the couplings have started to engage. Thus, the installing personnel do not have to provide the effort necessary to overcome the spring rates and seal friction of the couplings. The gear drive mechanism must be used to pull the ground carrier up to the vehicle carrier to engage the couplings.

The coupled (synchronized) gear drive mechanism is powered manually with a standard universal (flexible) drive socket with an extended speed-handle (crank-not ratchet). Approximately 300 turns of the crank are required to move the carrier in the 2 1/2 inches to full engagement. As the gear drive mechanism on the collet locking device pulls the ground carrier up to the vehicle carrier, the four corner guide pins are being pulled back into the carrier at the same rate. The carrier plates are thus held parallel as the engaging forces of the couplings attempt to force them out of alignment. At full engagement, the surrounding skirt of the ground plate and its interior compartment walls will be sealed against the flat surface of the vehicle carrier. These walls and skirts will form the separately purged compartments.

Note that this carrier gear drive engaging mechanism does not require any auxiliary power or supporting systems to engage the couplings and pull the carrier plates together. This task can be accomplished by one person in four to five minutes.

To release the collet locking device 750 psig GN_2 will be used to pull the collet release pin. The pneumatic pressure will be supplied to the cylinder through redundant ports, check valves, hoses, solenoid valves and reservoirs. The four corner guide pins also incorporate kick-off pistons and will be pressurized with 750 psig GN_2 which is routed to the kick-off cylinders from separate ports connected to the release pin cylinder. Thus, the pressure must be applied to the release cylinder before the kick-off cylinders can be pressurized. This assures that the collet will be unlocked before the kick-off cylinders apply additional load to the collet making it more difficult to unlock.

The carrier may be manually disconnected from the vehicle if desired by reversing the connection procedure using the gear drive.

Another feature of the carrier and coupling design is that an individual coupling may be removed from the carrier without separating the carrier from the vehicle.

6.2.3 LEAK DETECTION SYSTEM. In order to verify in a minimum amount of time that the couplings have been engaged properly a convenient leak detection system is built into the ground carrier. The operational leak detection system proposed is an ultrasonic sound detection system. For the prototype system an additional leak detection system will be installed that will quantitatively measure leakage from the tell-tale connection located between the primary and secondary dynamic coupling seals. Use of this prototype leakage measuring system will provide for calibrating the operational ultrasonic system.

The ultrasonic system will utilize piezioelectric crystal transducers mounted in a contact mode, i.e., they will respond to the ultrasonic energy being conducted by the body of the coupling rather than the ultrasonic energy in the surrounding atmosphere. The ultrasonic energy being picked up, if any, will be the energy being produced by tracer gas leakage past the primary dynamic seal.

By mounting a separate transducer on each coupling the task of discriminating a detected leak will be much simpler than trying to search with a hand-held airborne[1] sound probe or with several fixed airborne sound probes. In addition, the contact probes eliminate the attenuation factors associated with transmitting the ultrasonic vibrations in the coupling body into the air and then picking them up with a microphone (airborne sound probe).

Each of the miniaturized contact probes will require a miniaturized signal conditioning circuit mounted nearby to transmit the transducer output to the remote switching and audio detection circuitry. It is planned to use a simple audio (speaker) output and an audio analyzer (CRT) calibrated to known leakage rates for each coupling for the initial installation. It is conceivable that more sophisticated computerized audio snalysis techniques may be incorporated into the ground checkout software as the Space Shuttle Launch Processing System matures.

6.2.4 FLEXIBLE HOSE INSTALLATION. Included in the prototype design are the flexible hoses requird to allow the degree of freedom of movement required of the ground umbilical carrier. The ground carrier must be free to be retracted away from the vehicle far enough for swing-arm rotation. It must also be free enough to allow carrier engagement by not more than two operating personnel with the aid of the counterbalanced boom. And, it must also be free to track the vehicle relative motions after the ground carrier has been engaged with the vehicle carrier.

It is intended that all hoses and couplings be installed in the ground carrier at the time that the carrier is engaged to the vehicle. This will ensure the minimum time expenditure in connecting the ground services to the vehicle.

Although not shown on the prototype design, it is intended that the mid-span of the hoses be supported by a spring suspension system. This will provide load relief during the manual engagement of the ground carrier.

6.2.5 BALL-AND-CONE COUPLING, 2 IN. DUAL SEALS. This coupling is used as a gaseous hydrogen vent connection (2 places) and a JP-5 fill connection (1 place). It is a nominal 2 inch size, incorporates dual ball and cone coupling seals, has debris poppets, and has a leak detection/measuring telltale tubing top between the primary and secondary coupling seals.

[1] airborne - refers to sound transmitted through the surrounding air and does not refer to vehicle borne (airborne) equipment.

Each of the coupling seals receives an initial compressive load due to the spring rate of the integral bellows sections. As internal pressure is increased, the bellows will generate a thrust load due to pressure. This additional thrust provides a greater compressive load for the coupling seals. Since the thrust load reaction on the primary seal tends to decrease the secondary seal compression, the secondary seal bellows has a larger effective diameter in order to assure that the compressive load on the secondary seal increases with increasing internal pressure.

6.2.6 PRESSURE BALANCED COUPLING, 1 IN., HIGH PRESSURE. This coupling is used as a high pressure gaseous helium fill connection (1 place). It is a nominal 1 inch size and incorporates sliding coupling seals, a debris protection poppet, and a debris protection sleeve. Since the fluid being handled does not provide a hazardous vapor, dual seals are not provided. The tubing connection is for the purpose of venting the force balancing cavity to ambient pressure.

6.2.7 BALL-AND-CONE COUPLING, 1 IN., DUAL SEALS. This coupling is used as an EC/LSS (water/glycol) supply and return connection (4 places), a gaseous oxygen vent connection (2 places), a full cell gaseous hydrogen purge vent (1 place), a JP-5 tank pressurization connection (1 place), and an auxiliary propulsion system gaseous hydrogen accumulator vent connection (1 palce). This coupling incorporates the same features as the 2 inch coupling except it is scaled down to 1 inch.

6.2.8 BALL-AND-CONE COUPLING, 1 IN., DUAL SEALS, VACUUM-JACKETED. This coupling is used as an LH_2 fill connection (2 places) and an LO_2 fill connection (2 places). It is a nominal 1 inch size and incorporates dual ball-and-cone seals, full vacuum-jacketed insulation, debris protection poppets, and a leak detection/measuring telltale tap between the dual seals.

The seals are compressed by a spring and a bellows in the ground half and by a bellows in the vehicle half. The vehicle bellows loads the primary seal and the spring and bellows in the ground half load the secondary seal. Since the primary seal compression tends to relieve the compression in the secondary seal, the bellows loading the secondary seal has a larger effective diameter than the vehicle half bellows.

The vacuum jacket is not continuously pumped. It will be evacuated and baked and sealed off.

6.2.9 BALL-AND-CONE COUPLING, 1/2 IN., SINGLE SEAL. This coupling is used as a fuel cell gaseous oxygen purge vent (2 places)and a fuel cell water vent (1 place). It is a nominal 1/2 inch size and incorporates a single ball-and-cone seal and debris poppets. Compression force for the low-pressure coupling seals is provided by a spring only.

APPENDIX A

LIST OF BOOSTER UMBILICAL DISCONNECT DETAIL DRAWINGS

APPENDIX A

LIST OF BOOSTER UMBILICAL DISCONNECT DETAIL DRAWINGS

DWG. NO,	TITLE	Sheet Size	Quantity
SK-DE-0020	Booster Umbilical Disconnect Panel Prototype System	J	1
SK-DE-0021	Extend/Retract System (Spec Control Dwg)	J	2
SK-DE-0022	Extend/Retract System (Procurement/ Development Specification	A	
SK-DE-0023	Parallelogram Assy. Ground Carrier Support	J	1
SK-DE-0024	Shield Assembly, Ground Carrier	J	3
SK-DE-0025	Actuator, Shield Assy. (Spec Control Dwg)	J	1
SK-DE-0026	Actuator, Shield Assy. (Procurement/ Development Specification)	A	
SK-DE-0027	Flex Duct, Liquid Hydrogen (Procurement/Development Specification)	A	
SK-DE-0028	Coupling Assy. LH_2, 10 inch, Booster	J C	1 60
SK-DE-0029	Coupling Assy. JP-5	J	2
SK-DE-0030	Coupling Assy. GH_2	J	2
SK-DE-0031	Coupling Assy. GHe	J	1
SK-DE-0032	Coupling Assy. GN_2	J	1
SK-DE-0033	Disconnect Assy. Electrical Power	J	1

APPENDIX A (Contd)

LIST OF BOOSTER UMBILICAL DISCONNECT DETAIL DRAWINGS

DWG. NO.	TITLE	Sheet Size	Quantity
SD-DE-0034	Disconnect Assy. Data Bus	J	1
SK-DE-0035	Coupling Assy. Hydraulic	J	1
SK-DE-0036	Vehicle Carrier Assy.	J	2
SK-DE-0037	Ground Carrier Assy.	J	2
SK-DE-0038	Propellant Hose Installation	J	1
SK-DE-0039	Electrical Cable Instl.	J	1
SK-DE-0040	Leak Detection System Instl.	J	1

APPENDIX B

LIST OF ORBITER UMBILICAL DISCONNECT DETAIL DRAWINGS

APPENDIX B

LIST OF ORBITER UMBILICAL CARRIER DETAIL DRAWINGS

DWG. NO.	TITLE	Sheet Size	Quantity
SK-DE-0001	Orbiter Umbilical Carrier Prototype System	J	1
SK-DE-0002	Boom Assy. Umbilical Carrier Handling	F C	1 9
SK-DE-0003	Assy. Ground Umbilical Carrier	F	3
SK-DE-0004	Assy. Vehicle Umbilical Carrier	F	2
SK-DE-0005	Assy. Secondary Eject Cylinder	F C	1 3
SK-DE-0006	Plate, Umbilical Carrier, Vehicle	F	1
SK-DE-0007	Guide Pin Assy.	F	1
SK-DE-0008	Locking Device Assy.	F	1
SK-DE-0009	Coupling Assy. LO_2/LH_2		
SK-DE-0010	Coupling Assy.		
SK-DE-0011	Coupling Assy.		
SK-DE-0012	Coupling Assy.		
SK-DE-0013	Pneumatic Controls Instl.	F	2
SK-DE-0014	Propellant Hose Instl.	F	2
SK-DE-0015	Leak Detection System Instl.	F	2

APPENDIX C

CALCULATION WORK SHEETS

1200

1.15
6.0
69.00

30/1 Reduction ratio of work gear

14½° Press. Angle

1¾" Dia. Acme Th'd.

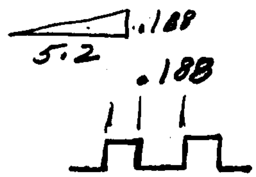
Approx. 3/32 Th'd.

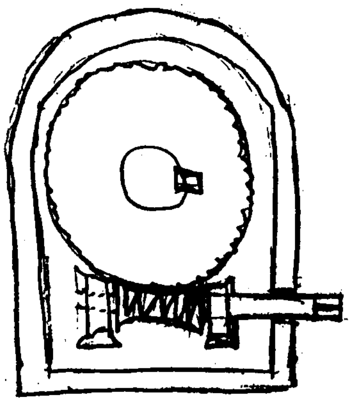
1 12/16

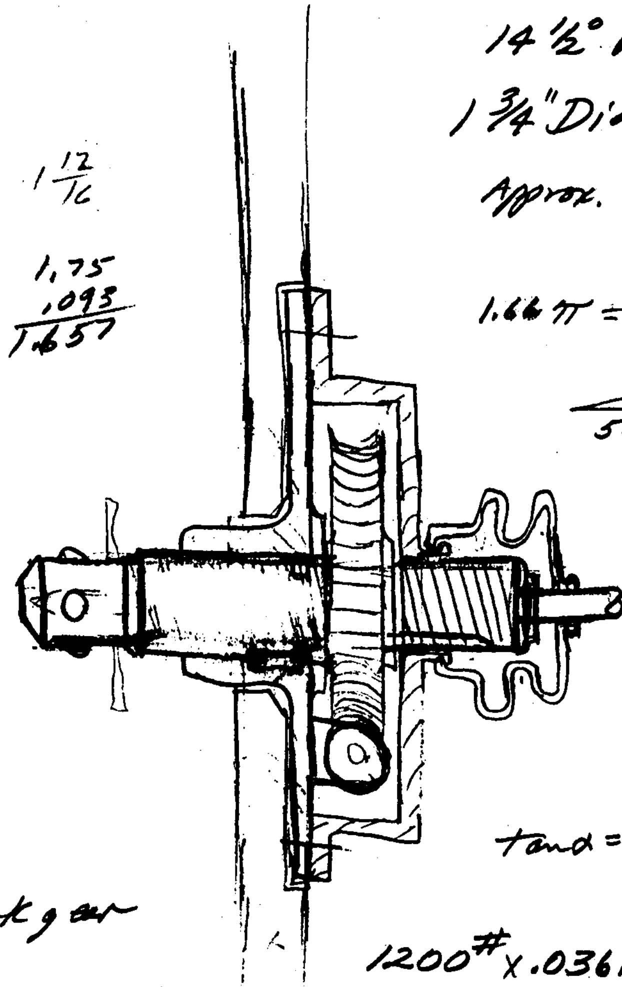
1200
.03
36.00

1.75
.093
1.657

$1.66\pi = 5.2$







$\tan\alpha = \frac{.188}{5.2} = .0361$

30 rev. to 1 in work gear

.188 per revolution at th'd.

1200# x .0361 = 43.3#

$\frac{43.3}{30} = 1.44\#$

neglecting friction

30 rev. = .188"

2½" req. 399 revolutions

$\frac{43.3}{15} = 2.88\#$

15 rev. = .188

2½" uses 200 revolutions

1" VJ Coupling, Poppet Areas

1.000   49
.098   49
.902   .98

I.D. Pipe (Tubing) 1.00" O.D. X .049 wall = 2 | .902"
.451

$A = \pi \times .451^2 = .638\ in^2$

Start of ribs (spider)

r = .530

$A = .53^2 \pi = .831\ in^2$

Plug = .375 D

$A = .188^2 \pi = .113\ in^2$

Ribs

.35 X .062 X 3 = .0657

.831
.113
.718
.066
$.652\ in^2$ ok

Poppet Dia. = .962

$A = .481^2 \pi = .723\ in^2$

Dia. Req'd. Around Poppet

$A_{Reqd.} = .723 + .65 = 1.373\ in^2$

$\frac{1.373}{\pi} = .437\ in^2$

$r = \sqrt{.437} = .663$

D = 1.326 use 1.375 nom.

1.375
.932
2 | .443
.221 poppet must open

Poppet movement Req'd. max. = .450 ∴ use 1/2" for design

2" Ball & Cone, Poppet Areas

I.D. = 1.870 Pipe (Tubing) .065 Wall

$A = .93^2 \pi = 2.78 \ in^2$

Poppet DIA = 2.00 in = $3.14 \ in^2$

$$\begin{array}{r} 3.14 \\ 2.78 \\ \hline 5.92 \end{array} \qquad \sqrt{\frac{5.92}{\pi}} = \sqrt{1.88} = 1.37 \text{ Radius}$$

D = 2.75

2" Coupling slots

2 1/4 Dia. =

1000# @ 750 psi

$.656 R^2 \times \pi = 1352 \ in^2$

$1.333 \ in^2$ Req'd for 1000# @ 750 psi

$$\begin{array}{r} 1.352 \\ 1.333 \\ \hline 2.685 \end{array} \ in^2 \text{ large Cylinder}$$

$$\sqrt{\frac{2.685}{\pi}} = \sqrt{.855} = 0.926 \ R = 1.852 \text{ Dia.}$$

$.345 \ in^2$ for 5/8 Dia.

1 1/8 D = .562 R

1.00

$.562^2 \pi =$

$$\begin{array}{r} .99 \\ .345 \\ \hline .645 \end{array} \ in^2 \times 750 = 485\#$$

Prelim. Working Paper

F = Load on worm

R = Radius of worm = 1.25

r = pitch radius of acme thd. = .839

p = lead of thread = 0.125

Q = Load = 1200#

μ = coefficient of friction = 0.2 hardened stl. on bronze.

$$F = Q \times \frac{p + 6.2832 \mu r}{6.2832 r - \mu p} \times \frac{r}{R}$$

$$= 1200\left(\frac{.125 + 6.2832 \times 0.2 \times .839}{6.2832 \times .839 - 0.2 \times .125}\right) \times \frac{.839}{1.25}$$

$$= 1200\left(\frac{.125 + 1.055}{5.28 - .0250}\right) \times .672$$

$$= 1200\left(\frac{1.18}{5.255}\right) \times .672 = 807 \times .2245$$

$$= 181.3^{\#} \quad \text{or} \quad 227 \text{ in}^{\#}$$

Neglecting Friction: (For Comparison only)

$$F = Q \times \frac{p}{6.2832 R} = \frac{1200 \times .125}{6.2832 \times 1.25} = 19.06^{\#}$$

15 to 1 ratio | 20 to 1 ratio

$\frac{227}{15} = 15.14$ in# | $\frac{227}{20} = 11.35$ in#

using 4" Tool (speedwrench)

F = 3.78# use | F = 2.84#

Revolutions to Take up 2 1/2"

$\frac{2.5}{.125}$ = 20 rev. of screw

15 to 1 20X15 = 300 revolutions of worm | 20 to 1 20X20 = 400 revolutions of worm

From Catalog: output torque of gear at 100 rpm:

15 to 1 @ .07 HP | 20 to 1 @ .09 HP
463 in.# | 794 in#
Max. Req'd. = 227 | 227
236 margin | 567 margin

.07 HP input
463 in# output

$T = \frac{63025 \times HP}{RPM}$

$= \frac{63025 \times .07}{100}$

$= 44.1$ in#

$44.1 \times \frac{227}{463} = 21.6$ in#

.09 HP input
794 in# output

$T = \frac{63025 \times .09}{100}$

$= 56.72$ in#

$56.72 \times \frac{227}{794} = 16.23$ in#

Using 4" moment arm on tool!

$\frac{21.6}{4} = 5.4$#
Actual
Use

$\frac{16.23}{4} = 4.06$#

Use Worm Gear No. D1401 Pitch Dia. = 2.500, 30 teeth, 1/2" Face, Bronze, Double Thread

Use Worm No. H1407K, Pitch Dia. = 1.000 Face 1 1/8, Hole 5/8", Keyway 1/8, Steel Hardened & Polished

BY J.T.B. DATE .... SUBJECT .... SHEET NO. 1 OF 3
CHKD. BY .... DATE .... JOB NO. ....

Worm Gear Drive Calculations

Using Boston Gear Data Page 121

Hard steel Worm, Bronze Worm Gear,

1/2" Face Worm Gear, Cat. No. DB 1401 or 1402

Pitch Dia. of 2.500 or 3.333

12 Pitch Double Thread

Ratio	15/1	or 20/1
Teeth	30	40

Acme Th'd. on Lockbolt 1.750 Dia., 8 threads/in.
.0625 Thd. width

Calculate Torque Req'd. to rotate lockbolt

F = Torque on screw

R = Radius of Moment Arm = 1.000 (To arrive @ in.#)

r = pitch radius of Acme th'd. = .839

p = lead of thread = .125

Q = Load = 1200#

μ = coefficient of friction = 0.2

$$F = Q \times \frac{p + 6.2832\mu r}{6.2832r - \mu p} \times \frac{r}{R} = 1200\left(\frac{.125 + 6.2832 \times 0.2 \times .839}{6.2832 \times .839 - 0.2 \times .125}\right)\frac{.839}{1.00}$$

$$= 1200\left(\frac{.125 + 1.055}{5.28 - .025}\right) \times .839 = 1007\left(\frac{1.18}{5.255}\right)$$

$$= 226 \text{ in.}^{\#}$$

BY EBF DATE .... SUBJECT .... SHEET NO. 2 OF 3
CHKD. BY .... DATE .... JOB NO. ....

Gear Drive Calc.

Neglecting Friction (For Comparison Purposes only)

$$F = \frac{Q \times P}{6.2832 R} = \frac{1200 \times .125}{6.2832 \times 1.00} = 23.9 \text{ in}^{\#}$$

Torque Req'd. on Worm

15 to 1 ratio

$$\frac{226}{15} = 15.07 \text{ in}^{\#}$$

20 to 1 ratio

$$\frac{226}{20} = 11.3 \text{ in}^{\#}$$

From Boston Gear Catalog:

15 to 1 @ .07 HP Input
Output = 463 in#

20 to 1 @ .09 HP Input
Output = 794 in#

$$T = \frac{63025 \times HP}{RPM}$$

T = Torque
HP = Horsepower
RPM = 100

$$= \frac{63025 \times .07}{100} = 44.1 \text{ in}^{\#}$$

$$= \frac{63025 \times .09}{100} = 56.72 \text{ in}^{\#}$$

$$44.1 \times \frac{226}{463} = 21.5 \text{ in}^{\#}$$

$$56.72 \times \frac{226}{794} = 16.15 \text{ in}^{\#}$$

Assuming 4" Offset on Speedwrench, Force =

$$\frac{21.5}{4} = 5.37^{\#} \text{ use}$$

$$\frac{16.15}{4} = 4.04^{\#}$$

BY EEC DATE SUBJECT SHEET NO. 3 OF 3
CHKD. BY DATE JOB NO.

Gear Drive Calc.

Revolutions to Take up 2½" Inches
2.5" Total Take up Req'd.
⅛" Lead on Acme Thd.

$\frac{2.5}{.125}$ = 20 rev. of screw

15 to 1
20 X 15 = <u>300</u> use   20 x 20 = 400
revolutions of worm

Use: Worm Gear No. D1401, Pitch Dia. = 2.500",
30 teeth, ½" Face, Bronze, Double Th'd,
12 pitch, 14½° Press. Angle

: Worm No. H1407K, Pitch Dia. = 1.000",
Face = 1⅛", Hole ⅝", keyway ⅛", steel,
Hardened, Ground & Polished.

2.00 to 2.125 ID

2.75 Max. O.D.

Need 584# Force Combined Spring Rate + Thrust

Media Pressure = 90 psig

Spring = 134# Total Thrust

Thrust Due to ~~Media~~ Press. = 450#

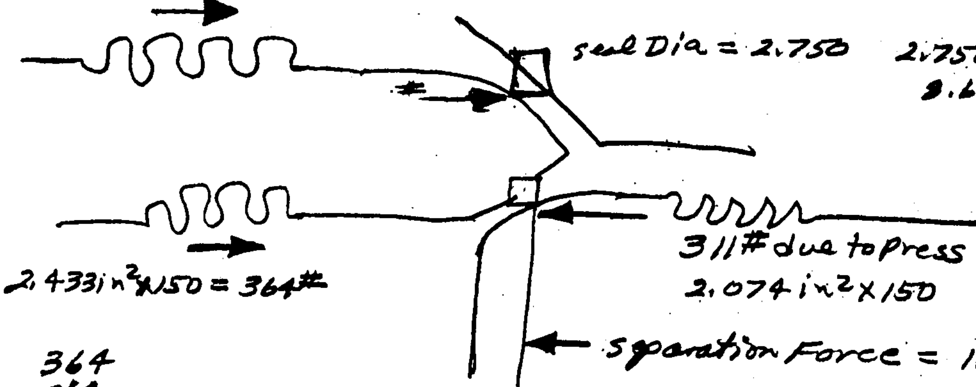
@ 90 psi = 5.00 in.^{2}

Assume

2.050 I.D.
2.75 O.D. Area = 4.52

4.52 X 90 = 407#

Inner Seal Dia = 1.5
1.5 × π = 4.7 in. circum.



2.750 π = 8.64 in. circum,
8.64 × 40 = 345# Needed on outer seal

364
− 264
100# Net on outer seal
− 36.5
63.5
345 − 63.5 =

311 − 264# = 47#   47/4.7 = 10#/in. on inner seal

Need Additional
40 × 4.7 = 188# to make 50#/in on inner seal

$$\frac{9250 \times D}{18.2} = 188\#$$

$$D = \frac{18.2 \times 188}{9250} = .370 \text{ Defl. Req'd.}$$

Pitch = .055   18.2 conv/in.
@ .020 per conv max. allow. defl. = 18.2 × .020 = .364

Total Force from Interal Bellows = 311 + 188 = 499#

Total Force Req'd. from Ground Inner Bellows and From Spring Rate of Outer Bellows. = 499 + ~~345~~ + 36.5
= 880.5#

880.5 − 364 = 516.5

Outer Bellows Spring Rate
18 coils × .020 = .36 max defl.

$$\frac{8350 \times .36}{18} = 167\#$$

Inner Bellows Spring Rate

216
167
49
49/8.64 = 5.67

Net Force on outer seal = 28.6#/in.

432.5
334.0
98.5

98.5/8.64 = 11.4

.125
.031
.156 X

.824D = .412R = .534 in²

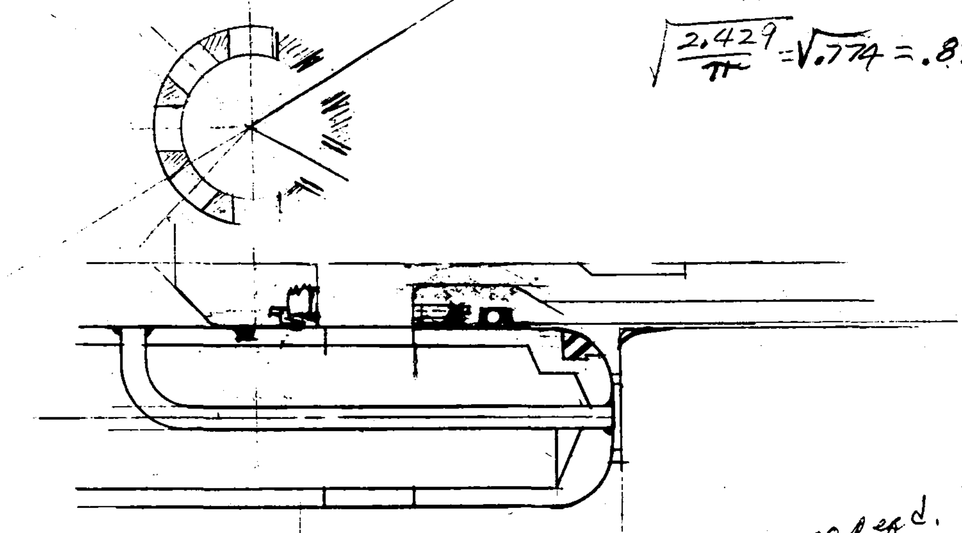
.75R = 1.76 in²
.669
2.429

$\sqrt{\frac{2.429}{\pi}} = \sqrt{.774} = .87$

1/4 x 1/2 = 1/8 x 4 = .500
.049 in²/1/4" Dia Hole
Req. 11 holes
.049 x 4 = .196

.500
.196
.696

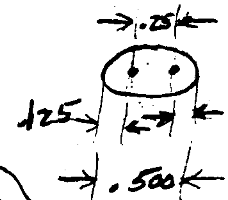
= 1.39 x Area

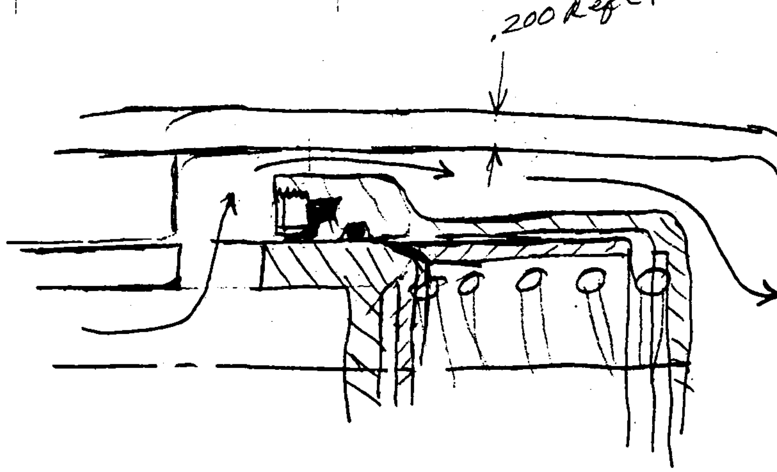


1/4 x 1/4 = 1/16 x 6 = 6/16 = .375
+ 6 x .049 = .294

.294
.669

$\frac{.669}{.534} = 1.25$





6 x .312 = 1872

.875
.031
.906 R
= 2.58 in²
+ .669
3.249

$\sqrt{\frac{3.249}{\pi}} = \sqrt{1.035}$

=

.824π = 2.59
1.872
.718

.718 x .095 = .0683

.0683 x 30,000 = 2045

6 x .25 = 1.50

2.59
1.50
1.09

.095 x 1.09 = .1035

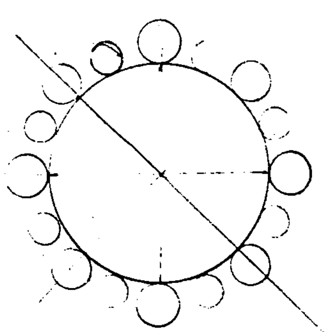
2.58
.534
3.114

$\sqrt{\frac{3.114}{\pi}} = \sqrt{.992}$

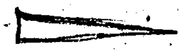
= .998

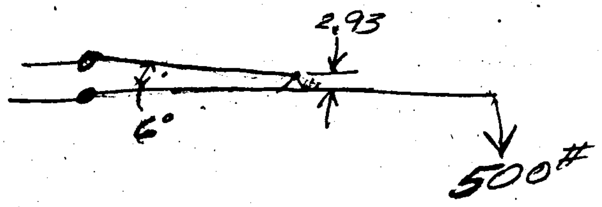
use 1.030R

$A = 1.03^2\pi = 3.33\ in^2$



$67 + 5 = 72''$





$$S = \frac{Wl}{4Z} = \frac{1000 \times 72}{4 \times .56} = 25{,}000 \text{ psi}$$

Press, Bal. Coupling

$$P = \frac{2T \times S}{OD} =$$

$$T = \frac{P \times OD}{2S} = \frac{3000 \times 2.375}{2 \times 7000} = .508$$

Barlow Formula

$$t = \frac{DP}{2S}$$

D = outside dia.
P = pressure (psi)
S = allow. tensile stress

$$1.441 = \frac{R}{r = 1.030}$$

$$R = 1.441 \times 1.030 = 1.485$$

$1.485 - 1.030 = .455$

$1.485 \times 2 = 2.970$

Lamé Formula

$$S = P \frac{R^2 + r^2}{R^2 - r^2}$$

$$= 3500\left(\frac{1.485^2 + 1.030^2}{1.485^2 - 1.030^2}\right)$$

$$= 3500\left(\frac{3.26}{1.14}\right) = 10{,}000 \text{ psi}$$

$2.20 + 1.06 = 3.26$ $\quad$ $2.20 - 1.06 = 1.14$

Th'd.

$3.14 - .99 = 2.15 \times 3500 = 7540\#$

$$S = 3500\left(\frac{R^2 + 1.06}{R^2 - 1.06}\right)$$

$(R^2 - 1.06)\, 20K = 3.5K(R^2 + 1.06)$

$20K R^2 - 1.06 \times 20K = 3.5K R^2 + 3.5K \times 1.06$

$6.28 \times .8 \times .25 = 1.256 \times 10{,}000 = 12{,}560$

This.

$16.5K R^2 = 3.5K \times 1.06 + 1.06 \times 20K$

$R^2 = \frac{3701 + 21200}{16.5} = \frac{24901}{16.5}$

$R^2 =$

$$t = r\left(\sqrt{\frac{S+P}{S-P}} - 1\right)$$

$$= 1.03\left(\sqrt{\frac{20k+3.5k}{20k-3.5k}}\right) - 1 = 1.03\left(\sqrt{\frac{23.5k}{16.5k}} - 1\right)$$

$$= 1.03\left(\sqrt{1.425} - 1\right) = 1.03(1.194 - 1) = 1.03 \times .194 = .200$$

Largest Dia. Under Press.

Male

$$t = .812\left(\sqrt{\frac{20k+3.5k}{20k-3.5k}} - 1\right) = .812\left(\sqrt{\frac{23.5k}{16.5k}} - 1\right) = .812(1.194 - 1) = .158$$

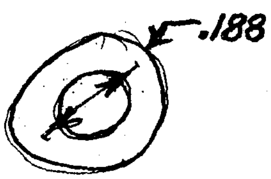
.049 × 8 = .392

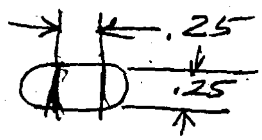
.688R = 1.483 in² + .7 = 2.183

$$\sqrt{\frac{2.183}{\pi}} = \sqrt{.694} = .835 R$$

.375 − .125 = .250

π 1.5 × .188 = .886





$.835^2 \pi$ = 2.19
$.688^2 \pi$ = 1.487
.703

.392 + 8 × 1/4 × 1/8 = .392 + .250 = .642

.824 D = .412 R = .532 in²

1/4 × 1/4 = 1/16 × 8 = .500

.500 + .392 = .892

.500 + .196 = .696

.049 × 8 = .392

.392 / 2 = .196

.0765 × 8 = .6120

Male – Ground Part – Spring

1½" Hole .125 wire Dia. Free Length 4.0"
1¼ ID – Installed Length 3.5
Compressed Length 2.0"

2" 317# Separation Force

Bellows

2.050 ID X 2.750 O.D. Thrust Area = 4.524 in²

@ 90 psig. Thrust = 4.524 X 90 = 407#

407
317
190#

$\frac{190}{6.68}$ = 13.54#/in on seal.

Need 40#/in on seal

40.0 - 13.5 = 26.5#/in. spring Force Reqd.

#Total spring Force Reqd.

Need .875 Compression

pitch .065 15.4 Conv/in .020/conv. .308 per inch

2.05 X 2.750 324#/in/conv.

$\frac{.875}{.308}$ = 2.85" free length

$\frac{324 \times .875}{44}$ = 6.45#

Compressed Length = 2.00

$77.5 = \frac{x \times .875}{44}$

$x = \frac{44 \times 77.5}{.875} = 3900$

Rear Bellows

Total Carrier Force

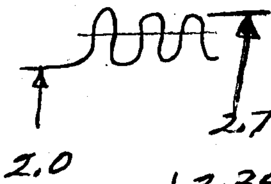
2" JP-5 = 869
1" LH_2, LO_2 = 3,520
1" H_2O Glycol = 4,800
GN_2,
GHe 100

1" - GO_2 @ 150 psi	2 ea.	2×880	= 1760 ✓	
1" - LH_2 @ 30 psi	2 ea	2×500	1000 ✓	2760
2" LH_2 Vent @ 5 psi	2 ea	2×10	20 ✓	2780
1" H_2O Glycol @ 150 psi	4 ea	4×600	2400 ✓	5180
1" GHe Fill @ 3500	1 ea.	100#	100 ✓	5280
1" LO_2 vent @ 5 psi	2 ea	10#	10 ✓	5290
1" GO_2 vent APS Accum. 150	1 ea.	600	600	
½" H_2O vent @ 5 psi	1 ea.	—	✓	
1" GH_2 Purge Vent @ 5 psi	1 ea.	10#	10	
½" GO_2 Purge vent	2 ea.	2×10	20	
2" JP Fill @ 90 psig	1 ea.	869	869	
1" GN_2 @ 150 JP Tank Pres.	1 ea.	600	600 ✓	5890

5890# Total
Simultaneous Forces

2" JP-5 Coupling

2" I D Bellows
O.D. = 2.7
4 convolutions per inch



$2 \overline{)2.35}$ = 1.175

4000 #/in/convolution – spring rate

5.0 in² thrust area

$\frac{4000}{6} \times .188 = 125$ # spring

.046 Rated Axial Defl./convolution

$\frac{4000}{32} \times .125 = 125$ #

Need 7/8" compression ∴ $\frac{.875}{.046} = 19$ convolutions
∴ $\frac{19}{4} = 4.75$ in – length of bellows

$\frac{4000 \times .875}{19} = 184$ #

Seal Dia = 2.25 × π = 7.07 in.
$\frac{184}{7.07} = 26$ #/linear inch due to spring rate

Thrust area of 5.0 in²
Seal Area of 1.125R = 3.97 in²
5.0 − 3.96 = 1.04 in² × 90 = 93.7 #
$\frac{93.7}{7.07} = 13.3$ #/linear in.

26 + 13.1 = 39.1 #/linear inch

Total Separation Force on Carrier =

1" ECLSS Coupling

1" I.D. Bellows
O.D. = 1.4"
6.65 Conv. per inch avg.

5000#/in./convolution – Spring Rate

1.25 in^2 Thrust Area

.022 Rated Axial Defl./convolution

Need 3/8" Compression ∴ $\frac{.375}{.022}$ = 17 convolutions

$\frac{17}{6.65}$ = 2.55 in. – length of bellows

$\frac{5000 \times .375}{17}$ = 111#

Seal Area = 1.25×π = 3.92 in.

$\frac{111}{3.92}$ = 28.3# due to spring rate

Thrust Area of 1.25 in^2 × 150 psi = 187.5# Thrust Load

$\frac{187.5}{3.92}$ = 47.8#/linear inch

Allowable Load for Collet Locking Device

Weakest point in the collet is the midpoint of the fingers. The diameter in this area is 0.750 in. and the fingers are 0.062 thick. Slots are milled to form 8 fingers, each 0.233 in. wide. Material will be a precipitation hardened stainless steel, Tensile strength of approx. 120,000 psi; Rockwell C-30 to C-35. (17-4PH)

$.750$ dia $= 2.3562$ circum.

$\frac{2.3562}{8} = .2945$, $.0625$ slots

$.2945 - .0625 = .232$ width of each finger

$.232 \times .062 \times 8 \times 120k = \underline{\underline{13,920^{\#}}}$

Operating load if failure is not designed in as a redundant release mode is:

$\frac{13,920}{5} = \underline{\underline{2,790^{\#}}}$.

With minor design changes, load capability (apprx) can be increased to $\underline{\underline{5580^{\#}}}$

Allowable Load for 4 Ball Locking Device

Brinelling of Ball Lock Ring

$$\text{Brinell Number} = \frac{\text{Load on Ball in Kilograms}}{\text{Surface Area of Indentation in mm}^2}$$

Using 304 SS, Brinell hardness = 180

Load on Ball = 3000 kg, Ball dia = 10 mm = .393"

$\therefore\ 180 = \frac{3000}{A}$ then $A = \frac{3000}{180} = 16.67\ mm^2$

Area of spherical segment $= 2\pi r h$,
where r = radius of ball
h = depth of indentation

Assume an allowable indentation of approx. .015"

Brinell std. .393 dia. ball

$A = 16.67\ mm^2$, $r = 5\ mm$
$= 2\pi r h$

$h = \frac{A}{2\pi r} = \frac{16.67}{6.2832 \times 5} = .530\ mm.$

$= 0.020"$

1/2" Dia. Ball

$r = \frac{.500}{2 \times .0393} = 6.38\ mm.$

$h = \frac{16.67}{6.2832 \times 6.38} = .401\ mm$

$= \underline{\underline{0.01585"}}$

Acceptable

3000 kg = 1362#
Using 4 balls, total allowable load = 5448#

Since the balls contact a 45° sloped surface on the ball lock ring, the load must be reduced by:

$5448 \times \sin 45° = 5448 \times .707 = \underline{\underline{3850\#}}$

Allowable Load

Shear Out of Balls thru Ball Lock Ring

1/2" dia. ball, circum. = 1.5708"

Shear Area = $\frac{1.5708}{2} - .0625 = .7229$

Avg. thickness of ring = .156"

Area = $.7229 \times .156 \times 4 = .451 \text{ in}^2$

Shear strength of 304 SS = 70% of 75,000 = 52.5K

Failure Load = $52.5K \times .451 = 23,700\#$

Due to Angle of contact and rolling displacement of metal on the ball lock ring, the failure force should be reduced by sin 45°

$\therefore 23,700 \times .707 = \underline{\underline{16,770\#}}$, SHEAR OUT FORCE

The shear-out force can be reduced if desired for a redundant release mode by reduction of the lock ring thickness, or by increasing the clearance diameter thru the ring.

Work hardening of the lock ring surface by the Brinelling action thru repeated use will increase the allowable loads on the lock ring.

Brinelling of the release pin will be minimum since it is case hardened to Rockwell C-60.

The allowable loads due to Brinelling of the balls on the lock ring can be increased by use of a different material for the lock ring, i.e. heat treated.

The total tensile load the locking device is capable of withstanding is limited by the area of cross-section remaining in the area of the balls. This area is equivalent to a circle of .625 dia (4 quarter segments of .312 radius).

$A = .3068\ in^2$

$P = 75K \times .3068 = \underline{\underline{23{,}000^{\#}}}$

4 Ball Locking Device – Cyl. size & Wall Th. Calc.

Using 750 psi pneumatic pressure for release pin,
Calculate Area req'd. for release piston.

Small dia. of pin = .625 DIA. $A = .3026\ in^2$

Use 800# for pin retract force.

$.3026\ in^2 \times 750\ psi = 229\#$

$800 + 229 = 1029\#$ $\quad \frac{1029}{750} = 1.374\ in^2$

$r = \sqrt{\frac{1.374}{\pi}} = \sqrt{.437} = .663$ radius $= 1.326$ Dia.

Use $1\frac{3}{8} = 1.375$ Dia. for standard "O"-Ring

$Force = \frac{1.375^2}{4}\pi \times 750 = 1113\#$

$1113 - 229 = \underline{884\#}$ ok

Connect Force:

Use 1200# Required to Mate all Connectors, Compress springs, compress bellows, and overcome seal friction forces.

Outside Dia. of smaller cylinder = $1.375 + (2 \times .090)$

$$\begin{array}{r} 1.375 \\ .180 \\ \hline 1.555 \end{array}$$

1.555 Dia. × 750 psi = 1166#

$1200 + 1166 = 2366\#$

$A = \frac{2366}{750} = 3.155\ in^2$

$r = \sqrt{\frac{3.155}{\pi}} = \sqrt{1.0042} = 1.002$ $\quad$ Dia. = 2.004"

Use $\underline{2.000"}$ for Std. "O"-Ring

$A = \pi\ in^2$ $\quad F = 750\pi = \underline{2360\#}$ OK.

BY E.E.O. DATE ________ SUBJECT ________ SHEET NO. 2 OF 2
CHKD. BY ________ DATE ________ JOB NO. ________

Four Ball Locking Device

Calculation on Connect Cylinder Wall Thickness

Use Lame' Formula for cylinder subjected to High Internal Pressure

$t = r\left(\sqrt{\frac{S+P}{S-P}} - 1\right)$

$t = 1.375\left(\sqrt{\frac{15{,}000+750}{15{,}000-750}} - 1\right)$

$= 1.375\left(\sqrt{\frac{15{,}750}{14{,}250}} - 1\right)$

$= 1.375\left(\sqrt{1.107} - 1\right) = 1.375(1.052 - 1) = 1.375 \times .052$

$= .0715''$ Use .09 to allow for larger machining tolerances for cost reduction.

$t = P - r$ = Thickness of cylinder

r = I.D. = 1.375"

S = Max. Allow. Fiber Stress $= \frac{75{,}000}{5} = 15{,}000$ – 304 SS.

P = Press. within Cylinder = 750 psi

W. R KILLIAN
9-24-71

1/7

Ball & Cone, V.J., Dual seal

LH_2 DISCONNECT TEMP. CALC.

$$Q = \frac{K A \Delta T}{L} = \frac{BTU \cdot IN}{hr \cdot ft^2 \cdot °F} \cdot \frac{ft^2 \; °F}{IN} = \frac{BTU}{hr}$$

Q = BTU/hr ~ HEAT FLUX

SEE FIG 1 K = BTU·IN / hr·ft²·°F ~ THERMAL CONDUCTIVITY

4½" L = IN ~ Length OF HEAT PATH

-423
-250
173

ΔT = °F ~ Temp. Differential

A_2 = Ft² ~ AREA

$$A = (12.50)(\pi)(.125) / 144 = .0342 \text{ Ft}^2$$

K AT T_{AVE}, $T_{AVE} = \frac{-423 - 250}{} = -673 = -337°F$

$K_{AT\,-337°F} = 41.8 \frac{BTU \cdot IN}{hr \cdot ft^2 \cdot °F}$

MAX Q TO LIMIT TEMP AT -250°F.

$$Q_{MAX} = \frac{(41.8)(.0342)(173)}{(4.5)}$$

$$Q_{MAX} = 55.1 \text{ BTU/HR}$$

IF THE TEMP AT THE AMBIENT INTERFACE IS TO BE −250 °F OR WARMER, THE Q (HEAT FLUX) MUST BE 55.1 BTU/hour OR GREATER.

IF Q is Less Than 55.1 BTU/hr, Then The Δt must be Less than 173 °F WITH THE RESULTANT TEMP AT THE WARM ITERFACE COLDER THAN −250 °F. EXAMPLE − AS $\Delta T \cong 0$ BTU/hr, $\Delta T \cong 0$, & TEMP AT WARM FACE = LH_2 TEMP.

APPROACH −

1) CALCULATE THE ACTUAL HEAT FLUX WHICH MAY BE TRANSPORTED TO THE GN_2 ATMOSPHERE SURROUNDING THE COUPLING.

a) Calc. h (BTU/hr·ft²)

b) Knowing h & A calc Q_{ALLOW}.

c) IF $Q_{ALLOW} > Q_{MAX}$

Then recalc. Δt from

$$Q_{ALLOW} = \frac{KA\Delta T}{L}$$

CONSIDER Natural Convection to Still Ambient Air @ 90 °F.

$$h = .42 \left(\Delta_T / D' \right)^{0.25}$$

where:

h = film coef $\frac{BTU}{hr \cdot ft^2 \cdot °F(diff.)}$

Δ_T = Temp difference ~ pipe to ambient air
-250 °F to +90 °F = 340 °F

D' = Outside diam fitting = 12.5 IN.

$$h = .42 \left(\frac{340}{12.5} \right)^{.25} [2.26] = .95 \frac{BTU}{hr \cdot ft^2 \cdot °F}$$

$$Q_{ALLOW} = (.95)(A_1)(\Delta_S)$$

Δ_S = 340 °F

$$A_1 = \frac{(\pi)(12.5) \times (1.0)}{144} = .274 \ ft^2$$

(1.0) ← 1" effective @ OUTER SKIN.

$$\therefore Q_{ALLOW} = (.95)(.274)(340) = 88.5 \ BTU/hr$$

CALC OF ACTUAL Δt

$$Q = \frac{(K)(A)(\Delta T)}{L}$$

$$88.5 = \frac{(41.8)(.0342)(\Delta t)}{4.5}$$

$$\Delta T = \frac{(4.5)(88.5)}{(41.8)(.0342)}$$

$\Delta T = 278\ °F$

$$\therefore \quad \begin{array}{r} -423 \\ +278 \\ \hline -145\ °F \end{array}$$

ACTUAL SKIN TEMP WILL NOT BE LESS THAN −145 °F.

ASSUME T_o ~ Temperature @ outside of fitting = −150 °F

$\Delta T = -423 - (-150) = 273$ °F

Ave Temp $= (-423 - 150)/2 = -286$ °F

$K_{AVE} = 56$ BTU·IN/hr·ft²·°F

2 From Graph.

$h = .42 \left(\Delta_s / D'\right)^{.25}$

$\Delta_s = +90 - 150 = 240$ °F

$h = .42 \left(240 / 12.5\right)^{.25}$

$h = .878$ BTU/hr·ft²·°F

$Q = (.878)(.274)(240) = 57.7$ BTU/hr

6/7

$$Q = \frac{K A \Delta T}{x}$$

$$Q = \frac{(56)(.0342)(273)}{4.5}$$

$$\begin{array}{r} -423 \\ -150 \\ \hline 273 \end{array}$$

$Q = 116$ BTU/hr ← TOO HIGH
ΔT TOO HIGH

TRY −200 °F

623 $\Delta T = -423 - (-200) = 223$ °F

$T_{AVE} = -311$ °F

$K_{AVE} = 49$ BTU·IN/hr·ft²·°F

$$h = .42 \left(\Delta_S / D_1 \right)^{.25}$$

$\Delta_S = -200 + 90 = 290$ °F

[2.195]

$$h = .42 \left(\frac{290}{12.5} \right)^{.25}$$

$h = .92$ BTU/hr·ft²·°F

$Q_{ALLOW} = (.92)(290)(.274) = 73.2$ BTU/hr

7/7

-423
-200

$$Q_{REQD} = \frac{K A \Delta t}{x}$$

$$Q_{REQD} = \frac{(49)(.0342)(223)}{4.5}$$

$Q_{REQD} = 83.0$ BTU/hr — TOO HIGH, ΔT TOO HIGH

TRY −210°

633 $\Delta_T = -423 - (-210) = 213$ °F

$T_{AVE} = -316$ °F

$K_{AVE} = 47.5$ BTU·IN/hr·ft²·°F

$h = .42 \left(\frac{\Delta_S}{D_1} \right)^{.25}$ $\Delta_S = -210 + 90 = 300$

$h = .42 \left(\frac{300}{12.5} \right)^{.25}$ [2.233]

$h = .935$ BTU/hr·ft²·°F

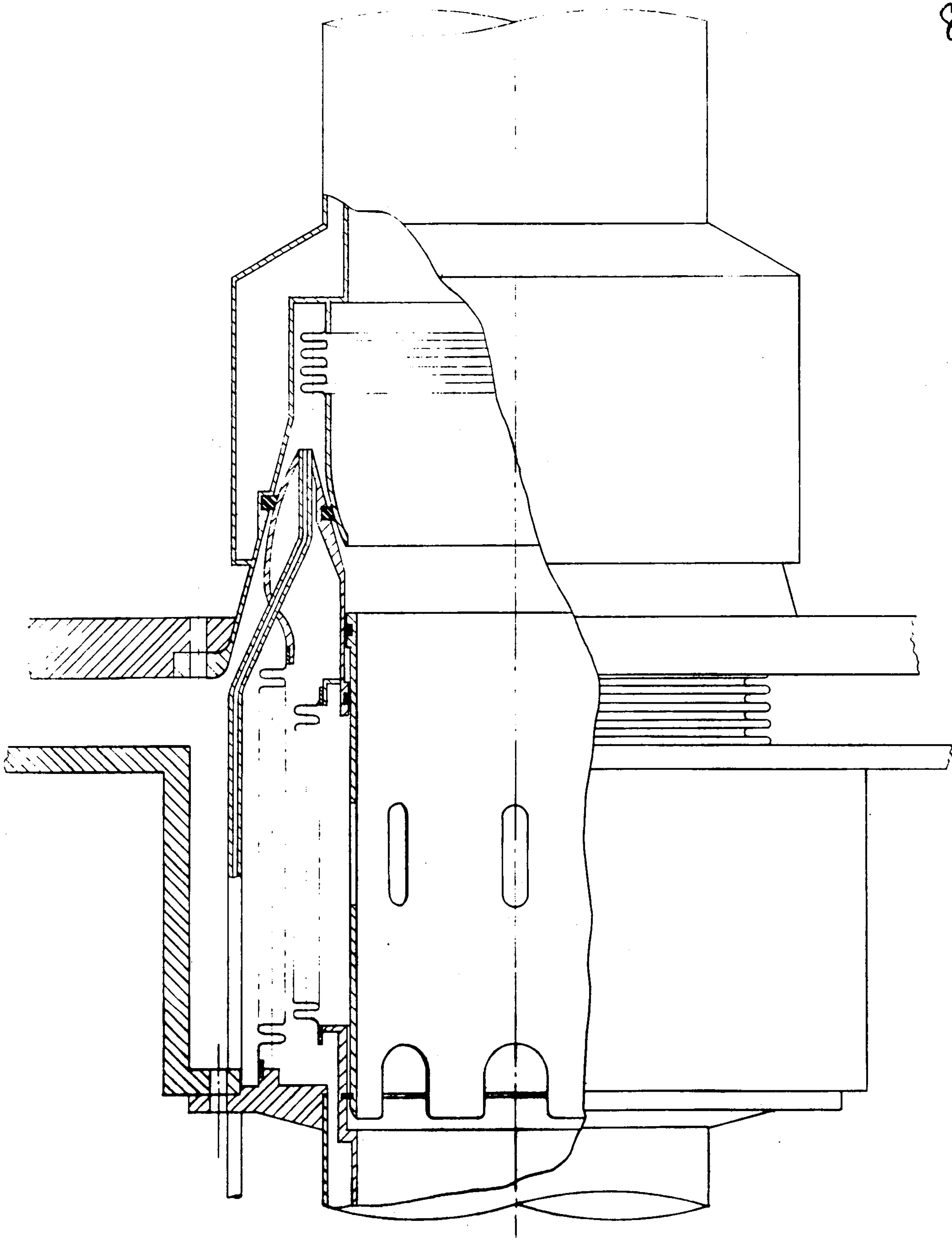
$Q_{ALLOW} = (.935)(.274)(300) = 76.9$ BTU/hr

$Q_{REQD} = \frac{K A \Delta T}{x} = \frac{(47.5)(.0342)(213)}{4.5}$

$Q_{REQD} = 76.9$ BTU/hr OK

FINAL TEMP = −210 °F

8/8



W.R. KILLIAN
10 / 28 / 71
1/7

BALL AND CONE, V. J., DUAL SEAL - 1"
LOX AND LH_2 DISCONNECT

TEMPERATURE CALCULATIONS

HEAT FLUX INPUT REQD = Q_{REQD}

$$Q_{REQD} = \frac{KA\Delta T}{L} \sim \frac{BTU \cdot IN}{hr\ ft^2 \cdot °F} \cdot \frac{ft^2\ °F}{IN} = BTU/hr$$

L:
REF FIGURE 1 - LENGTH OF HEAT PATH
(A) TO (B) - INNER PATH = .80 + .40 + .32 = 1.52"
(A) TO (B) - OUTER PATH = .60 + .85 + .25 + .62 = 2.32"

REF FIGURE 1 - AREA OF HEAT PATH

$$\text{INNER PATH} = \frac{(.80)(2)(\pi)(.063)}{144} = .0022\ ft^2$$

$$\text{OUTER PATH} = \frac{(1.00)(2)(\pi)(.080)}{144} = .00349\ ft^2$$

$$\text{INNER PATH}\quad \frac{A}{L} = \frac{.0022}{1.52} = .00145\ ft^2/IN$$

$$\text{OUTER PATH}\quad \frac{A}{L} = \frac{.00349}{2.32} = .00151\ ft^2/IN$$

1" DISCONNECT, TEMP. CALC. (CONT)

ASSUMPTIONS:

IN ORDER TO SUPPLY THE Q_{REQD} AT THE COUPLING HEAT MUST BE REMOVED BY CONVECTION TO THE AMBIENT ATMOSPHERE. IF THE

$$h = .42 \left(\frac{\Delta T_S}{D} \right)^{0.25}$$

IS UTILIZED TO DETERMINE THE CONVECTIVE HEAT TRANSFER COEFICIENT WHERE

h = HEAT TRANSFER ~ $\left(\frac{BTU}{hr \cdot ft^2 \cdot {}^\circ F} \right)$

ΔT_S = TOTAL ΔT ~ AMBIENT AIR TO PIPE SURFACE °F

D = DIAM OF COUPLING AT PIPE SURFACE

AND

$$Q_{ALLOW} = h \times A \times \Delta T_S = BTU/hr$$

WHERE

ΔT_S = ΔT ~ AMBIENT AIR TO PIPE SURFACE ~ °F
A = AREA OF 1/4" BAND ~ EST EFFECTIVE CONVECTIVE LENGH OF PIPE ~ FT^2

BY CUT & TRY - WHEN $Q_{ALLOW} = Q_{REQD}$

$$\text{OR} \quad .42 \left(\frac{\Delta T_S}{D} \right)^{.25} (\Delta T)(A) = \frac{K A \Delta T}{L}$$

THEN THE ΔT_S SELECTED WILL MATCH THE ΔT SELECTED SINCE A HEAT BALANCE HAS BEEN OBTAINED.

TEMP AT POINT B ~ INNER PATH

CALCULATION OF Q_{REQD} ~ INNER PATH

$Q_{REQD} = \frac{KA\Delta T}{L}$ ASSUME SURFACE TEMP = -293°F

WHERE $A/L = .00145\ ft^2/IN$ (REF SHT 1)

$\Delta T = -423 - (-293) = 130\ °F$

$K = 36.0$ @ AVE TEMP = -358 °F REF FIGURE 2

$\therefore Q_{REQD} = (36)(.00145)(130) = 6.79\ BTU/HR$

CALCULATION OF Q_{ALLOW} ~ INNER PATH

$h = .42\left(\Delta T_S / D\right)^{0.25}$ ASSUME AMB. TEMP = 90°F

WHERE

$\Delta T_S = -293° + 90° = 383\ °F$

$D = 1.66''$

$\therefore h = .42\left(\frac{383}{1.66}\right)^{0.25} = 1.64\ BTU/hr \cdot ft^2 \cdot °F$ [3.90]

$\therefore Q_{ALLOW} = (1.64)\ \Delta T_S\ A$

$A = (1.66 \times .25 \times \pi)/144 = .00905\ ft^2$

$\therefore Q_{ALLOW} = (1.64)(383)(.00905) = 5.68\ BTU/HR$

SINCE $Q_{ALLOW} < Q_{REQD}$, TEMP MUST BE LOWERED.

CALC OF Q_{REQD} ~ INNER PATH (CONT)

ASSUME SURFACE TEMP = −305 °F

$$Q_{REQD} = \frac{K\,A\,\Delta T}{L}$$

WHERE:

$$A/L = .00145 \ ft^2/IN$$

$$\Delta T = -305 - (-423) = 118\ °F$$

$$K = 34.2$$

$$\therefore Q = (34.2)(.00145)(118) = 5.85\ BTU/HR$$

CALC OF Q_{ALLOW} ~ INNER PATH (CONT)

$$h = .42\left(\Delta T_S / D\right)^{0.25}$$

ASSUME AMB. TEMP = 90°F

WHERE:

$$\Delta T_S = -305 + 90 = 395\ °F$$

$$D = 1.66\ IN$$

$$\therefore h = .42\left(\frac{395}{1.66}\right)^{0.25} = 1.645\ \frac{BTU}{hr \cdot ft^2 \cdot °F}$$

[3.92]

$$Q_{ALLOW} = h\,A\,\Delta T_S$$

$$Q_{ALLOW} = (1.645)(.00905)(395) = 5.87\ BTU/HR$$

SINCE $Q_{REQD} \cong Q_{ALLOW}$ ~ HEAT BALANCE HAS BEEN OBTAINED & SURFACE TEMP = −305°F

TEMP. AT POINT B ~ OUTER PATH

CALC OF Q_{REQD} ~ OUTER PATH

$$Q_{REQD} = \frac{KA\Delta T}{L}$$

ASSUME SURFACE TEMP = −300 °F

WHERE $A/L = .00151\ ft^2/IN$

$\Delta T = -423 - (-300) = 123\ °F$

$K = 35$

REF. FIGURE 2

$\therefore Q_{REQD} = (35)(.000151)(123) = 6.50\ BTU/HR$

CALC OF Q_{ALLOW} ~ OUTER PATH

$$h = .42\left(\frac{\Delta T_S}{D}\right)^{0.25}$$

ASSUME AMB. TEMP = 90°F

WHERE

$\Delta T_S = 90° - -300° = 390\ °F$

$D = 2.08\ IN$

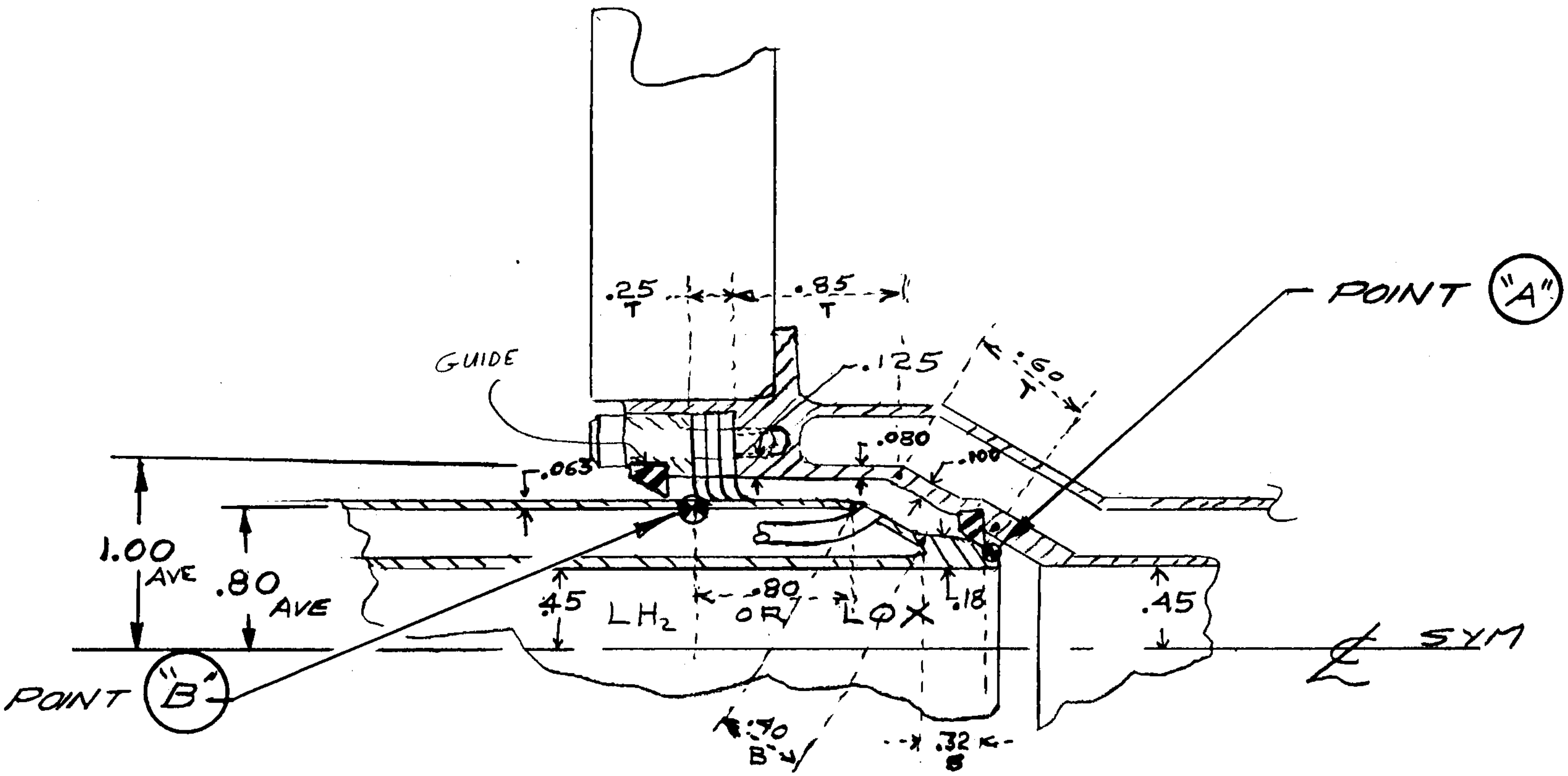
$$h = .42\left(\frac{390}{2.08}\right)^{0.25} = 1.552\ \frac{BTU}{hr \cdot ft^2 \cdot °F}$$

$\therefore Q = (1.552)(390)(.01138) =$

$A = (2.08)(.25)(\pi)/144 = .01138\ ft^2$

$\therefore Q = 6.90\ BTU/HR$

FINAL EST TEMP AT SURFACE = **−295 °F**



1" DISCONNECT

SCALE: 1" = 1"

FIGURE 1

NAS 10-7702

6/7

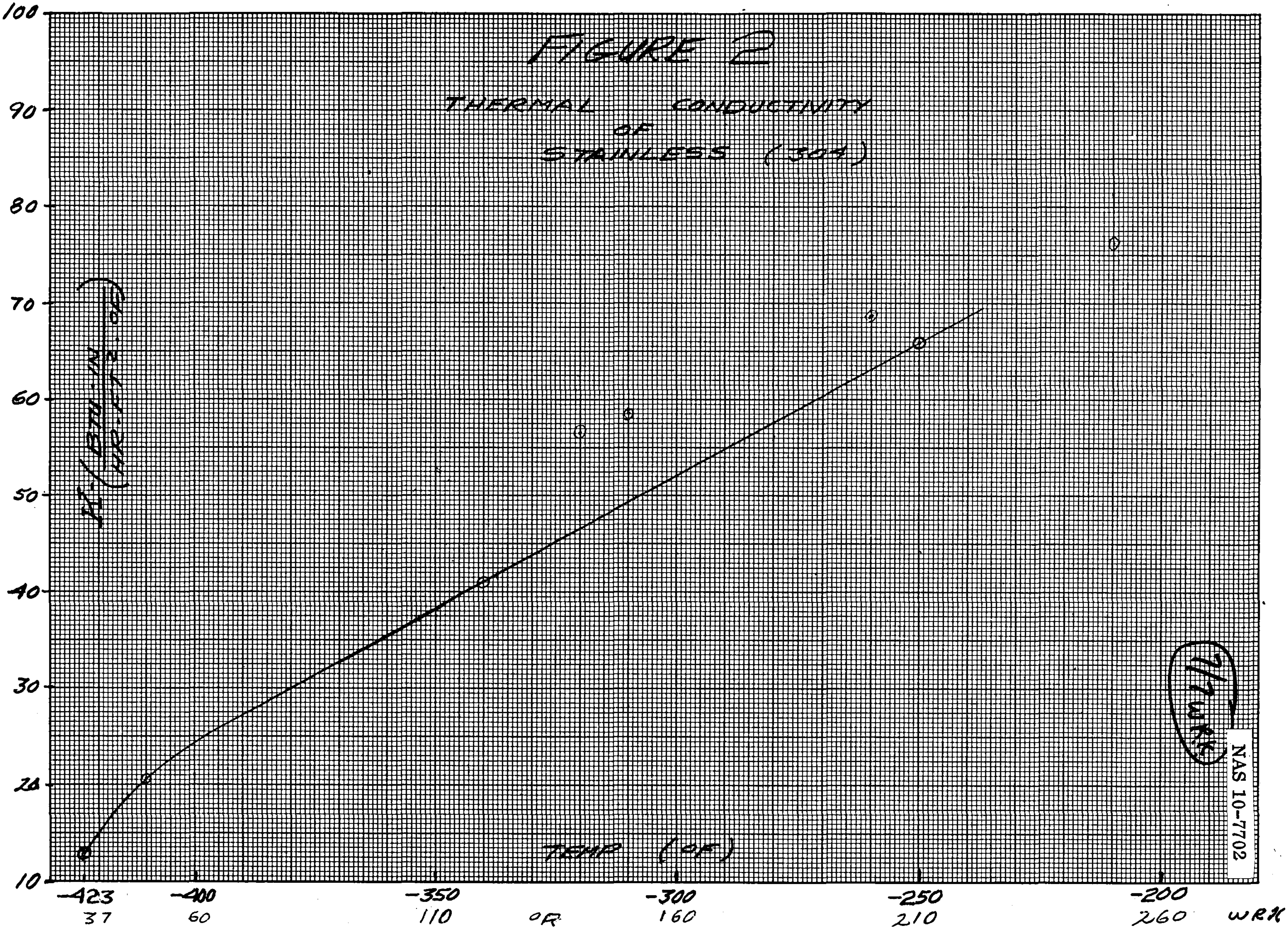


FIGURE 2
THERMAL CONDUCTIVITY OF STAINLESS (304)
K-(BTU-IN / HR-FT²-°F)
TEMP (°F)
100
90
80
70
60
50
40
30
20
10
-423
-400
-350
-300
-250
-200
37
60
110
160
210
260
°R
WRK
NAS 10-7702

SUPP. 1/4

SINCE -305 °F & -295 °F BOTH TEND TO APPROACH THE LIQUEFACTION POINT OF AMBIENT AIR, THE WALL THICKNESSES SHOULD BE REDUCED PER FIGURE 3 TO .040" (INNER) & .060" (OUTER)

LENGTH - INNER PATH = 1.52"
LENGTH - OUTER PATH = 2.32"

$$AREA \sim INNER = \frac{(.80)(2)(\pi)(.040)}{144} = .0014 \ ft^2$$

$$AREA \sim OUTER = \frac{(1.00)(2)(\pi)(.060)}{144} = .00262 \ ft^2$$

$$INNER \quad A/L = .000922 \ ft^2/IN$$

$$OUTER \quad A/L = .00113 \ ft^2/IN$$

SUPP 2/A

TEMP AT POINT B - INNER PATH, FIGURE 3

CALC OF Q_{REQD} ~

$$Q_{REQD} = \frac{KA\Delta T}{L}$$

ASSUME SURFACE TEMP = -277 °F

WHERE

$A/L = .000922 \ ft^2/in$

$\Delta T = -423 - (-277) = 146\,°F$

$K = 38.3$ @ -350°F AVE TEMP

$Q_{REQD} = (38.3)(.000922)(146) = 5.16 \ BTU/hr$

CALC OF Q_{ALLOW}

$$h = .42\left(\Delta T_S / D\right)^{.25}$$

AMB TEMP = 90°F

WHERE

$\Delta T_S = -277 + 90 = 367\,°F$

$h = .42\left(367/1.66\right)^{.25} = 1.625 \ BTU/hr \cdot ft^2 \cdot °F$

$Q_{ALLOW} = (1.625)(367)(.00905) = 5.38 \ BTU/hr$

BALANCE OF $Q_{REQD} = Q_{ALLOW}$ WILL OCCUR AT SURFACE TEMP OF **-276 °F**

SUPP. 3/4

TEMP AT POINT B - OUTER PATH, FIGURE 3

CALC OF Q_{REQD} ~

$Q_{REQD} = \frac{KA\Delta T}{L}$ ASSUME SURFACE TEMP = -273 °F

WHERE

$A/L = .00113 \ ft^2/IN$

$\Delta T = -423 - (-273) = 150 \ °F$

$K = 38.5$ AT AVE TEMP - 348°F REF FIG 2

$\therefore Q_{REQD} = (38.5)(.00113)(150) = 6.52 \ BTU/hr$

CALC OF Q_{ALLOW} ~

$h = .42 \left(\Delta T_S / D \right)^{.25}$ AMB TEMP = 90°F

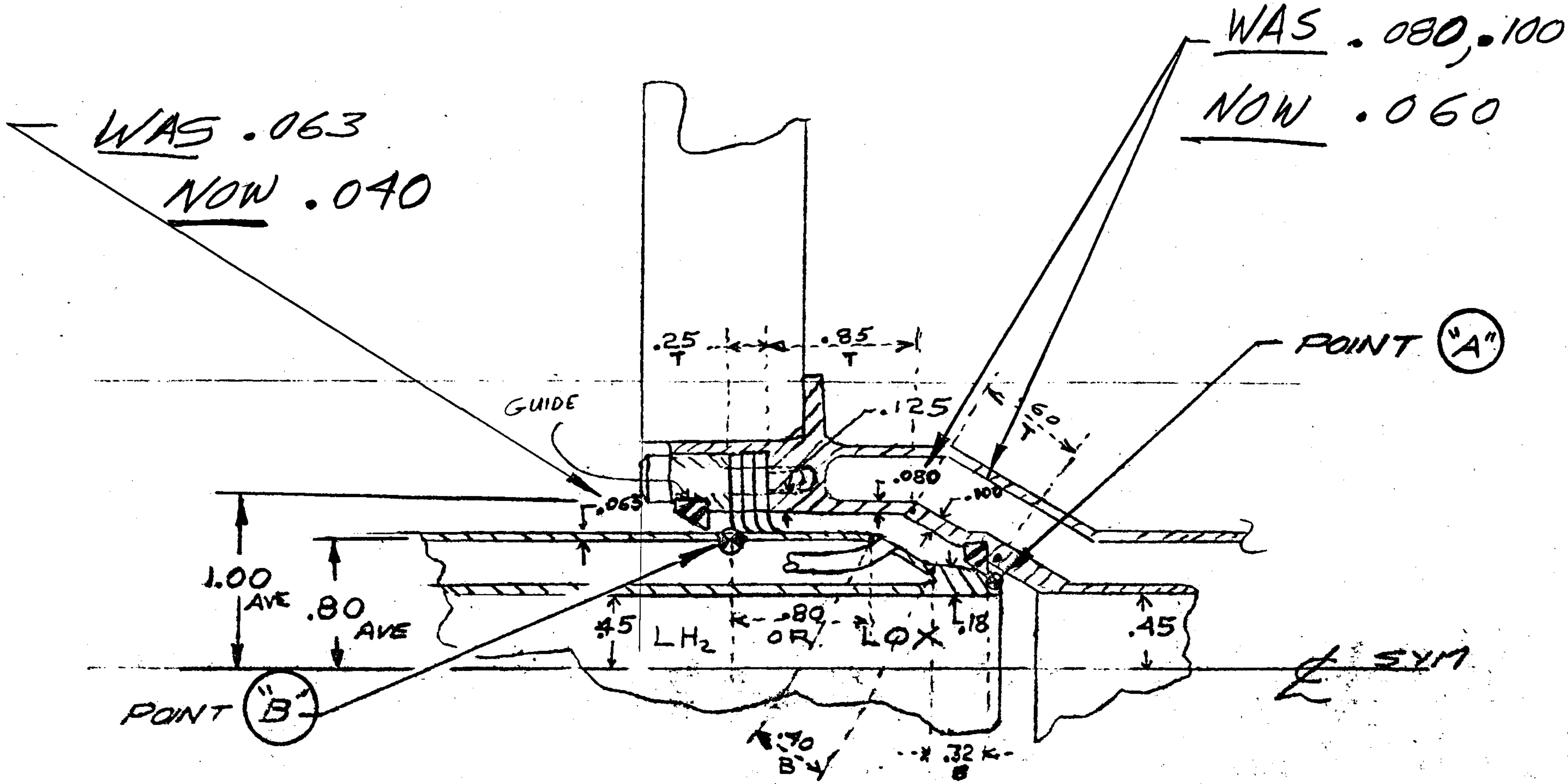
$\Delta T_S = -273 + 90 = 363 \ °F$

$D = 2.08$

$\therefore h = .42 \left(363 / 2.08 \right)^{.25} = 1.526 \ BTU/hr \cdot °F \cdot ft^2$

$Q_{ALLOW} = (1.526)(363)(.001138) = 6.31 \ BTU/hr$

SINCE $Q_{REQD} \cong Q_{ALLOW}$, SURFACE TEMP. WILL = -273°F



1" DISCONNECT

SCALE: 1" = 1"

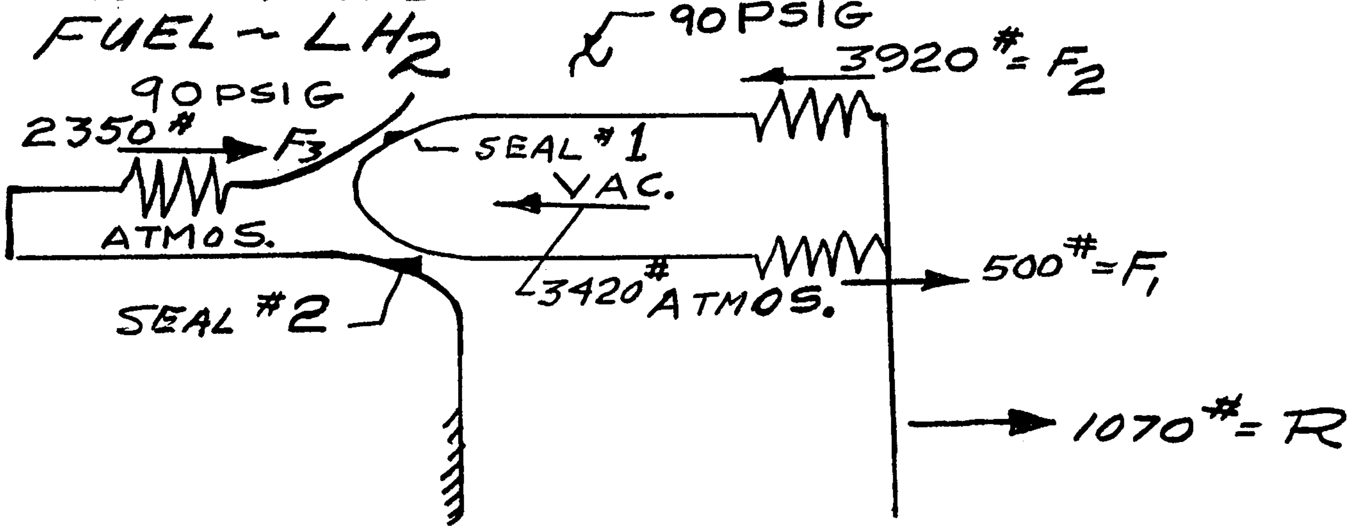
FIGURE 3

NAS 10-7702

4/4

CALCULATION OF THRUST FORCES DEVELOPED BY BELLOWS:

REF FIG. 1



REF FIG 1

CALC OF RESULTANT THRUST - R

```
  3920
 - 500
  3420
- 2350
  1070 # = R *
```

LINEAR LOAD AT SEAL #1

$$(3420/2 + 2350) / 34'' = 119 \ \#/IN$$

LINEAR LOAD AT SEAL #2

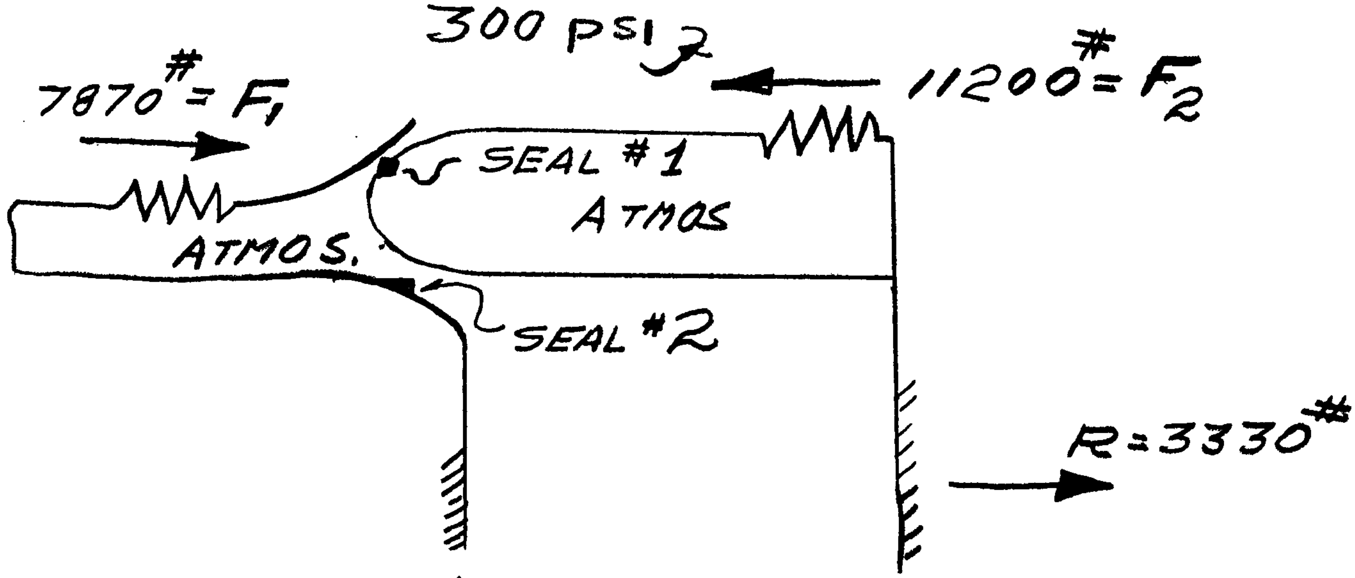
$$1710 / 44.7'' = 38 \ \#/IN$$

* THE RESULTANT LOAD R WILL OPPOSE THE INITIAL COMPRESSION OF BELLOWS BY THE GROUND HALF OF THE COUPLING.

INITIAL COUPLING LOAD $\geq$ 1070 #.

 9/24/71

CALCULATION OF THRUST FORCES DEVELOPED BY BELLOWS:



REF FIG 1

CALC OF RESULTANT THRUST - R

$$\begin{array}{r} 11200 \\ 7870 \\ \hline 3330 \end{array} \# = R^*$$

LINEAR LOAD AT SEAL #1

$$\left(11200/2 + 7870\right) / 34'' = 396 \ \#/IN$$

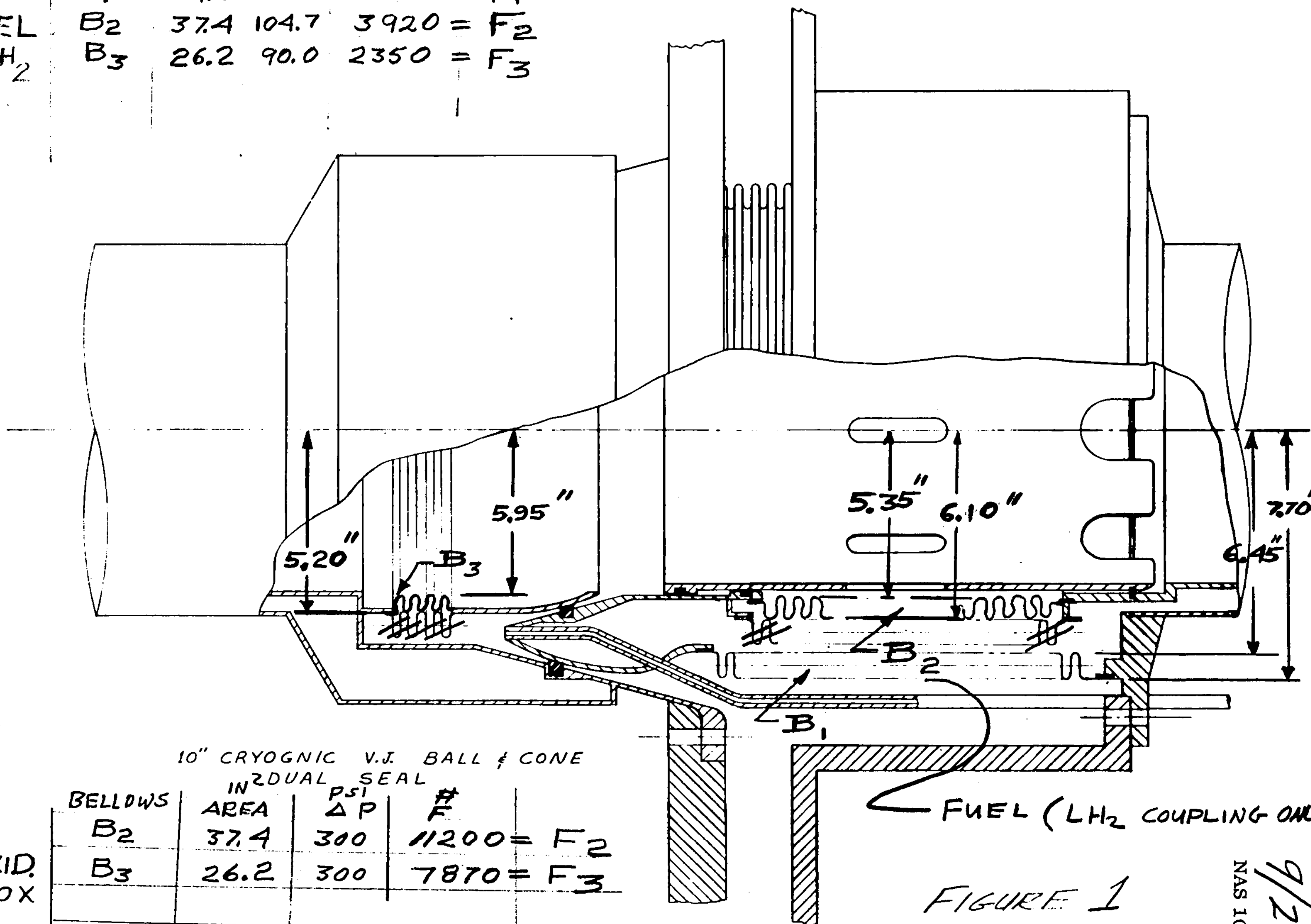
LINEAR LOAD AT SEAL #2

$$\left(11200/2\right) / 44.7 = 125 \ \#/IN$$

* THE RESULTANT LOAD R WILL OPPOSE THE INITIAL COMPRESSION OF THE BELLOWS BY THE GROUND HALF OF THE COUPLING.

INITIAL COUPLING LOAD $\geqq$ 3330#

	Bellows	Area (IN²)	ΔP (PSI)	F (#)
FUEL LH_2	B_1	34.0	-14.7	- 500 = F_1
	B_2	37.4	104.7	3920 = F_2
	B_3	26.2	90.0	2350 = F_3



10" CRYOGNIC V.J. BALL & CONE DUAL SEAL

	Bellows	Area (IN²)	ΔP (PSI)	F (#)
OXID. LOX	B_2	37.4	300	11200 = F_2
	B_3	26.2	300	7870 = F_3

FIGURE 1

9/27/71

NAS 10-7702

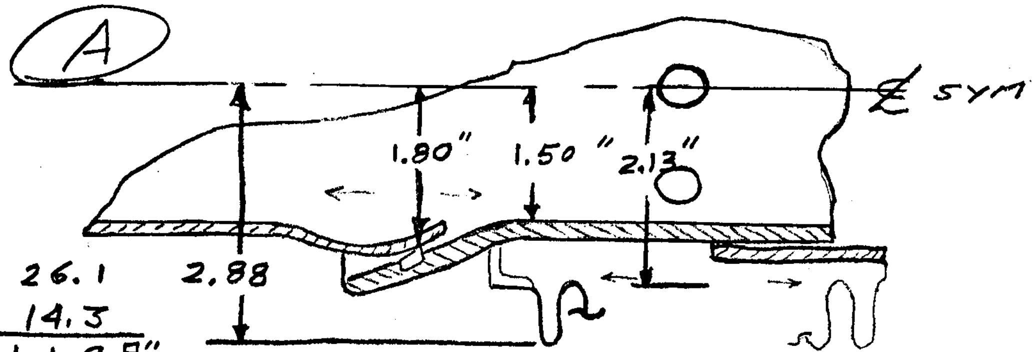
Umbilical Carrier Separation Forces

CONCEPT #1 SLIP TYPE

NAS 10-7702

WRK, 10/4/71

SHT 1/5



$2.88^2 \times \pi = 26.1$

$2.13^2 \times \pi = \underline{14.3}$

11.9 □"

3" COUPLING ~ BALL & CONE ~ 150 psi

AREAS :

$1.80^2 \times \pi = 10.18$

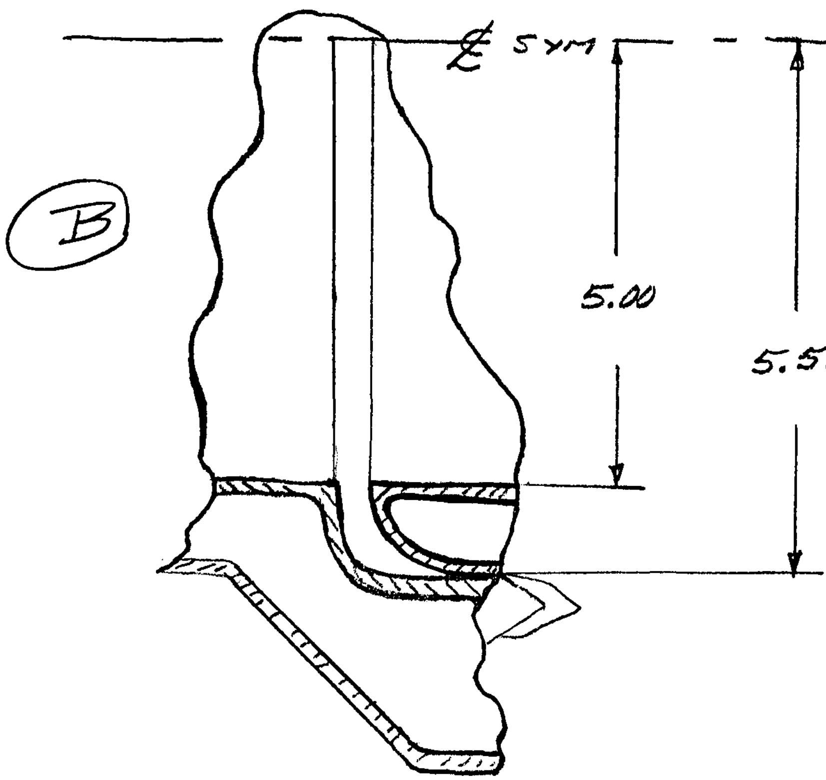
$1.50^2 \times \pi = \underline{7.07}$

3.11

11.9 × 150 = 1782 #

3.11 × 150 = 467 #

2249



OK

10" V.J. SLIP ~ 90 psi

AREAS :

$5.50^2 \times \pi = 95.0$

$5.00^2 \times \pi = \underline{78.6}$

16.4 □"

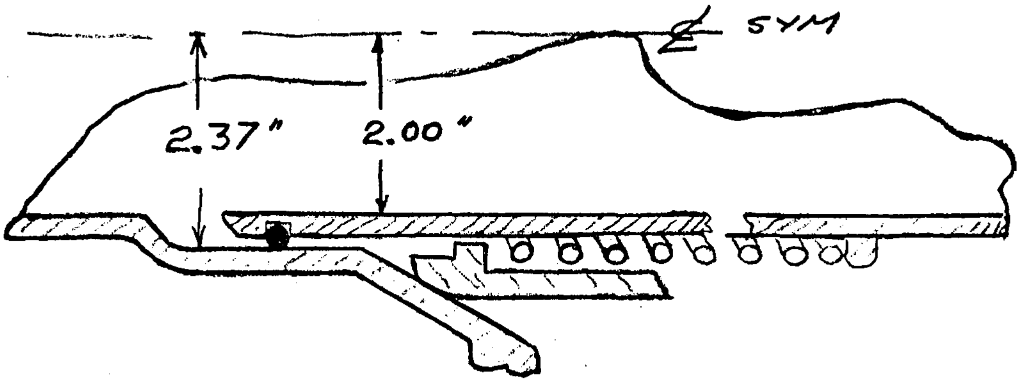
FUEL 16.4 × 90 = 1480 #

OXIDIZER 16.4 × 300 = 4920 #

CONCEPT #1 SLIP TYPE NAS 10-7702

WRK: 10/4/71
SHT 2/5

(C)



OK

4" PNEU. COUPLING ~ 150 psi – SLIP

AREAS:

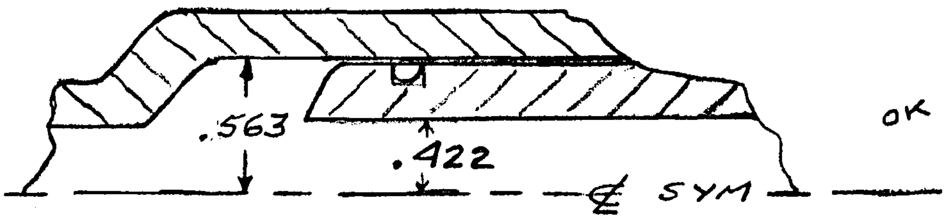
$2.37^2 \times \pi$ = 17.72

$2.00^2 \times \pi$ = – 12.58

AREA = 5.14 □"

150×5.14 = 770 #

(D) (E)



OK

1" PNEU COUPLING ~ 1000 psi ~ SLIP
3700 psi

AREAS:

$.563^2 \times \pi$ = .997

$.422^2 \times \pi$ = .559

AREA = .438 □"

$.438 \times 1000$ = 438 #

$.438 \times 3700$ = 1,620 #

(F)

ASSUME 100 # FOR ELECT. DISCONNECT.

ITEM	# REQD
A	2249
B	1480
C	770
D	438
E	1,620
F	100

FUEL → 6657 # ~ + ANY SEATING FORCES ← REQUIRED.

OXID → 10097 # ←

WRK
10/4/71
SHT 3/5

CONCEPT #2 ~ PRESS. BALANCED

1" PNEU. PRESS. BALANCE COUPLING (2 REQD)
180# each per 65B64001
"COUPLINGS, FLUID - SATURN, V/S-IC, SPEC."
TOTAL = 2 × 180 = 360# MAX

10" CRYOGENIC V.J. PRESS. BALANCED
EST. UNCOUPLING FORCE = 1000# MAX

4" SLIP COUPLING ~ 150 PSI
(REF SHT 2/5, ITEM (C) = 770#

3" BALL & CONE ~ 150 psi
(REF SHT 1/5, ITEM (A) = 2249#

TOTAL COUPLING LOAD
100 ~ ELECT. COUPLING
360
1000
770
2249

4,479#

WRK
10/4/71
SHT 4/5

CONCEPT # 3 COMBINED BALL & CONE
+ PRESS. BALANCE

REF LH_2 BALL & CONE (10")
CALC. OF 9/24/71

@ 90 psi ~ FORCE = R = − 1070 #

REF LOX BALL & CONE (10")
CALC. OF 9/24/71

@ 300 psi ~ FORCE = R = −3330 #

2 - 1"- PRESS. BALANCED PNEU. COUPLINGS = 360 #
└ REF SHT 3/5

4" SLIPTYPE PNEUMATIC COUPLING = 770 #
└ REF SHT 2/5 ITEM Ⓒ

3" BALL AND CONE = 2249 #
└ REF SHT 1/5 ITEM Ⓐ

3 M.S. ELECT CONNECTOR = 180 #
60 # each

TOTAL FORCE - FUEL COUPLING = 2669 #

TOTAL FORCE LOX COUPLING = 409 #

WRK
10/4/71
SHT 5/5

DISCONNECT FORCE SUMMARY

→ CONCEPT #1 ~ SLIP TYPE
A- FUEL = 6,657 #
B- OXIDIZER = 10,097 #

→ CONCEPT #2 ~ PRESS. BALANCE = 4,479 #

→ CONCEPT #3 ~ COMBINED BALL & CONE + PRESS. BALANCE
A- FUEL = 2,669 #
B - OXIDIZER = 409 #

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