NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

August 21, 2000

ADDENDUM TO SYSTEMS GROUP CHAIRMAN FACTUAL REPORT, MISCELLANEOUS DATA

A. **ACCIDENT** : DCA96MA070

Location : East Moriches, New York

Date : July 17, 1996

Time : 2031 Eastern Daylight Time

Airplane : Boeing 747-131, N93119
Operated as Trans World Airlines (TWA) Flight 800

B. **SYSTEMS SUB-GROUP**

Chairman : Robert L. Swaim
Systems Engineer, NTSB
Washington, D.C.

C. **SUMMARY**

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK). All 230 people aboard were killed. The airplane was being operated as a Code of Federal Regulations (CFR) Part 121 flight to Charles De Gaulle International Airport (CDG) at Paris, France, as Trans World Airlines (TWA) Flight 800.

This addendum adds information to the docket that was collected during the investigation and not entered into the docket previously.

Robert L. Swaim
TWA800 Systems Group Chairman
8/21/00

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

January 7, 2000

MATERIALS LABORATORY FACTUAL REPORT — Report No. 00-008

A. ACCIDENT

Place	: East Moriches, New York
Date	: July 17, 1996
Vehicle	: Boeing 747-131, N93119
NTSB No.	: DCA96-M-A070
Investigator	: Scott Warren (AS-40)

B. COMPONENTS EXAMINED

The components examined were removed from a Boeing 747-136, G-AWNN, in desert storage, Roswell, New Mexico.

Fuel Probe with wiring bundle.
Bulkhead with grommet.

C. DETAILS OF THE EXAMINATION

The as-received components are displayed in figure 1. The fuel probe had a bundle of wiring attached that consisted of two larger diameter white wires and 5 smaller diameter red wires. Areas of damaged insulation had been marked on one of the white wires and one red wire. Exposed cross sections of the wires showed that the white wire was a shielded coaxial cable with an inner stranded conductor core and an outer shielding layer of wire strands. The shield layer was separated from the conductor by a white insulating material and the entire cable was spiral wrapped by white insulation. The red wire was not shielded and only contained a central core of stranded conductor surrounded by an extruded outer insulation layer. On both wire lengths the individual conductor strands appeared to be silver plated copper.

The points of wire damage reportedly corresponded to the location where the wires pass through the grommet in the received bulkhead section (shown in the top center in figure 1). The grommet was a hard plastic donut inserted into a hole through the bulkhead.

Close optical inspections of the damage areas on the wires showed that the insulation had been worn or chafed away on both wires and that strands of conductor wire were exposed, see figure 2. The photographs in figures 3 and 4 show closer views of the damage on the white and red wires, respectively. The chaffing removed two adjacent scallop shaped areas of the insulation on each wire. The entire area of damage was less then 0.2 inches long on both wires. The shape of the wear areas indicated that they were sequential and not concurrent. The shape also indicated that the wearing object had a rounded or cylindrical profile at the point of contact. Blackish deposits were also found associated with the damage areas on both wires.

On the white wire, two strands of the shielding conductor were exposed at one of the scallops, as can be seen in the lower photograph in figure 3. The exposed wires had a white brass tarnished appearance in contrast to the bright silver metallic finish visible at the cut ends. The exposed strands were partially obscured by dark overlaying deposits. The obscuring deposits were partially removed for later analysis. The wire was cut on either side of the damage and the piece was examined with the aid of a scanning electron microscope (SEM). An SEM view of the exposed shielding strands is presented as figure 5. The exposed wire strands did not show evidence of arcing, wear or other types of mechanical damage.

Energy dispersive x-ray spectra (EDS) acquired during SEM examinations determined that the exposed strands from the white wire were silver coated. Spot and area EDS spectra also determined that the insulation showed high levels of fluorine, oxygen and carbon and the deposits consisted mainly of silver and sulfur.

On the damaged red wire, a single strand of conductor was exposed at each of the scalloped wear areas. Other conductor wire strands were visible through the thinned translucent insulation but were not uncovered. Similar to the white wire, blackish deposits were noted at and adjacent to the wear areas. Some relatively heavy deposits were found on the exterior surface of the wire out of the immediate wear areas. In addition, deposits appeared to have penetrated into the wire strands surrounding the exposed wires. A portion of the deposits obscuring the strands were removed and retained for later analysis. The wire was cut on either side of the damage, thereby separating an approximate 1-inch long piece for SEM examinations.

The exposed wire strands from the red wire are displayed in figure 6. No wear or arcing damage was noted on either wire, however, the probe used to remove the obscuring deposits from the surface inadvertently marked one of the exposed wires. EDS spectra showed that the silver coating was intact on the exposed wires. Further, EDS spectra established that the insulation and the deposits contained similar elements to those that were found on the white wire (fluorine, oxygen and carbon in the insulator with traces of aluminum and silicon and mainly silver and sulfur in the deposits).

The larger rounded nose of the bulkhead grommet was partially covered by blackish deposits as shown in figure 7. The deposits were in the form of two distinct bull's eye shaped areas where the centers had a shiny black appearance and the outer rings had a gray cast. The grommet and a surrounding ring of the bulkhead material were machined out of the larger piece for SEM inspection.

EDS spectra acquired during SEM examination found that the grommet material was a plastic showing significant peaks for carbon, oxygen, and potassium with minor amounts of aluminum and sulfur. In contrast, the deposits showed high levels of fluorine, carbon, sulfur, and silver.

Joe Epperson
Senior Metallurgist

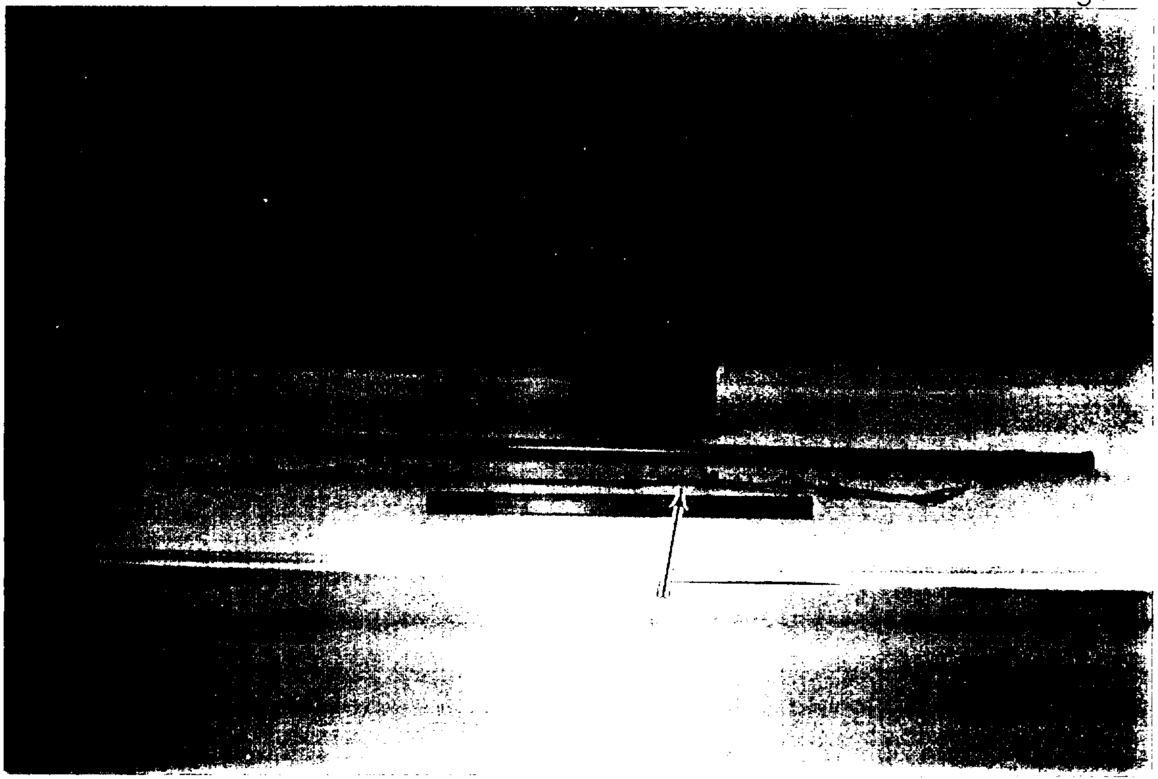


Figure 1. An overall view of the as received components. The arrow indicates the location of wire damage

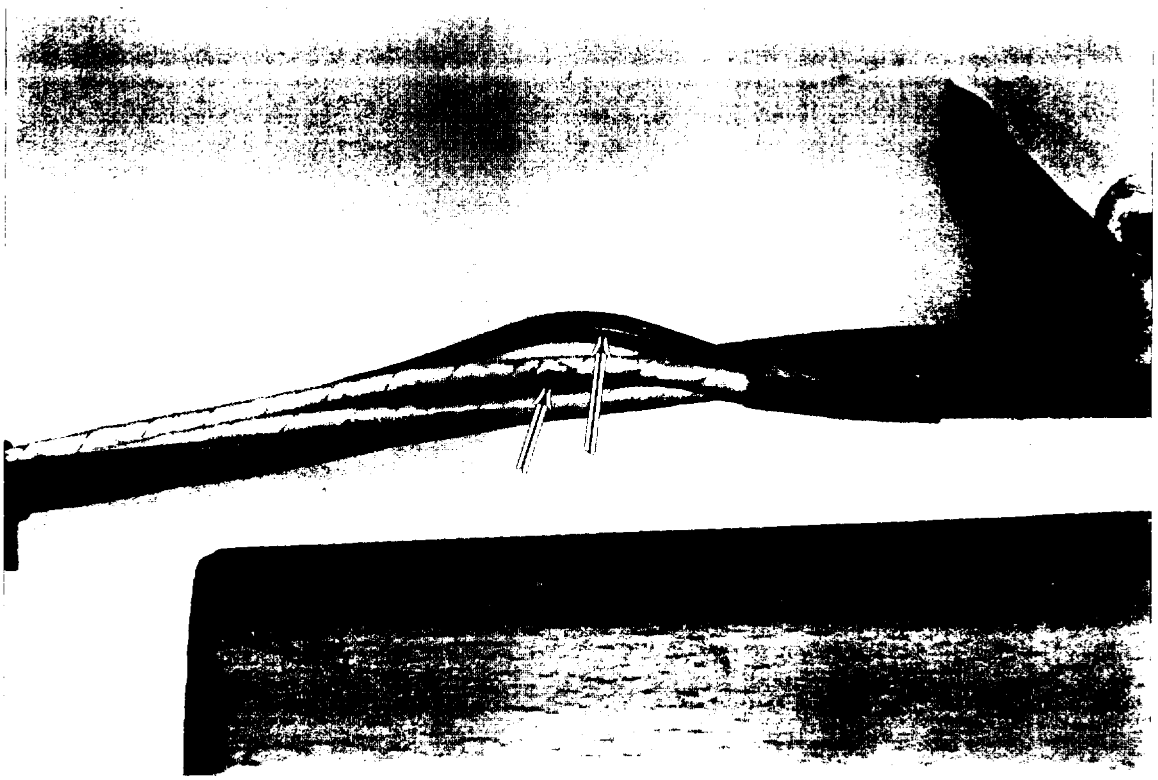


Figure 2. A closer view of the area of wire damage (arrows)

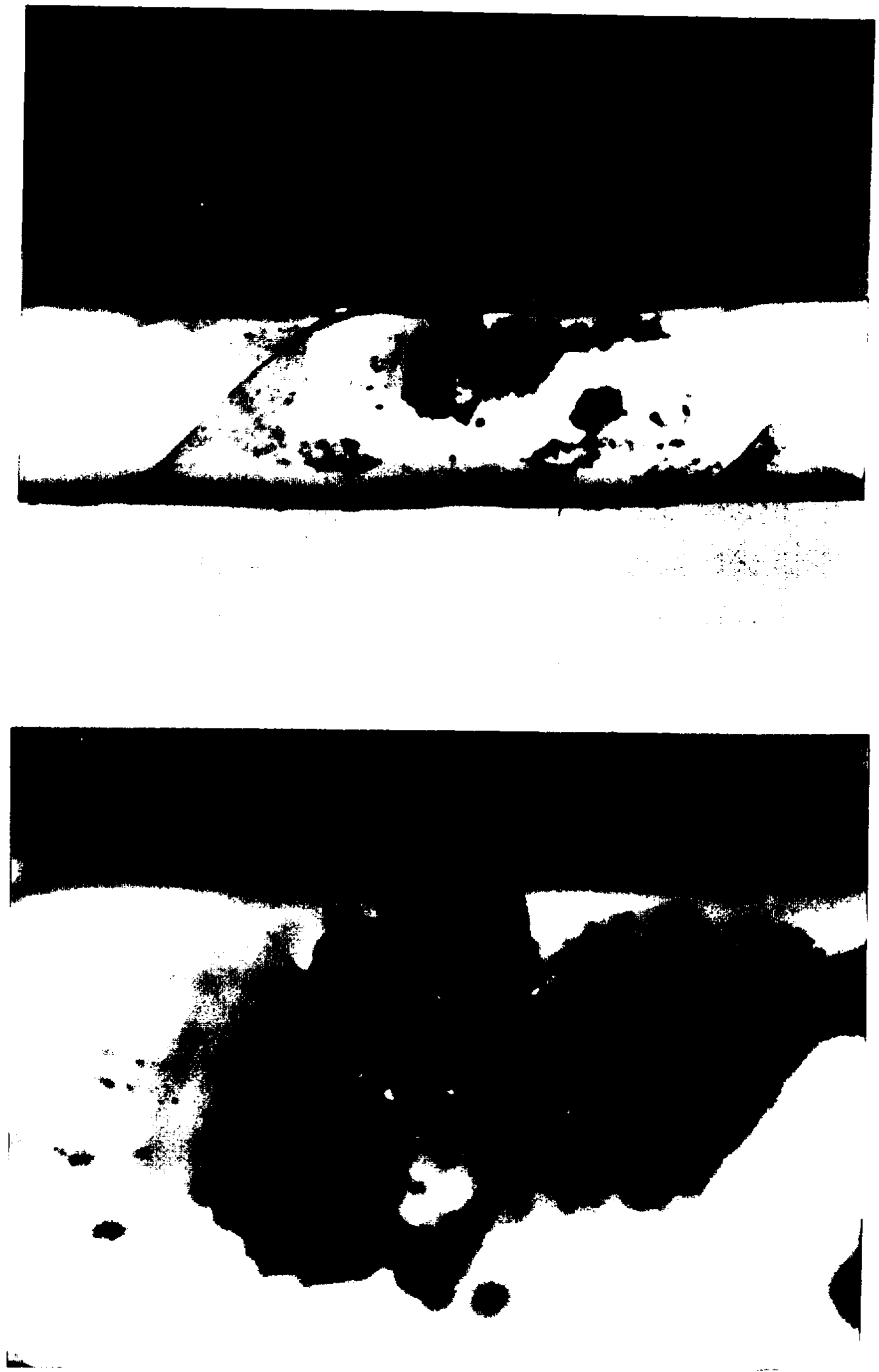


Figure 3. Two views of the damage and dark deposits on the white wire, upper view at 12X, lower at 40X.

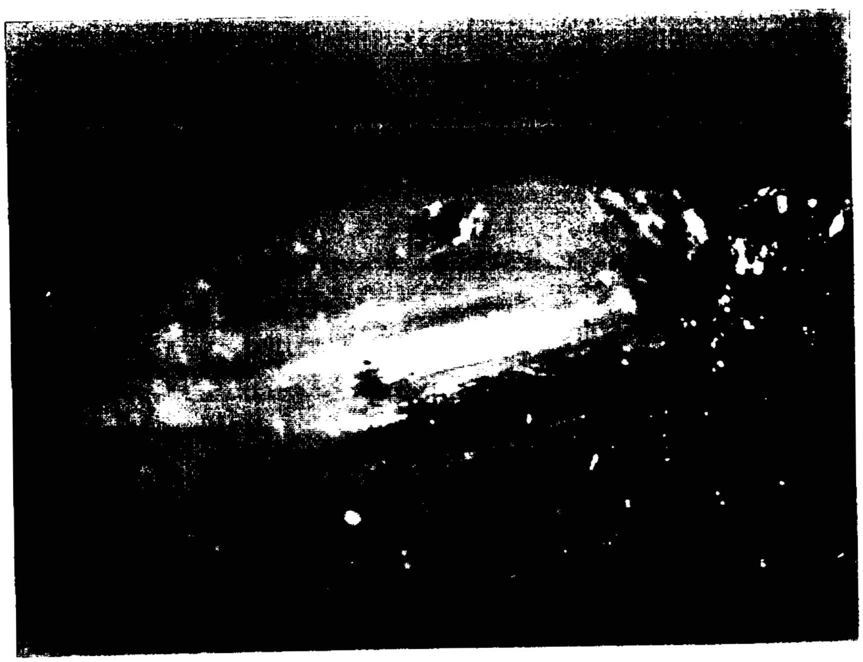


Figure 4. Two views of the damage and dark deposits on the [illegible] wire upper view at 20X lower at 40X

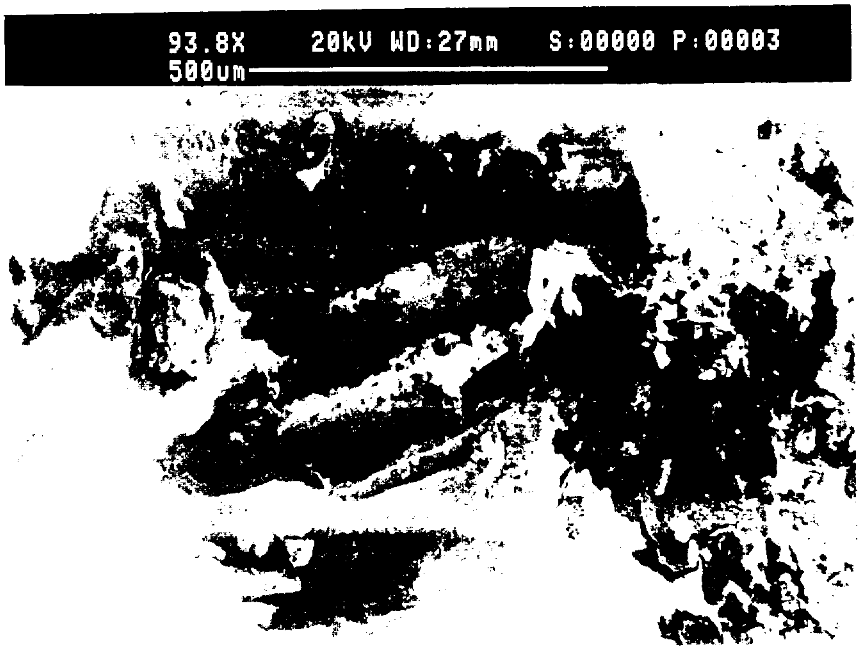


Figure 5. An SEM micrograph of the exposed strands of the white wire

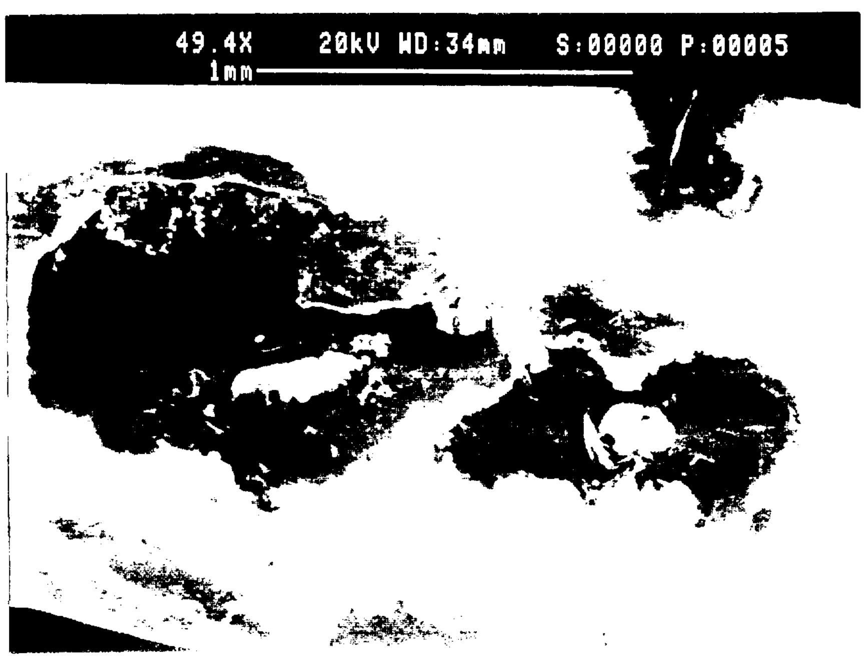


Figure 6. An SEM micrograph of the exposed strands of the red wire

Figure 7. An oblique view looking at the two areas of deposits on the nose of the bulkhead grommet. (Mag 5X)

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

March 30, 2000

MATERIALS LABORATORY FACTUAL REPORT Report No. 00-054

A. ACCIDENT

Place	: East Moriches, New York
Date	: July 17, 1996
Vehicle	: Boeing 747-100
NTSB No.	: DCA96-M-A070
Investigator	: Robert Swaim, AS-40

B. COMPONENTS EXAMINED

A section of the lower skin of the center wing fuel tank removed on February 2, 2000, from the Federal Aviation Administration's Cabin Simulator at CAMI in Oklahoma City.

C. DETAILS OF THE EXAMINATION

An overall view of the section of the lower skin of the center wing fuel tank is shown in figure 1, as received. The section was removed because it contained a spot of "blistered paint" and was reportedly from an area that was located immediately above an air conditioning pack. The suspect spot measured approximately 0.30 inches in diameter and is indicated by arrow "s" in figure 1.

The submitted piece of the fuel tank skin was painted white on the side that contained the suspect spot (exterior surface) and was painted green on the opposite side (interior surface). The exterior surface of the piece, except for a small area surrounding the spot, was covered with powdery black deposits that could be easily wiped off. The deposits looked significantly denser in the vicinity of the spot. The paint on the back surface showed no evidence of discoloration and appeared intact.

A close up view of the suspect spot and the adjacent area of the fuel tank skin is shown in figure 2. The spot was dark in appearance and was surrounded by blistering paint around its periphery. Examination of this spot at higher magnifications with the aid of a scanning electron microscope (SEM) revealed that it was covered with a network of fibrous deposits. The SEM view of the typical deposits in the spot is shown in figure 3. The energy dispersive X-ray spectroscopy (EDS) of the fibrous deposits, performed in conjunction with the SEM examination, produced a spectrum containing carbon as a major peak with minor peaks of aluminum, oxygen, sulfur, copper, calcium, phosphorous, silicon and magnisium. Also present in this spectrum were the peaks of a number of other light elements[1].

EDS analysis of all other deposits in the spot generated spectra containing aluminum as the major peak with minor peaks of oxygen, carbon, sulfur, silicon, and calcium. EDS analysis performed in the area with powdery black deposits located immediately adjacent to the dark spot generated spectra containing carbon and titanium as the major peaks with minor peaks of oxygen, aluminum, silicon, and sulfur.

A small coupon containing the suspect spot was cut out from the remaining portion of the fuel tank skin for further examination. The cut off piece was ultrasonically cleaned in acetone and then reexamined with the SEM. The examination revealed that the cleaning removed all fibrous deposit from the surface of the spot. EDS analysis performed at various locations within the spot generated spectra containing aluminum and oxygen as major peaks with minor peaks of carbon, sulfur, silicon, phosphorous, and calcium.

Figure 4 depicts a view of the suspect spot after the cleaning. A metallographic specimen was cut from the location indicated by sectional arrows "X-X" in this figure. Examination of the polished and etched specimen revealed that in the area of the spot the fuel tank skin was subjected to exfoliation corrosion. The typical microstructure in this area is shown in figure 5. Examination disclosed no evidence of corrosion in any other area of the specimen.

Figure 6 is a low magnification micrograph showing the width of the spot (see unlabeled bracket) at the location denoted by arrows "X-X" in figure 4. Measurements indicated that the corrosion damage extended to a depth of about 0.005 inch. Examination revealed no evidence of metal overheating in the area of the suspect spot.

Jean Bernstein
Senior Metallurgist

[1] This spectrum and other characteristic spectra referenced in this report are present in the appendix.

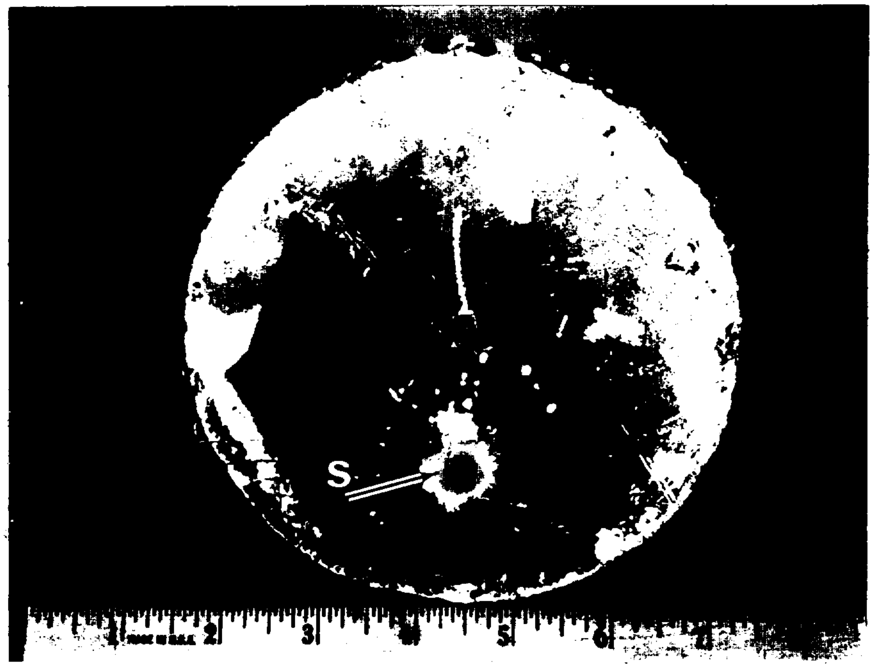


Figure 1. An overall view of the submitted section of the lower skin of the center wing fuel tank showing the suspect spot by arrow "s".

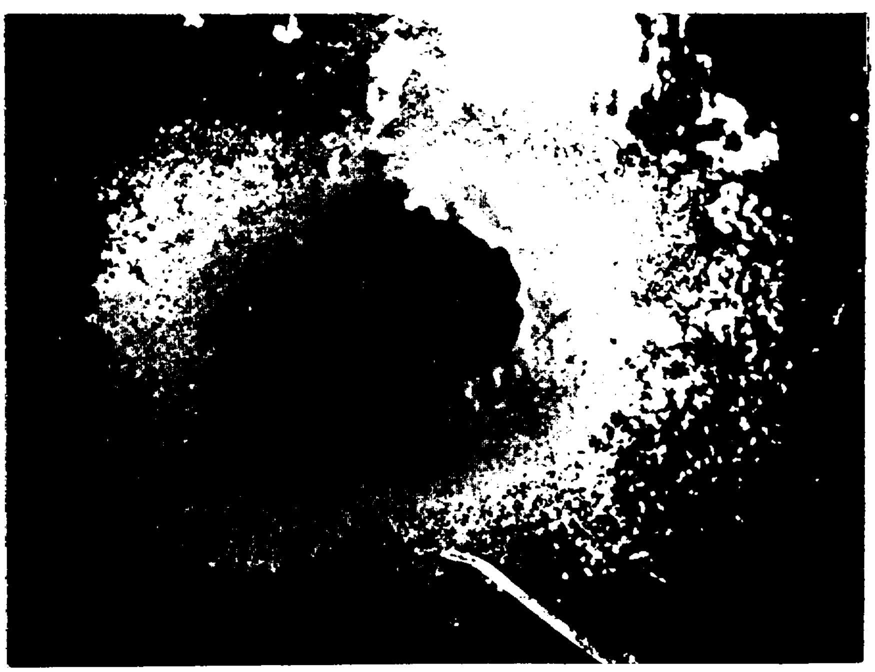


Figure 2. Close up view of the suspect spot on the surface of the fuel tank skin. (≈3X).

Figure 3. SEM view of the deposits on the surface of the spot. (286X).

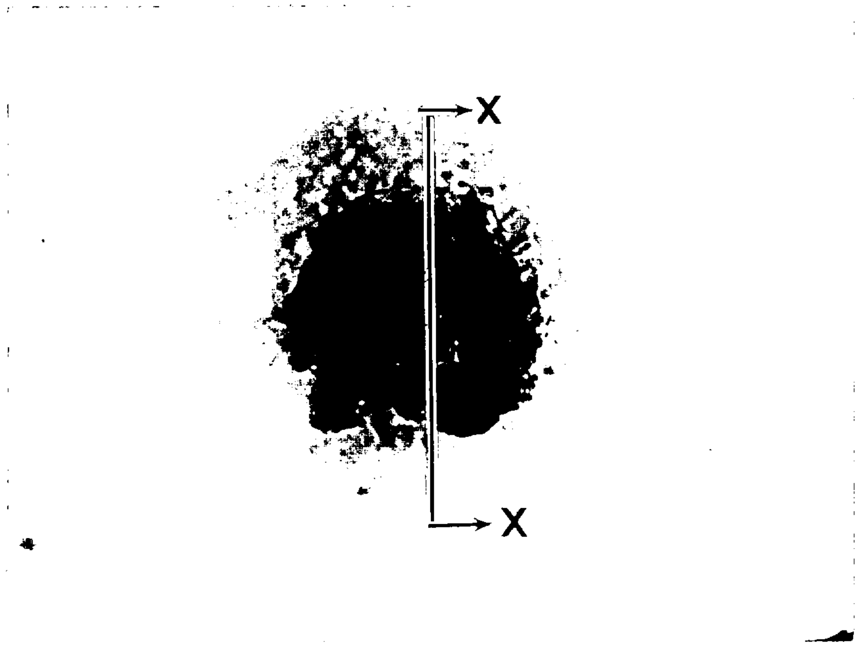


Figure 4. Close up view of a portion of the fuel tank skin containing the suspect spot after it had been ultrasonically cleaned in acetone. Sectional arrows "X-X" denote the location of the metallographic specimen. (≈3X).

Figure 5. Corrosion at the surface of the fuel tank skin in the area of the suspect spot. Keller's etch, magnification 100X.

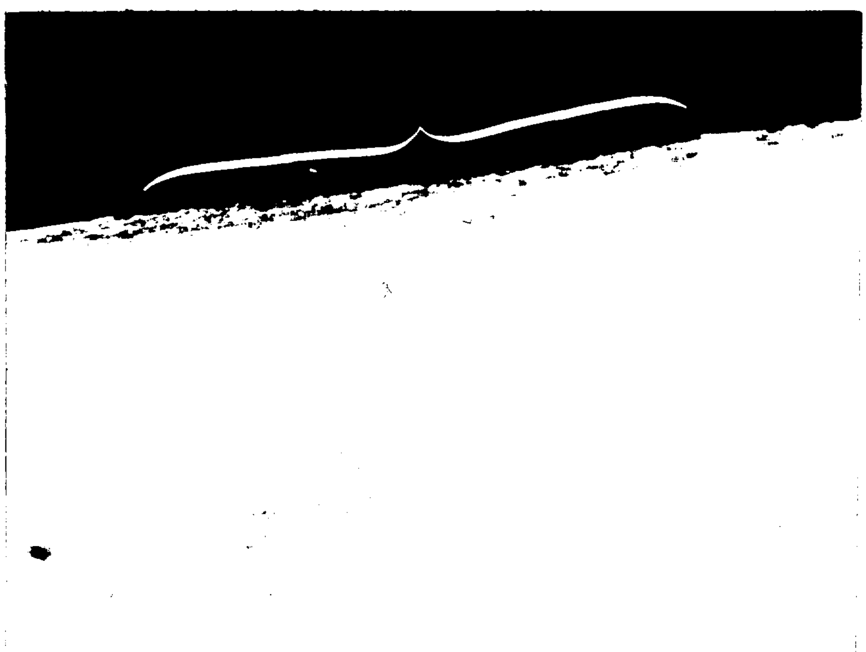
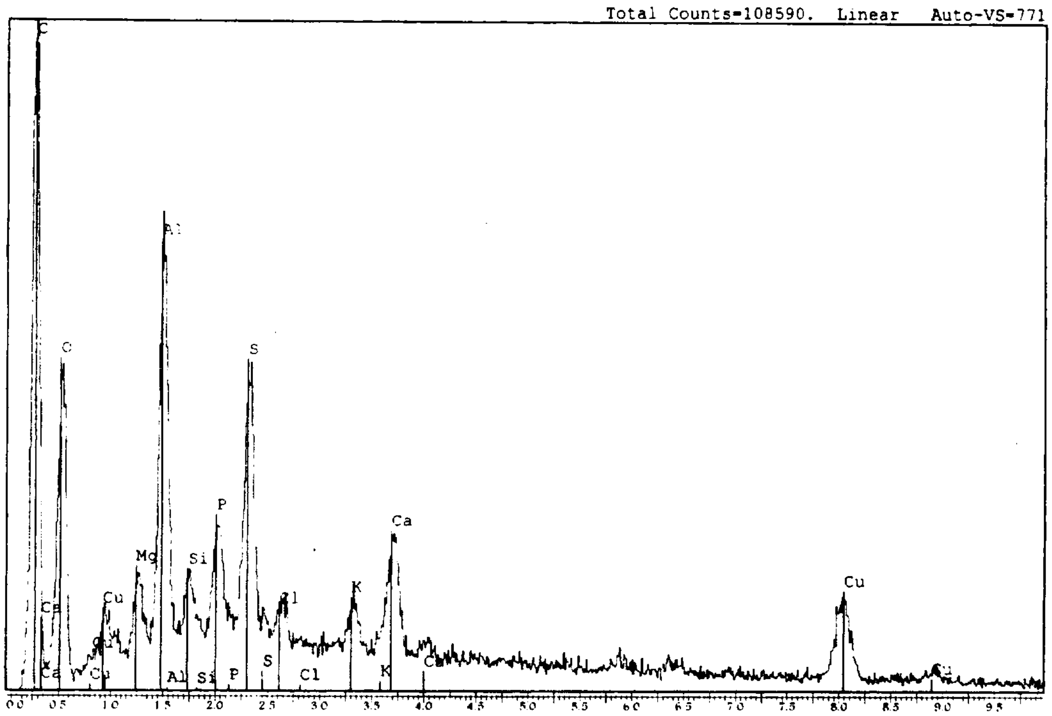
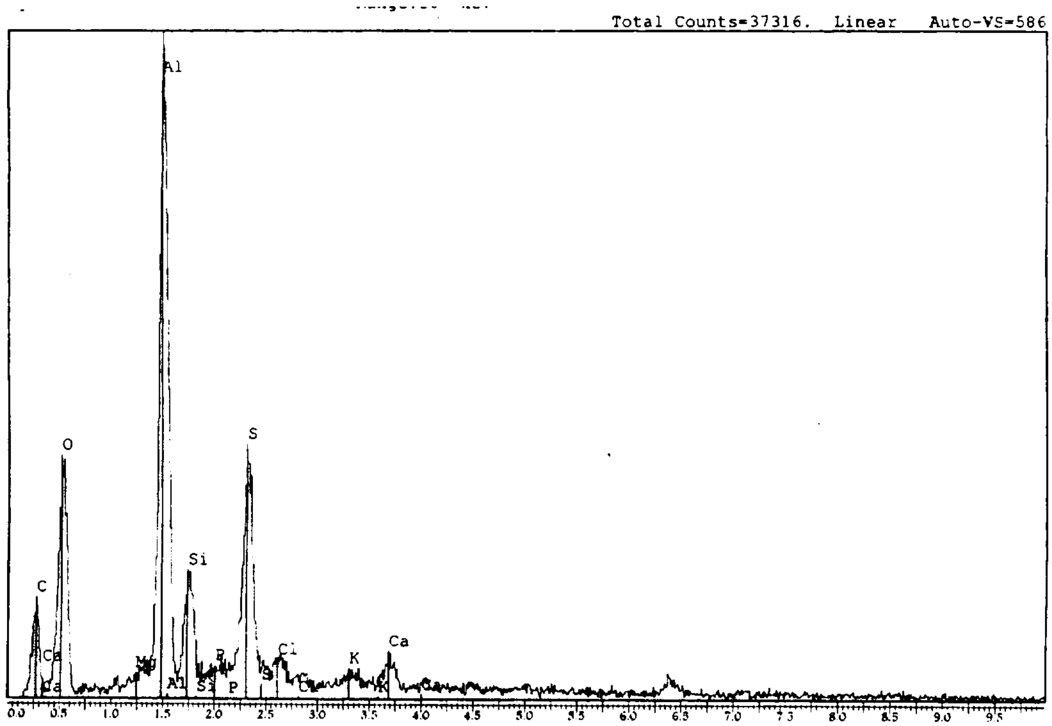


Figure 6. Low magnification micrograph of the cross sectional specimen through the suspect spot showing the minimal corrosion damage along the spot. Keller's etch, 10X.

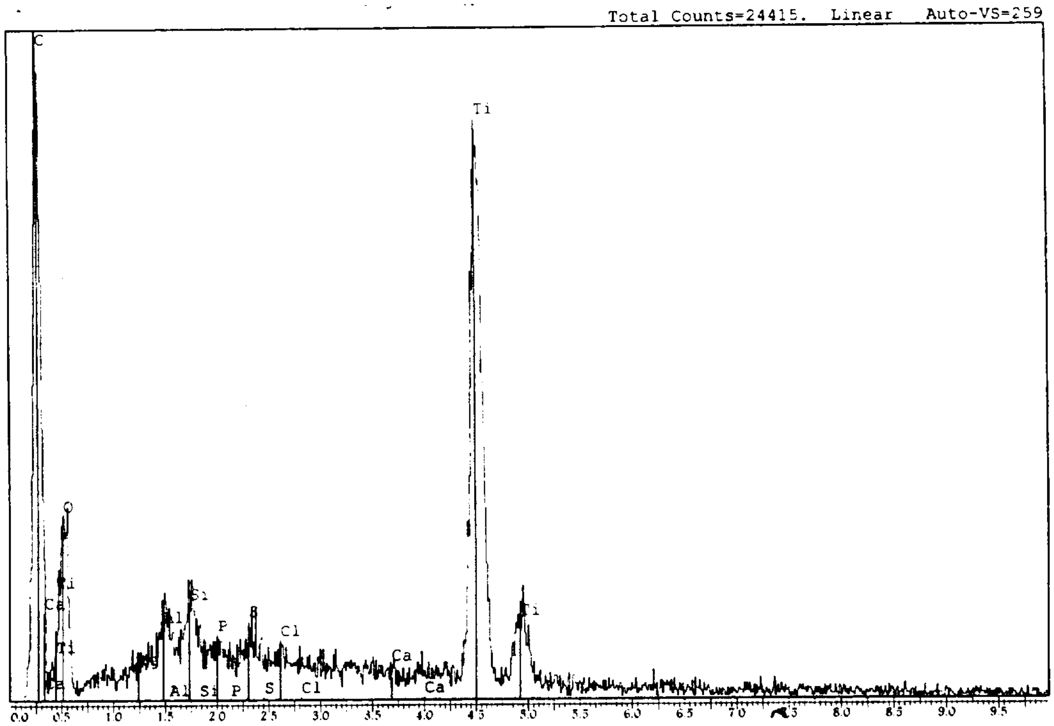
APPENDIX



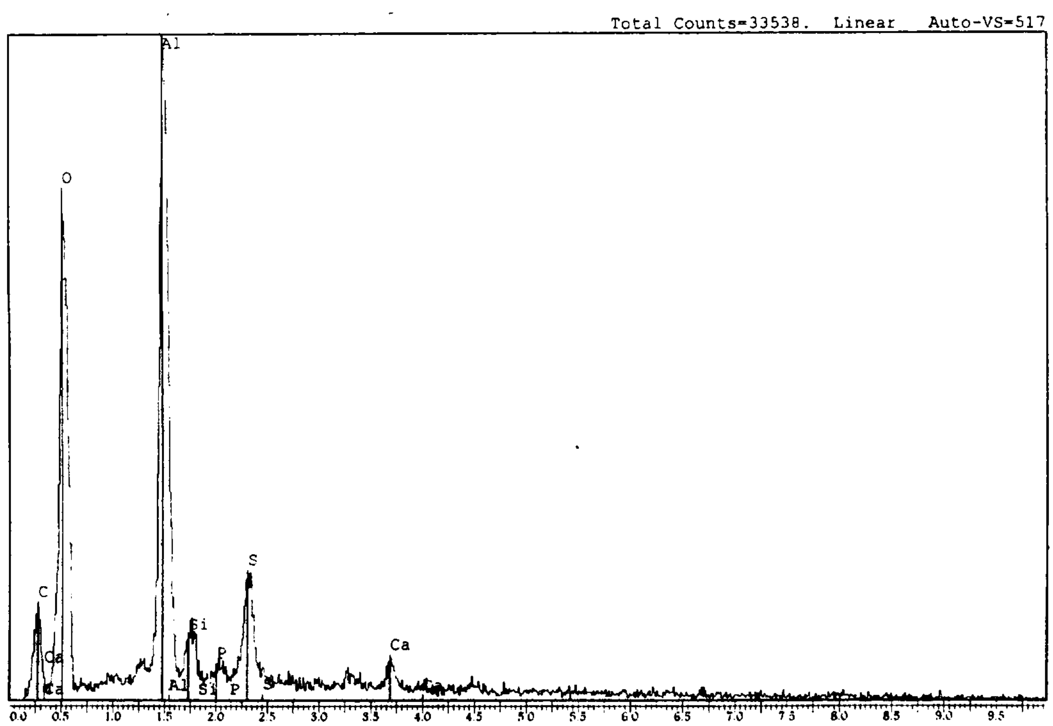
Typical EDS spectrum generated from fibrous deposits.



Typical EDS spectrum generated from other than fibrous deposits.



Typical EDS spectrum generated from the paint surrounding the suspect spot.



Typical EDS spectrum generated from the surface of the suspect spot after cleaning in acetone.

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

June 8, 2000

MATERIALS LABORATORY FACTUAL REPORT Report No. 00-72

A. ACCIDENT

Place	: East Moriches, New York
Date	: July 17, 1996
Vehicle	: Boeing 747-131, N93119
NTSB No.	: DCA96-M-A070
Investigator	: Robert Swaim, AS-40

B. COMPONENTS EXAMINED

W332 bundle of electrical wiring (24 pieces).

C. DETAILS OF THE EXAMINATION

An overall view of the separated wires submitted for examination is shown in figure 1. The wires were submitted so that the separated ends could be examined under laboratory conditions for evidence of electrical arcing damage. Each wire (or bundle of wires) had been labeled, using pen markings on scotch tape, before receipt in the laboratory. All of the wires were labeled with multiple alphanumeric digits, starting with the prefix W332. For ease of reference the wires will be referred to using the remainder of their identification characters. Three sections of twisted and jacketed wire triplets, each containing three individual wires (a co-axial white wire, a red wire, and a blue wire), had the same label, "Q306, Q309, and Q312". To differentiate between these three wire triplets, each bundle was further arbitrarily identified (in the laboratory) as "A", "B" or "C".

Using the above system, there were 15 submitted individual wires, which were identified with the labels "Q97", "H18", "Q98", "H572", "Q94", "H97", "Q88", "Q304", "Q90", "H16", "W481", "H15", "H483", "Q305", "Q93", and nine wires in three triplets, which were identified as "Q306 Q309 Q312 - A", "Q306 Q309 Q312 - B", and "Q306 Q309 Q312 - C". A paper tag had been attached near one end of triplet "Q306 Q309 Q312 - C". This tag was labeled "W332 See Other End JB".

Initial examination showed that all of the wires contained a stranded conductor. Most of the separated individual wires contained what appeared to be two layers of insulation as well as a topcoat with green letters that began with "W42A". In each of the triplets, one of the three wires (the white wire) contained shielding.

The separated ends on the wire pieces were examined using a binocular microscope at magnifications up to 70X. Many of the wire ends were cleaned in soapy water solution and/or acetone in order to remove corrosion deposits and other debris that obscured the fracture features on the strands. Separations of the individual strands in the conductors were almost always co-located (not spread along the length of the wire) with minimal spreading apart of the separated strands. Figures 2 and 3 show the typical features found on most of the wires. The individual strands contained necking down deformation, indicative of a tensile separation, or pinching deformation (flattening), indicative of a separation as a result of a cutting action.

Examination of the separated strands on the conductor from the white (shielded) wire from the bundle labeled "Q306 Q309 Q312 - A" revealed the presence of a globule of material (see figure 4) that obscured the individual strands at the separated end. This wire was cut about one inch from the separation, then the outer insulation, shielding, and inner insulation were removed from the conductor. The conductor was ultrasonically cleaned in an Alconox solution in order to remove deposits and corrosion material. The separated wire end was then examined in a scanning electron microscope. As shown in figure 5, the cleaning process had removed a substantial amount of deposit materials, allowing the individual separated strands to become visible. The separation in this conductor appeared similar to the others, with deformation typical of separation as a result of a cutting action. No evidence of electrical arcing was found on this wire or on any of the other wires examined.

James F. Wildey II
Supervisory Metallurgist

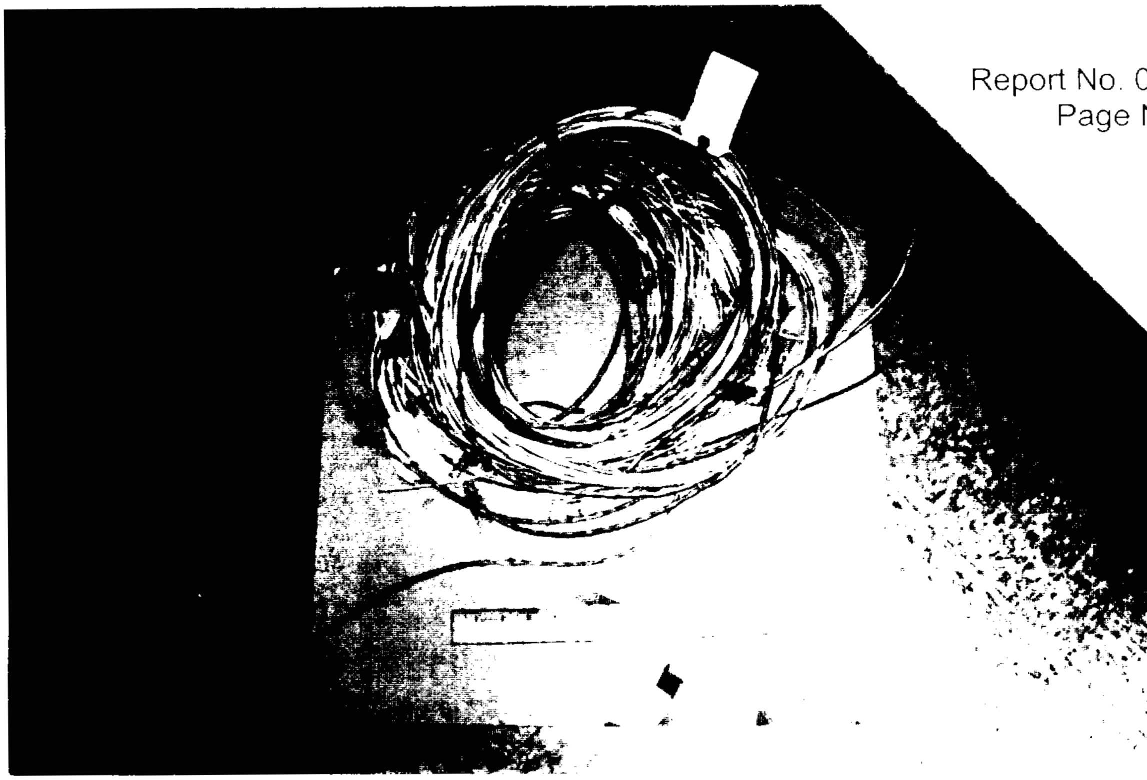


Figure 1. Overall view of the wires lengths received for examination.

Figure 2. Appearance of the separated strands on wire "H572". (15X)

Figure 3. Appearance of the separated strands on wire "Q94". (15X)

Figure 4. Optical photograph of the separated end on the white wire from bundle "Q306 Q309 Q312 - A". (20X)

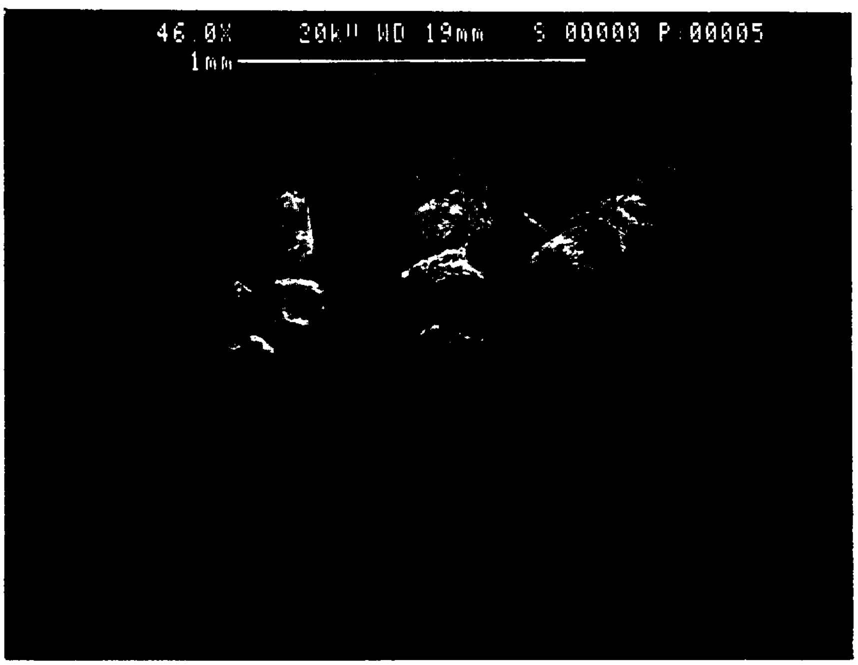


Figure 5. Scanning electron microscope photograph of the separated end on the white wire from bundle "Q306 Q309 Q312 - A" after cutting, removal of the insulation, and cleaning. (46X)

Lectromec
Lectromechanical Design Co.
45000 Underwood Lane • Suite L
Dulles, VA 20166-2305

February 15, 2000

Robert Swaim
Chairman, TWA800 Systems Group
National Transportation Safety Board
490 L'Enfant Plaza East, S.W.
Washington, DC 20594

Subject: Comments on electrical activity during longer term Wet Arc Tracking test.

The results reported in Lectromec Report Number N191-RPT4AU99 *Electrical Arcing of Aged Aircraft Wire* for wet arc tracking testing of Boeing Specification W-2A/8/1-20 wire, were for tests that had a duration of up to 25 minutes. These tests were stopped because the electrical activity (scintillation, flashing etc) had reached a steady state and not because a specific end of test point had been reached such as a circuit breaker tripping.
The question has been asked, if the activity would have continued for longer periods of time?
The answer is that it surely would have continued for some time longer; Whether hours or days is uncertain. As long as there are exposed conductors, with a potential difference (in this case 208 400 Hz AC) in the presence of the aliphatic polyimide insulation and a partially conducting fluid (saline), the scintillation and flashing processes will continue. The insulation will slowly be charred and consumed and the conductors melted and evaporated. It is possible that conditions would become favorable to a stronger arcing event which would cause circuit breakers to trip and stop the event.

In addition, the following data that was developed in house at Lectromec may be of use.

1. In a single phase wet arc tracking test performed on a Mil Spec wire of similar construction (dual wall aliphatic polyimide), the sample was tested for a total of more than 2 hours. There were periods of scintillation and flashing as well as periods of dormancy. The test was ended after two wires had welded themselves together. This created a short that repeatedly tripped the circuit breaker.
Notes on test:

- The total time included an initial test of 20+ minutes followed by a second test several months later of 1 hours and 45 minutes. Similar events were observed in both parts of the test.

- As the electrical activity continued the insulation was charred and the conductor was slowly melted and evaporated. This caused the spot of activity to slowly migrate down the wire and therefore out of the way of the saline drip. When the drip was moved so that it again stuck the active area the activity resumed.

2. In other tests, performed on wire insulated with fluorinated polymers, there were cases of the test running for more than 8 hours. In general, the electrical activity during these tests was less severe than observed for the aliphatic polyimide, although both scintillation and flashing were observed.

I hope this is useful information. Please call with any additional questions.

Sincerely

William Linzey Ph.D.
Lectromechanical Design Company

Lectromec
Lectromechanical Design Co.
45000 Underwood Lane • Suite L
Dulles, VA 20166-2305

Thursday, April 20, 2000

Robert Swaim
Chairman, TWA800 Systems Group
National Transportation Safety Board
490 L'Enfant Plaza East, S.W.
Washington, DC 20594

This letter addresses the question of how much energy survives a parent arc to enter the victim wire and subsequently be available to a 2nd arc in the victim wire involving a ground fault situation.

Referring to the data presented in the report "Electrical Arcing of Aged Aircraft wire", the power and energy that is available to the victim wire during a typical single flash event is 1.3 kW peak power with a potential energy dissipation of 400 mJ (millijoules) during the ¾ millisecond flash event. During a series of flash events that was observed, 8250 mJ of energy was available in less than 20 milliseconds.

Please note that the above numbers have been scaled down to represent a phase to ground fault as opposed to a phase to phase fault. Also note that changing the circuit constants from those used when the data was collected could change the value of these numbers.

I hope this is useful information. Please call with any additional questions.

Sincerely

William Linzey Ph.D.
Lectromechanical Design Company

T: 703•481•1233 F: 703•481•1238 E: lectromec@aol.com

June 14, 2000

Mr. Robert Swaim
National Transportation Safety Board
Aviation Engineering, AS-40
490 L'Enfant Plaza, E, SW
Washington, DC 20594

Dear Mr. Swaim:

David Dini, of UL's Research Department, has brought to my attention your request to include portions of an article, "AFCIs show promise to save lives by preventing electrical fires," that originally appeared in UL's client publication, *On the Mark*, Vol. 5, No. 3-4. It is my understanding that passages from the article are to appear in a National Safety Transportation Board report on the aircraft accident involving TWA Flight 800.

Please note that you have Underwriters Laboratories Inc.'s permission to include portions of this article in the NTSB report. Please attribute the quoted passages as follows. **Reprinted with permission of Underwriters Laboratories Inc., "AFCIs show promise to save lives by preventing electrical fires,"** ***On the Mark*****, Vol. 5, No. 3-4.** This statement may appear adjacent to the passage(s) or as a footnote in the report.

I asked Mr. Dini and his co-author, Richard Wagner, also of UL's Research Department, to recheck the select passages for technical accuracy. If you would kindly change the bracketed reference in the first paragraph to read: **"Arcing" is defined [in an article published by Underwriters Laboratories (UL)] . . .**

We very much appreciate the NSTB's interest in UL's publications. If you or your staff need further assistance, please do *not* hesitate to contact me at (847) 272-8800, ext. 43844. For technical assistance, please contact Mr. Dini at ext. 42982.

Sincerely yours,

Lorraine Swanson
Managing Editor
On the Mark

333 Pfingsten Road
Northbrook, Illinois 60062-2096
United States Country Code (1)
(847) 272-8800
FAX No. (847) 272-8129
http://www.ul.com

Underwriters Laboratories Inc.®

June 14, 2000

Mr. Robert Swaim
National Transportation Safety Board
Aviation Engineering, AS-40
490 L'Enfant Plaza, E, SW
Washington, DC 20594

Dear Mr. Swaim:

David Dini, of UL's Research Department, has brought to my attention your request to include portions of an article, "AFCIs show promise to save lives by preventing electrical fires," that originally appeared in UL's client publication, *On the Mark*, Vol. 5, No. 3-4. It is my understanding that passages from the article are to appear in a National Safety Transportation Board report on the aircraft accident involving TWA Flight 800.

Please note that you have Underwriters Laboratories Inc.'s permission to include portions of this article in the NTSB report. Please attribute the quoted passages as follows: **Reprinted with permission of Underwriters Laboratories Inc., "AFCIs show promise to save lives by preventing electrical fires," *On the Mark*, Vol. 5, No. 3-4.** This statement may appear adjacent to the passage(s) or as a footnote in the report.

I asked Mr. Dini and his co-author, Richard Wagner, also of UL's Research Department, to recheck the select passages for technical accuracy. If you would kindly change the bracketed reference in the first paragraph to read: **"Arcing" is defined [in an article published by Underwriters Laboratories (UL)] . . .**

We very much appreciate the NSTB's interest in UL's publications. If you or your staff need further assistance, please do not hesitate to contact me at (847) 272-8800, ext. 43844. For technical assistance, please contact Mr. Dini at ext. 42982.

Sincerely yours,

Lorraine Swanson
Managing Editor
On the Mark

A not-for-profit organization
dedicated to public safety and
committed to quality service

333 Pfingsten Road
Northbrook, Illinois 60062-2096
United States Country Code (1)
(847) 272-8800
FAX No. (847) 272-8129
http://www.ul.com

Underwriters Laboratories Inc.®

June 26, 2000

Mr. Robert L. Swaim
National Transportation Safety Board
Aviation Engineering, AS-40
490 L'Enfant Plaza, E, SW
Washington, DC 20594

Subject: Arc-Fault Circuit Interrupters

Dear Bob:

You should have by now received the permission from our business communications staff to use the information from our recent article on Arc-Fault Circuit Interrupters in your NTSB report. I trust that this information on AFCI's was useful, and I'm glad that you were able to use it.

As indicated in our previous correspondence, I am including some information on AFCI's that may be of benefit to you, especially with regard to the aging of electrical wire and insulation.

1) In 1995 UL conducted a project for the US Consumer Product Safety Commission (CPSC), regarding, "Technology for Detecting and Monitoring Conditions That Could Cause Electrical Wiring System Fires." The purpose for this project was to conduct an in-depth study of technologies to detect and monitor precursory conditions that could lead to or directly cause fires in residential wiring systems. Specifically, five different technologies were explored in detail, and the study found that arc-fault detection technology appeared to be very promising, especially with regards to providing protection against many electrical ignition scenarios likely to be encountered in residential wiring systems. The final report was quite extensive, however, I have copied for you the executive summary from that work.

2) In 1996 UL conducted a research investigation on Arc-Fault Detection Circuit Breakers for the National Electrical Manufacturers Association (NEMA). The scope of this work focused on the development of a threshold curve of arc current versus time characteristics for ignition of a fire indicator during an arcing fault. Unwanted operation and operation inhibition of these devices was also explored. The results of this work was used to develop the first edition of the Standard for Arc-Fault Circuit-Interrupters, UL 1699. A copy of this report and the UL standard are enclosed.

I have also included some general information about UL's engineering research services, the group which I am directly involved with. If there is any further information or help which I could provide, please feel free to contact me.

Very truly yours,

Dave

Dave Dini (x42982)
Senior Research Engineer
Research Department

SMITHS INDUSTRIES
Aerospace

Fax Transmission

Display &Control Systems–
Malvern
255 Great Valley Parkway
Malvern, PA 19355
Telephone: (610) 296-5000
Fax: (610) 296-7805

Sender's Ref:

To:	***Robert Swaim***
Company:	***NTSB***
Fax No:	***202-314-6349***
From:	***John Wyler***
Date:	***August 7, 2000***

Total Number of Pages (including this one): ***3***

CONFIDENTIAL CORRESPONDENCE - REPLY TO 610-251-9896, UNLESS OTHERWISE INDICATED BY SENDER

X ***THE FOLLOWING INFORMATION MUST BE UNCLASSIFIED AND NOT SUBJECT TO U.S. GOVERNMENT APPROVAL FOR DISCLOSURE TO A FOREIGN NATIONAL. ALL OTHERS MUST FOLLOW ESTABLISHED PROCEDURES.***

Message:

Attached is a letter describing why resistors alone can not solve the fuel tank ignition source isolation problem. Please let me know if this is what you were looking for, or if more detail is needed. Do you need the original letter?

John

If this fax transmission is unclear or you have not received all pages indicated, please telephone the sender immediately.

A Smiths Industries Company

SMITHS INDUSTRIES
Aerospace

Display & Control Systems-Malvern
255 Great Valley Parkway
Malvern, PA 19355
Telephone: (610) 296-5000
Fax: (610) 296-2805

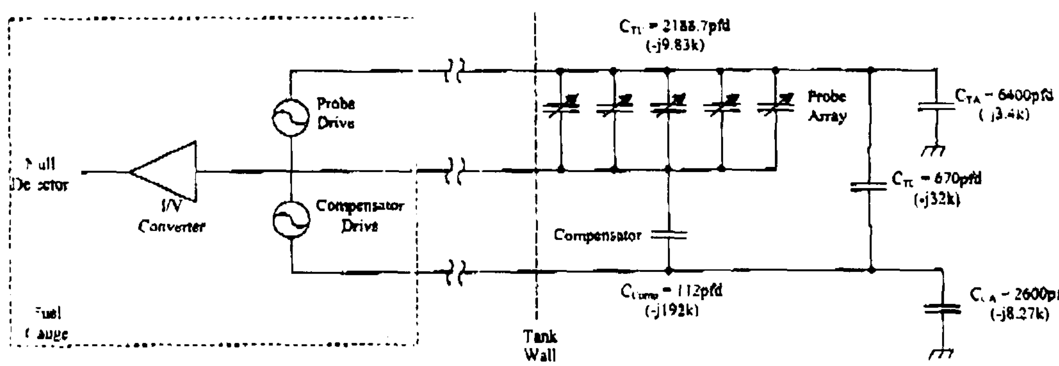
August 7, 2000

Mr. Robert L. Swaim
NTSB
Aviation Engineering Division (AS-40)
490 L'Enfant Plaza East, S. W.
Washington D. C. 20594

Subject: Ignition Source Isolation in Fuel Gauging Systems Using Resistors

Dear Mr. Swaim,

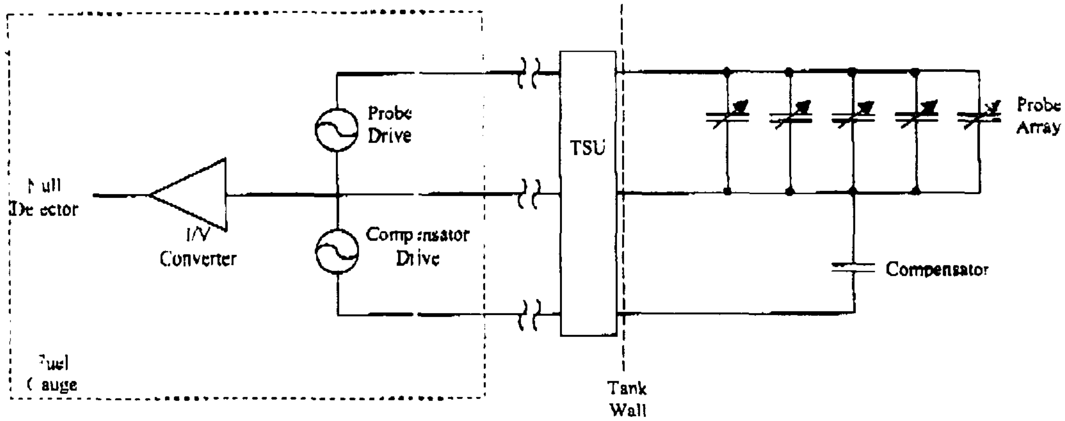
The Smiths Industries 2300 series Fuel Quantity Indication System (FQIS) operates similar to other systems. It uses an array of capacitive probes and a capacitive compensator in a bridge configuration to determine the amount of fuel in the tank. The probes and compensator are driven with a 7,400 Hz sinusoid voltage of from 0 to 10 volts peak amplitude. The two drive signals are 180° out of phase and their relative amplitudes are adjusted by the fuel gauging system until the return signal is at null.



2300 FQIS Functional Diagram

The ratio of the drive signals is inversely proportional to the ratio of the probe to compensator capacitance. From this ratio the quantity of fuel within the tank is determined.

The Transient Suppression Unit (TSU) is placed in line with the fuel gauge wiring, as close to the tank wall as possible. The TSU clamps the voltage that enters the tank at approximately 11 volts so that the maximum energy storage within the in-tank capacitances is below 20 µJ. Note that stored energy equals ½ CV^2. This 20 µJ level is below the worst case ignition energy that could occur within the fuel tank. The TSU also limits the RMS current that can flow into the tank to less than 10 mA RMS. By limiting the current, the amount of heating is also limited, so that the worst case auto-ignition temperature can not be reached.



2300 FQIS with TSU

If a resistor were to be used in each circuit to limit the current and stored energy, a resistance of about 35 kohms would be needed to ensure that the current into the tank is limited to 10 mA (assuming a hot short on any line to the 350 VAC lighting power). Unfortunately, this resistance is of larger magnitude than the capacitive reactances in the circuit, which includes not just the tank units and compensator, but also the stray capacitance from each drive line to airframe and between the two drive lines. Incorporating resistors of this magnitude would result in significant attenuation and phase shifting of the drive signals, which would cause gauge inaccuracy and Built In Test error indications by the gauge. In fact, the gauge would not be able to drive the circuits sufficiently and the gauge would not function at all. The power required to drive the circuits with the added resistance would be more than two orders of magnitude greater than originally designed for assuming the same current levels ($P=i^2R$).

Assuming these large resistors are present, there still is no way to limit the stored energy. Assuming the 350 VAC signal is present, it could charge up the tank capacitances to in excess of 135 μJ which is well above the specified 20 μJ.

The Smiths Industries Transient Suppression Unit circumvents these issues by using a proprietary design circuit to limit both current and stored energy without disturbing the operation of the fuel gauging system.

Sincerely

John S. Wyler
FAA Fuel Systems DER, DERY-429981-NE

Smiths Industries Aerospace &
Defense Systems Inc.
A Smiths Industries Company

Swaim Bob

From: Swaim Bob
Sent: Wednesday, March 15, 2000 12:42 PM
To: Swaim Bob
Subject: FW: NTSB Meeting - Bob Swaim

-----Original Message-----
From: Rodrigues, J D [mailto:J.Rodrigues@PSS.Boeing.com]
Sent: Thursday, February 17, 2000 6:55 PM
To: 'swaimbo@ntsb.gov'
Subject: FW: NTSB Meeting - Bob Swaim

> ----------
> From: Lidicker, Richard J
> Sent: Thursday, February 17, 2000 3:46 PM
> To: Rodrigues, J D
> Cc: Hulm, Jerome R
> Subject: FW: NTSB Meeting - Bob Swaim
>
> Dennis
>
> Jerry Hulm asked me if we had any more comments for Bob Swaim on the airplane wiring addendum. Bob told Jerry he is finalizing the report of the second review of the airplane wiring (that Lonnie and I worked on). He said if we have any additional comments on the draft report to get them to him before the end of this week so he can incorporate them.
>
> The only copy I have is the draft of "System Group Factual Report Addendum for Airplane Wire Inspection and Collected Service Reports", dated March 22, 1999. Both Lonnie and I have already commented on that draft copy and Bob indicated in his message dated April 12, 1999 that "I've got your comments incorporated on the draft for the survey". However, in the April 12th message he also indicated there was one Boeing comment that was not incorporated. When Boeing objected to this, he indicated in another message, date April 17,1999, he was going to review a Boeing letter dated November 20, 1997 and change the draft as required. The comment and letter dealt with a the wiring over the CWT, in particular the APU and Galley power feeder location. Has Bob incoporated this comment?
>
> Below is a copy of the paragraph and our comments (approximately page 8 or 9 of the draft) and a quote from the letter.
>
> BOEING REFERENCES
>
> The following information is from a Boeing Proprietary letter of November 20, 1997:
>
> The wiring routed over the CWT is contained in trays and the tray height over the CWT varies from .7 at the forward end to 21.5 inches at the aft. The trays are made of glass fabric or glass fabric reinforced material to Boeing BMS 8-80R or BMS 8-2K. The trays contain power wires that include service to the auxiliary power unit (APU, not used for flight), ground handling bus, galley power, the P14/P15 panel power to aft service panels, and the seat and passenger service unit (PSU) power. (Bob: This sentence leaves the impression that the power wires were in the trays with the FQIS wiring, when in fact, the power wires that are listed are clamped to "U" channels over the CWT and not in the trays.(see below for the appropriate paragraphs from the above referenced Boeing Letter. In particular, the second paragraph)). Please revise the sentence to state that the power wires are clamped to the "U" channels and are above the tank from 0.7 inches at the forward end of the!
tank to 21.5 inches at the aft end of the tank
>
>
> The material that is quoted below is from Boeing Letter Number: B-B600-16293-ASI; Dated: November 20, 1997.
>
> "Most of the wiring over the center wing tank are contained within raceway trays. The trays are composed of BMS 8-80R(Fire resistant, polyester resin preimpregnated glass fabric for general use) or BMS 8-2K(General purpose, rigid, fire retarded glass fabric reinforced plastic sheeting). These trays provide support for the wiring and at the same time assist manufacturing during the installation of the wire across the center wing tank structure.
>
> The remaining wiring consists of the APU power, the Ground
> Handling Bus, the Galley Power, the P14/P15 Panel power to Aft Service Panels, the Seat and PSU Power, and the ADF antenna. They are supported and clamped above the top plate of the tank on top of U channels which are spaced approximately every 20 inches between the floor beams. Their height above the tank varies from approximately 0.7" at the

forward end of the tank to approximately 21.5" at the aft end of the tank..
>
> Both the APU generator feeders and the galley feeders have
> differential protection as well as overload protection. The APU generator feeder differential protection is set to trip at 20 + 5 amperes in less than 40 milliseconds. Similarly the galley feeders are protected when the differential current exceeds 20 amperes by the ELCU via an inverse time delay le> ss than 700 milliseconds. It should also be noted that during normal Electrical System Operation, as electrical power is transferred to the main engine generators the APU generator fields are tripped, de-energizing the APU generator feeders. The APU generators are not used for electrical power in > flight on the 747."
>
>
> Dick Lidicker
> Phone: 425-342-0088>
> Pager: 425-631-8680
> M/S: 04-JU
>
> ----------
> From: Hulm, Jerome R
> Sent: Thursday, February 17, 2000 7:38 AM
> To: Lidicker, Richard J
> Subject: NTSB Meeting - Bob Swaim
>
> Dick,
>
> Bob stated that he is finalizing the report of the second review of the airplane wiring (that you and Lonnie worked on).
>
> He said if you have any additional comments on the draft report to get them to him before the end of this week so he can incorporate them.
>
> Have we already commented on this report?
>
> Jerry Hulm
> Manager - Electrical Systems C&C - Cert Focal/Wiring DERs/ Safety (B-E24G)
> Boeing Commercial Airplanes Everett, WA 98203
> Phone: 425-294-4638 FAX: 425-342-4616
> Alpha Pager: 425-631-5525 Home Phone: 425-338-2496
> E-mail: jerome.r.hulm@boeing.com MS: 04-JU
> Pager Web Link: http://webpager.boeing.com/htbin/pagem?pagee=jerome.hulm
>
>
>

Ronald J. Hinderberger
Director
Airplane Safety
Commercial Airplanes Group

The Boeing Company
P.O. Box 3707 MC 67-XK
Seattle WA 98124-2207

BOEING

May 2, 2000

B-H200-16947-ASI

Mr. R. Swaim, AS-40
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington DC 20594

Subject: FQIS Circuit Capacitance, TWA 747-100 N93119 Accident off Long Island NY – 17 July 1996

Reference: Your email to J. Hulm, dated Apr 24, 2000

Dear Mr. Swaim:

In your reference email, you requested our calculations on the amount of energy that can be stored by the FQIS and whether the 51K and 200K ohm resistors provide enough protection.

In response to your request, we believe the best way to address this subject is to go through the failure modes and provide the calculations for those. Please refer to the enclosed schematic.

1. **Failure Mode**: Continuous 115VAC 400 Hz short to the Comp Lo-z wire or Lo-z wire with no other faults.

   Effect: The wires would have stored energy that would follow the voltage frequency cycle. The worst case would be when the 400 Hz cycle reached its peak. The peak of 115 Vrms is approximately 162 volts.

   For the Comp Lo-z, the wire stray capacitance to ground is 7.9 nF. The maximum energy stored in the wire by this fault would be determined by the following calculation:

   E = 1/2*C*V^2 = 1/2*(7.9*10-9)*(162)^2 = 104 uJ at the peak of the cycle. For 115 Vrms the value is 52 uJ.

   For the Lo-z, the wire stray capacitance to ground is 6.5 nF. The max energy stored in the wire by this fault would be:

BOEING

E = 1/2*C*V^2 = 1/2*(6.5*10-9)*(162)^2 = 85 uJ at the peak of the cycle. For 115 Vrms the value is 43 uJ.

For these 2 cases, the maximum energy stored along the affected wire is only present at the peak of the cycle. For VAC, here 400 Hz, the energy (as is power) is actually related to the Vrms. Note: the actual charge buildup, which is done by current (charge/time - dq/dt), is distributed along the entire length of the wire. It is not concentrated at any endpoint along the length of the affected wire.

2. **Failure Mode**: Intermittent 115VAC 400 Hz short to the Comp Lo-z wire or Lo-z wire with no other faults.

   Effect: With an intermittent short, any energy stored beyond the normal system limits, would be dissipated through the resistors in the master indicator within 0.5 milliseconds after the short was removed. Where time for discharge is calculated by at least 5 time constants which is quantified by Resistance times Capacitance (R*C):

   5*R*C = (15x10^3)*(7.9x10^-9) = 0.5 milli-sec.

   If the hot short fault were to disconnect, and then immediately a ground short fault were to occur in the tank on the (Comp) Lo-z wire, then the energy stored above would discharge into the master gauge and into the fault. Since the charges are distributed along the wire, a smaller amount of the above-calculated energy stored would go through the fault. In other words, the total energy available to the fault is less than the total distributed energy along the wire.

3. **Failure Mode**: Continuous 115VAC short on the AIDS side of isolation resistor R5 (51Kohm).

   Effect: The voltage on the Comp Lo-z wire would be the resistor divider network (R1/R5) looking back into the master indicator and the totalizer. The totalizer resistance effect on the calculation is negligible so the voltage at the compensator would be:

   V = (15/(15+51))115 = 26Vrms

   This is within the normal operating voltage supplied by the FQIS to the Comp Lo-z.

4. **Failure Mode**: Continuous 115VAC short on the AIDS side of isolation resistor R5 (51Kohm), in combination with a short-to-ground fault in the tank on the Compensator Lo-Z circuit.

   Effect: the maximum current available to the fault in the tank would be:

   I = 115/51K = 2 mA.

   This current is below the 10mA maximum in-tank current allowed by Boeing requirements for this system.

5. **Failure Mode**: Continuous 115VAC 400Hz short on the Hi-z shield.

   Effect: The Hi-z shield is grounded inside the master indicator. Either the circuit breaker for the shorting wire will pop or the Hi-Z shield braid will vaporize at the spot of the short, re-opening the circuit.

6. **Failure Mode**: Intermittent 115VAC 400Hz short on the Hi-z shield.

   Effect: The shield braid will vaporize at the spot of the short, re-opening the circuit.

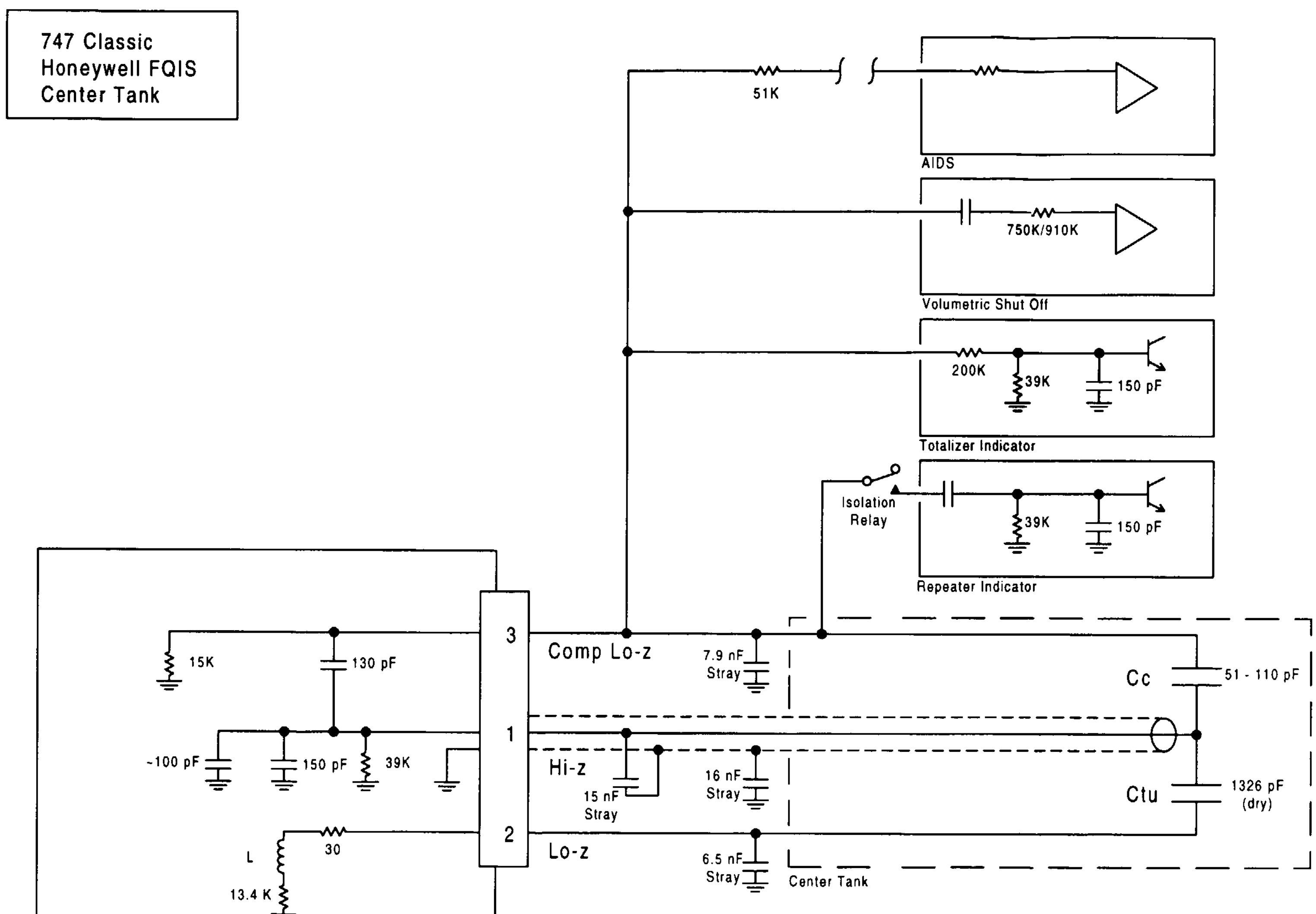
If you have any questions, please do not hesitate to call.

Very truly yours,

for Ronald J. Hinderberger
Director, Airplane Safety
Org. B-H200, MC 67-PR
Telex 32-9430, STA DIR AS
Phone (425) 237-8525
Fax (425) 237-8188

Encl: Circuit Schematic, 1 page

cc: Mr. A. Dickinson, IIC



Note: Circuit drawn for fault analysis

J. E. Groat
4-28-2000

Ronald J. Hinderberger
Director
Airplane Safety
Commercial Airplanes Group

The Boeing Company
P.O. Box 3707 MC 67-XK
Seattle, WA 98124-2207

18 July 2000
B-H200-17004 -ASI

BOEING

Mr. R. Swaim, AS-40
National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington D.C. 20594-2000

Subject: Contents of wire bundle W1360, TWA 747-100 N93119 Accident off Long Island, N.Y. – 17 July 1996

Reference: Email from R. Swaim to D. Rodrigues dated 13 July 2000

Dear Mr. Swaim:

In the referenced email, you requested the identification of the wires in wire bundle W1360 as shown in PI 61B70103, Sheet 1F, in Section view 1A6. The attached charts contain the requested information.

If you have any questions, please do not hesitate to call.

Very truly yours,

for

Ronald J. Hinderberger
Director, Airplane Safety
Org. B-H200, MC 67-PR
Telex 32-9430, STA DIR AS
Phone (425) 237-8525
Fax (425) 237-8188

Encl: "RA164 (R0103), C/L – 153, Engine – RX131: Wire Bundle W1360 Content" chart, 3 pages

RA164 (R0103), C/L - 153, Engine - RX131: Wire Bundle W1360 Content
(TWA 747-100 N93119 Accident off Long Island, N.Y. 17 July 1996)

WIRE NUMBER	FROM EQUIP.	TO EQUIP.	DIAGRAM	SYSTEM FUNCTION
E 0296-20	D01410J-26 (P2 Panel)	GD08080-AC (STA 261,WL 324,LBL 5)	77-12-11	AC Ground Eng. 4 – N1 Tach Indication
Q 0601-20D	D02679J-1 (E3-1 Shelf)	D02680J-1 (W/B Disc-R)	28-41-12	Comp Volume HiZ Signal (Mn Tnk 4)
Q 0602-20R	D02679J-2 (E3-1 Shelf)	D02680J-2 (W/B Disc-R)	28-41-12	Comp Volume LoZ Signal (Mn Tnk 4)
Q 0603-20B	D02679J-3 (E3-1 Shelf)	D02680J-3 (W/B Disc-R)	28-41-12	Surge Tank LoZ Signal
Q 1006-22	D01410J-3 (P2 Panel)	SP04024 (STA 965,WL 190, RBL 55)	82-41-11	Water Flow Eng. 4 Indication (28V-DC-Bus 1, Water Injection Pump 4 Control)
4D0098-24	D01410J-25 (P2 Panel)	SP01866 (STA 390,WL 345, RBL 60)	24-27-52	Generator Control No 4, Eng. Tach Input (Open or Ground)
4E0001-20	D01410J-12 (P2 Panel)	D01873P-3 (W/B Disc-R)	78-36-12	28V-DC Ess Bus, Eng. 4 Trust Reverser Indication
4E0003-20	D01410J-16 (P2 Panel)	D01875J-1 (W/B Disc-R)	77-11-11	115V-AC 400CPS-Bus 4, Eng. 4 EPR & Oil Quantity
4E0004-20	D01410J-17 (P2 Panel)	D01875J-3 (W/B Disc-R)	77-11-11	EPR, Eng. 4 Servo Control Indication (28V-AC Synchro Transmitter)
4E0005-20	D01410J-18 (P2 Panel)	D01875J-4 (W/B Disc-R)	77-11-11	EPR, Eng. 4 Servo Control Indication (28V-AC Synchro Transmitter)
4E0006-20	D01410J-19 (P2 Panel)	D01875J-5) (W/B Disc-R)	77-11-11	EPR, Eng. 4 Servo Control Indication (28V-AC Synchro Transmitter)
4E0012-20	D01410J-15 (P2 Panel)	D01875J-6 (W/B Disc-R)	79-33-11	Low Oil Pressure Indication (28V-DC Ess TR Bus)
4E0042-22	D01410J-13 (P2 Panel)	D01873J-4 (W/B Disc-R)	78-36-12	Eng. 4 Reverser Operating Indication (28V-DC Ess Bus)
4E0046-22	D01410J-14 (P2 Panel)	D01873J-5 (W/B Disc-R)	78-36-12	Eng. 4 Reverser In Transit Indication (28V-DC Ess Bus)
4E0049-22R	D01410J-30 (P2 Panel)	SP02892 (STA 390,WL 345, RBL 60)	77-12-21	N2 Tach Indicating Eng. 4 (4 to 120V-AC Peak to Peak)
4E0050-22B	D01410J-31 (P2 Panel)	SP02894 (STA 390,WL 345, RBL 60)	77-12-21	N2 Tach Indicating Eng. 4 (4 to 120V-AC Peak to Peak)
4E0058-22	D01330J-6 (E3-1 Shelf)	GD06124-AC	73-31-12	AC Ground, Fuel Flow Meter Eng. 4
4E0069-22	D01410J-8 (P2 Panel)	D01675J-1 (P4 Panel)	73-31-12	115V-AC 400Hz, Bus 4-Eng. 4 Fuel Flow (Eng. 4 Fuel Used)
4E0075-22	D01410J-24 (P2 Panel)	SP02196 (STA 390,WL 345, RBL 60)	73-31-12	115V-AC 400Hz, Bus 4, Eng. 4 Fuel Flow
4E0076-22	D01330J-5 (E3-1 Shelf)	SP02196 (STA 390,WL 345, RBL 60)	73-31-12	115V-AC 400Hz, Bus 4, Eng. 4 Fuel Flow

RA164 (R0103), C/L - 153, Engine - RX131: Wire Bundle W1360 Content
(TWA 747-100 N93119 Accident off Long Island, N.Y. 17 July 1996)

WIRE NUMBER	FROM EQUIP.	TO EQUIP.	DIAGRAM	SYSTEM FUNCTION
4E0079-22R	D01410J-9 (P2 Panel)	SM00001	73-31-12	Fuel Flow Meter-Rate Ground, Eng. 4 (Fuel Flow Indication, Signal Ground)
4E0080-22B	D01410J-10 (P2 Panel)	SM00002	73-31-12	Fuel Flow Meter-Rate Output, Eng. 4 (Fuel Flow Indication, 12V Peak)
4E0081-22Y	D01410J-11 (P2 Panel)	SM00003	73-31-12	Fuel Flow Meter-Rate Reference, Eng. 4 (Fuel Flow Indication, 5V-AC)
4E0085-20R	SM00004	D01871J-1 (W/B Disc-R)	77-12-11	N1 Tach Signal Common – Eng. 4 (Ground)
4E0086-20B	SM00005	D01871J-2 (W/B Disc-R)	77-12-11	N1 Tach Signal – Eng. 4 (0 to 5V-DC)
4E0087-20	D01410J-23 (P2 Panel)	D01871J-3 (W/B Disc-R)	77-12-11	28V-DC Standby Bus, Eng. 4 N1 Tach Transmitter
4E0089-20G	D01412J-1 (P2 Panel)	D01873J-1 (W/B Disc-R)	77-21-11	Eng. 4 EGT Indication (<1V-DC)
4E0090-20D	D01412J-2 (P2 Panel)	D01873J-2 (W/B Disc-R)	77-21-11	Eng. 4 EGT Indication (<1V-DC)
4E0169-20	D01410J-2 (P2 Panel)	GD03742-AC (STA 261,WL 315, RBL 10)	77-21-11	Eng. 2&3 EGT Indicator Power Ground
4E0171-20	D01410J-27 (P2 Panel)	GD03742-AC (STA 261,WL 315, RBL 10)	77-12-21	AC Ground, N2 Tach Indicating Eng. 4
4E0221-22	D01410J-20 (P2 Panel)	D01675J-3 (P4 Panel)	73-31-12	115V-AC 400Hz, Bus 4, Eng. 4 Fuel Flow (Eng. 4 Fuel FLRT)
4E0222-22R	SM00001	D01330J-1 (E3-1 Shelf)	73-31-12	Fuel Flow Meter-Rate Ground, Eng. 4 (Signal Ground)
4E0224-22B	SM00002	D01330J-2 (E3-1 Shelf)	73-31-12	Fuel Flow Meter-Rate Output, Eng. 4 (12V Peak)
4E0226-22Y	SM00003	D01330J-3 (E3-1 Shelf)	73-31-12	Fuel Flow Meter-Rate Reference, Eng. 4 (5V-AC)
4E0223-22R	SM00001	D01675J-5 (P4 Panel)	73-31-12	Fuel Flow Meter-Rate Ground, Eng. 4 (Signal Ground)
4E0225-22B	SM00002	D01675J-6 (P4 Panel)	73-31-12	Fuel Flow Meter-Rate Output, Eng. 4 (12V Peak)
4E0227-22Y	SM00003	D01675J-7 (P4 Panel)	73-31-12	Fuel Flow Meter-Rate Reference, Eng. 4 (5V-AC)
4E0247-20R	D02800J-1 (P4 Panel)	SM00004	77-12-11	N1 Tach Signal Common – Eng. 4 (Ground)
4E0249-20B	D02800J-2 (P4 Panel)	SM00005	77-12-11	N1 Tach Signal – Eng. 4 (0 to 5V-DC)

RA164 (R0103), C/L - 153, Engine - RX131: Wire Bundle W1360 Content
(TWA 747-100 N93119 Accident off Long Island, N.Y. 17 July 1996)

WIRE NUMBER	FROM EQUIP.	TO EQUIP.	DIAGRAM	SYSTEM FUNCTION
4E0248-20R	D01410J-21 (P2 Panel)	SM00004	77-12-11	N1 Tach Signal Common – Eng. 4 (Ground)
4E0250-20B	D01410J-22 (P2 Panel)	SM00005	77-12-11	N1 Tach Signal – Eng. 4 (0 to 5V-DC)
4E0307-22	D01410J-7 (P2 Panel)	D01873J-6 (W/B Disc-R)	75-41-11	Diagram not applicable, No connection – Spare Wire
4J0067-20	D01410J-28 (P2 Panel)	SP02904 (STA 390,WL 345, RBL 60)	80-11-11	Engine Cranking – Eng. 4 (28V-DC- Batt Bus)
4Z0001-20	D01410J-29 (P2 Panel)	D01330J-4 (E3-1 Shelf)	SP-AR-E	No connection - Spare Wire

Swaim Bob

From: Rodrigues, J D [J.Rodrigues@PSS.Boeing.com]
Sent: Thursday, August 17, 2000 4:08 PM
To: 'Swaim Bob'
Subject: RE: Bundle W1306 power source

Bob
Here is the information you requested in the message below and on your phone call to Lonnie Williams:

SWAIMW1306BUS.doc

Dennis

From: Swaim Bob[SMTP:SWAIMBO@ntsb.gov]
Sent: Friday, August 11, 2000 11:55 AM
To: Dennis Rodrigues (E-mail)
Subject: Bundle W1306 power source

Dennis -

I called and you were out, so called Lonnie, since it will be a question that you'll have to refer to him. The question is what electrical bus supplies W1306 and what other bundles does that bus supply. This is a repeat of a question from a long time ago (2 years?), when we first found the wires for fuel flow 4, the VSO, and lights routed down the STA 360 frame.

Thanks
Bob

TABLE I
W1306, BUS/CIRCUIT BREAKER ASSIGNMENT

BUS	CIRCUIT BREAKER	WIRE BUNDLE	DIAGRAM	
115V AC GROUND SERVICE TRANSFER BUS	C266, 15AMP, RIGHT CEILING LIGHTS, 24-51-61	W1306	CEILING LIGHTS ZONE A AND B	33-21-11
115V AC BUS 3	C304, 15AMP, WINDOW LIGHTS – RIGHT, 24-51-31	W1306	WINDOW LIGHTS ZONE A	33-21-31
		W1306 ***W1060*** ***W1368***	SIDEWALL LIGHTS – UPPER DECK	33-28-41
	C303, 15AMP, WINDOW LIGHTS – LEFT, 24-51-31	***W1060*** ***W1368***		
28V AC ESS A BUS	C189, 5AMP, CB – COMPARTMENT A & B NO SMOKING SIGNS, 24-53-31	W1306	PASSENGER SIGNS – ZONE A AND B	33-24-12
		W1368	PASSENGER SIGNS – UPPER DECK	33-24-21
28V AC ESS B BUS	C618, 5AMP, CB – COMPARTMENT A & B FASTEN SEAT BELT SIGNS, 24-53-31	W1306	PASSENGER SIGNS – ZONE A AND B	33-24-12
		W1368	PASSENGER SIGNS – UPPER DECK	33-24-21
28V DC ESS BUS	C274, 7.5AMP, CHG EMERGENCY LIGHTS – FORWARD, 24-54-51	W1306	EMERGENCY LIGHTS – ZONE A - RIGHT	33-51-13
		W1368	EMERGENCY LIGHTS – UPPER DECK	33-51-12

TABLE II
W1060, BUS/CIRCUIT BREAKER ASSIGNMENT

BUS	CIRCUIT BREAKER	WIRE BUNDLE	DIAGRAM	
115V AC BUS 3	C304, 15AMP, WINDOW LIGHTS – RIGHT, 24-51-31	***W1306***	WINDOW LIGHTS ZONE A	33-21-31
		W1306 W1060 ***W1368***	SIDEWALL LIGHTS – UPPER DECK	33-28-41
	C303, 15AMP, WINDOW LIGHTS – LEFT, 24-51-31	W1060 ***W1368***		
28V DC BUS 2	C777, 2.5AMP, CB – ATTENDANT CALL – UPPER DECK, 24-54-21	W1060 ***W1368***	ATTENDANTS CALL SYSTEM – UPPER DECK	33-25-21
28V AC GROUND SERVICE BUS	C253, 10AMP, TREAD LIGHTS, 24-53-21	W1060	TREAD LIGHTS – SPIRAL STAIR	33-28-21
	C639, 7AMP, SPIRAL STAIRWELL DOME LIGHT, 24-53-21	W1060 ***W1368***	DOME LIGHTS – SPIRAL STAIRWELL	33-28-11
28V DC GROUND HANDLING BUS	C1022, 7.5AMP, FLIGHT DECK ACCESS LIGHTS, 24-54-41	W1060 ***W1368***	DOME LIGHTS – SPIRAL STAIRWELL	33-28-11
115V AC GROUND HANDLING BUS	C675, 10AMP, SERVICE OUTLET VACUUM CLEANER – UPPER DECK, 24-51-71	W1060	PASSENGER COMPARTMENT SERVICE OUTLETS	25-29-11
115V AC BUS 2, SEC W	C1058, 15AMP, 24-51-21	W1060	POWER – LOUNGE BAR	25-33-11
115V AC BUS 1	C1519, 3AMP, FOOD AND BEVERAGE ELEVATOR, 24-51-12	W1060	FOOD AND BEVERAGE ELEVATOR	25-34-11
	C397, 1AMP, ENGINE NO. 2 IGNITION 1 – LOWER LEFT, 24-51-11	***W1362***	ENGINE IGNITION – ENGINE 1 AND 2	74-31-11
28V DC BUS 1	C1179, 2.5AMP, FOOD AND BEVERAGE ELEVATOR, 24-54-11	W1060 ***W1368***	FOOD AND BEVERAGE ELEVATOR	25-34-11
	C1081, 2AMP, UPPER DECK DOOR RELEASE LIGHTS, 24-54-11	***W1368***	DOOR RELEASE – FLIGHT COMPARTMENT	52-51-11

TABLE III
W1368, BUS/CIRCUIT BREAKER ASSIGNMENT

BUS	CIRCUIT BREAKER	WIRE BUNDLE	DIAGRAM	
115V AC BUS 3	C304, 15AMP, WINDOW LIGHTS – RIGHT, 24-51-31	***W1306***	WINDOW LIGHTS ZONE A	33-21-31
		W1306 ***W1060*** W1368	SIDEWALL LIGHTS – UPPER DECK	33-28-41
	C303, 15AMP, WINDOW LIGHTS – LEFT, 24-51-31	***W1060*** W1368		
28V DC BUS 2	C777, 2.5AMP, CB – ATTENDANT CALL – UPPER DECK, 24-54-21	***W1060*** W1368	ATTENDANTS CALL SYSTEM – UPPER DECK	33-25-21
	C1704, 7.5AMP, THRUST REVERSER SEQ & BLEED SYTEM – ENGINE 2, 24-54-21	***W1362***	ENGINE BLEED - THRUST REVERSER ACTUATED	75-32-11
			THRUST REVERSER SEQUENCING MECHANISM CONTROL	78-34-11
28V AC GROUND SERVICE BUS	C253, 10AMP, TREAD LIGHTS, 24-53-21	***W1060***	TREAD LIGHTS – SPIRAL STAIR	33-28-21
	C639, 7AMP, SPIRAL STAIRWELL DOME LIGHT, 24-53-21	***W1060*** W1368	DOME LIGHTS – SPIRAL STAIRWELL	33-28-11
28V DC GROUND HANDLING BUS	C1022, 7.5AMP, FLIGHT DECK ACCESS LIGHTS, 24-54-41	***W1060*** W1368	DOME LIGHTS – SPIRAL STAIRWELL	33-28-11
28V DC BUS 1	C1179, 2.5AMP, FOOD AND BEVERAGE ELEVATOR, 24-54-11	***W1060*** W1368	FOOD AND BEVERAGE ELEVATOR	25-34-11
	C1081, 2AMP, UPPER DECK DOOR RELEASE LIGHTS, 24-54-11	W1368	DOOR RELEASE – FLIGHT COMPARTMENT	52-51-11
28V AC ESS B BUS	C618, 5AMP, CB – COMPARTMET A & B FASTEN SEAT BELT SIGNS, 24-53-31	***W1306***	PASSENGER SIGNS – ZONE A & B	33-24-12
		W1368	PASSENGER SIGNS – UPPER DECK	33-24-21
28V DC ESS BUS	C274, 7.5AMP, CHG EMERGENCY LIGHTS – FORWARD, 24-54-51	***W1306***	EMERGENCY LIGHTS – ZONE A – RIGHT	33-51-13
		W1306 W1368	EMERGENCY LIGHTS – UPPER DECK	33-51-12
28V AC GROUND SERVICE TRANSFER BUS NO.2	C204, 5AMP, FORWARD & UPPER DECK LAVATORY DOME LIGHTS, 24-53-21	W1368	ACCESSORY LIGHTS – UPPER DECK – LAVATORY AND CREW	33-13-41
28V AC MAIN BUS	C160, 7.5AMP, UPPER DECK READING LIGHT – RIGHT, 24-53-11	W1368	READING LIGHTS – UPPER DECK	33-28-31
	C575, 7.5AMP, STATEROOM READING LIGHT – LEFT, 24-53-11			
	C698, 5AMP, COAT CLOSET AND STOWAGE LIGHTS, 24-43-11		CLOSET LIGHTS – UPPER DECK	33-28-61
28V DC BATTERY BUS	C1366, 5AMP, ATTENDANT CALL, 24-31-11	W1368	CABIN INTERPHONE SYSTEM – ATTENDANT STAIRWELL STA 1-LEFT AND RIGHT	23-42-12
	C1266, 5AMP, ENGINE NO. 2 & 3 START AIR CONTROL, 24-31-11	***W1362***	ENGINE CRANKING – ENGINE 2 AND 3	80-11-12

TABLE IV
W1362, BUS/CIRCUIT BREAKER ASSIGNMENT

BUS	CIRCUIT BREAKER	WIRE BUNDLE	DIAGRAM	
28V DC MAIN BATTERY BUS	C1041, 2.5AMP, FUEL CONDITION ACTUATOR ENGINE 2, 24-31-11	W1362	ENGINE FUEL CONDITIONING CONTROL - ENRICH	76-11-11
			ENGINE FUEL CONDITIONING CONTROL - IDLE	76-11-12
115V AC ESS BUS	C453, 2.5AMP, CB – WHEEL WELL FIRE DETECTOR, 24-51-52	W1362	FIRE PROTECTION – WHEEL WELL	26-17-11
UNK	UNK	W1362	GENERATOR DRIVE – OIL TEMPERATURE INDICATORS	24-11-21
28V DC STANDBY BUS 1	C411, 5AMP, NACELLE ANTI-ICE ENGINE NO. 2, 24-33-11	W1362	ENGINE / NACELLE THERMAL ANTI-ICE	30-21-11
			STATOR VANE ANTI-ICE	75-11-11
28V DC BUS NO. 2	C1704, 7.5AMP, THRUST REVERSER SEQ & BLEED SYTEM – ENGINE 2, 24-54-21	W1362	ENGINE BLEED - THRUST REVERSER ACTUATED	75-32-11
			THRUST REVERSER SEQUENCING MECHANISM CONTROL	78-34-11
	C777, 2.5AMP, CB – ATTENDANT CALL – UPPER DECK, 24-54-21	***W1060*** ***W1368***	ATTENDANTS CALL SYSTEM – UPPER DECK	33-25-21
28V DC BATTERY BUS	C1266, 5AMP, ENGINE NO. 2 & 3 START AIR CONTROL, 24-31-11	W1362	ENGINE CRANKING – ENGINE 2 AND 3	80-11-12
	C1366, 5AMP, ATTENDANT CALL, 24-31-11	***W1368***	CABIN INTERPHONE SYSTEM – ATTENDANT STAIRWELL STA 1-LEFT AND RIGHT	23-42-12
115V AC STANDBY BUS	C1045, 2.5AMP, STANDBY IGNITION ENGINE 2 & 3 LOWER LEFT, 24-33-11	W1362	ENGINE IGNITION – ENGINE 1 AND 2	
115V AC BUS NO. 1	C397, 1AMP, ENGINE NO. 2 IGNITION 1 – LOWER LEFT, 24-51-11	W1362	ENGINE IGNITION – ENGINE 1 AND 2	
	C1519, 3AMP, FOOD AND BEVERAGE ELEVATOR, 24-51-12	***W1060***	FOOD AND BEVERAGE ELEVATOR	25-34-11

TABLE V
W864, BUS/CIRCUIT BREAKER ASSIGNMENT

BUS	CIRCUIT BREAKER	WIRE BUNDLE	DIAGRAM	
28V DC HOT BATTERY BUS	C425, 5 AMP, SURGE TANK FIRE - EXT R C426, 5 AMP, SURGE TANK FIRE - EXT L 24-31-11	W864	SURGE TANK FLAME SUPPRESSION	26-31-11
			MASTER DIM AND TEST – UPPER PANEL	33-12-43
28V DC BUS NO. 1	C82, 7.5 AMP, 1 AND 4 FUEL RESERVE TRANSFER VALVE, 24-54-11	W864	TRANSFER VALVES	28-16-11
	C579, 5 AMP, ENGR IND LIGHTS, 24-54-11		OVERHEAT DETECTION – WING LEADING EDGE	26-18-11
28V DC ESS BUS	C1080, 2.5 AMP, MAIN FUEL TRANSFER VALVE, 24-54-51	W864	TRANSFER VALVES	28-16-11
28V DC BUS NO. 3	C84, 7.5 AMP, JETTISON AND NOZZLE VALVE – RIGHT CENTER., 24-54-31	W864	FUEL JETTISON VALVES	28-31-11
115V AC BUS NO. 2	C66, 2.5 AMP, WING THERMAL ANTI – ICE VALVEL, 24-51-21	W864	WING THERMAL ANTI - ICE	30-31-11
28V DC BUS NO. 2	C67, 1 AMP, WING ANTI – ICE CONTROL, 24-54-21	W864	WING THERMAL ANTI - ICE	30-31-11
115V AC ESS BUS	C123, 5 AMP, FLIGHT ENG PANEL LIGHTS VIA C/B C1173, 24-51-52	W864	INSTRUMENT PANEL LIGHTS P4, UPPER DECK	33-12-31
28V DC MAIN BATTERY BUS	C76 5 AMP, CROSS FEED VALVE 1, 24-31-11	W864	FUEL QUANTITY GAGES – SIGNAL 1	28-41-11

BOEING COMMERCIAL AIRPLANE COMPANY
A Division of the Boeing Company
Seattle, Washington

DOCUMENT NO. D045Y41102TR

TITLE: 270 VDC Wet Dielectric Arc Tracking Tests

MODEL 7J7

PROPRIETARY NOTE

PREPARED BY	J. A. Craig Jr.	12/18/86
SUPERVISED BY	C. B. Tenning	12/18/86
APPROVED BY	J. A. Arline	2/20/87
APPROVED BY		

ORIGINAL

0587z

SUMMARY

The intent of this testing was to determine an appropriate 270 VDC trip curve that provided protection equivalent to a standard thermal circuit breaker with an AC source. To accomplish this goal, a test setup similar to the AC wet dielectric test setup was con... ..ted and the test procedure written to duplicate the AC wet dielectric arc tracking tests.

Phase I Testing was intended to evaluate current 115/200 VAC circuit breakers when used in 270 VDC systems. It was determined that 115/200 VAC circuit breakers were unacceptable for use in 270 VDC systems due to excessive arcing and subsequent melting of the breaker contacts. An electronic circuit breaker was designed and built which interrupted current from the AC source that supplied the 270 VDC lab supply. This eliminated the arcing problems associated with DC switches and allowed examination of several trip characteristics under consideration. A new test procedure was then defined.

Phase II Testing examined several trip characteristics and twenty Nicolet traces of fault voltage, current, and power were recorded. One observation noted during a fault condition was the magnitude of the fault. In all cases, the current level increased over 10.0 p.u. current in less than 5 msec. Also, wire damage was observed to be worst in [redacted] BMS 13-51 (Kapton) and then [redacted] BMS 13-51 (Kapton). In all but one case, [redacted] BMS 13-48 (Tefzel) exhibited the least amount of damage.

A trip characteristics which offers protection equivalent to, or greater than AC circuit protective devices during arcing faults was derived from the tests. The recommended trip characteristic below the 1000% current level is the same as existing AC circuit breakers, with a trip time for all faults above 1000% rated current being interrupted within 10 msec. See Figure 7 for a graphical representation. This trip characteristic would guarantee equivalent or greater circuit protection than AC circuit protective devices while allowing motor or inrush load switching.

1.0 PURPOSE

The purpose of this test was to determine the capability of existing circuit protective devices under all conditions (normal and abnormal), for use in 270 VDC electrical power systems and define requirements for prototype hardware to be developed.

1.1 Background Information

Since the purpose of this testing is to redefine requirements for DC circuit protection devices, and compare them to their AC counterpart, a basic comparison of AC vs DC is required. When a circuit breaker (or switch for that matter) is opened, an arc is created whose magnitude and duration is dependent upon the magnitude of current and voltage being interrupted. Current will continue to flow until the arc is extinguished or current across the contact points creating the arc reduced to zero. One fact, commonly known, yet commonly ignored in this situation is the nature of the two signals. AC voltage and current varies with time and at 400 Hz, becomes zero every 1.25 msec. DC on the other hand does not become zero at all. So, in an AC breaker (or switch), an arc created by an AC signal has a chance to extinguish itself every 1.25 msec where a DC signal must wait for physical separation of the contacts before extinguishing.

5.0 CONCLUSIONS

By examining the results of this testing and wire damage in AC and DC wet dielectric arc tracking tests, the following conclusions can be made:

1) Current 115/200 VAC circuit breakers are unacceptable for use in 270 VDC systems.

2) When damage from an arcing fault occurs, the current level rises abruptly (within 5 msec for this testing) from load current to over 1000% rated current.

3) Damage to the wire is equivalent or less than AC when the time at the 1000% current level and above is faster than standard trip time characteristics presently allow, while leaving the other current levels at their present AC values. For our tests, the damage was equivalent or less than AC, when current was interrupted within 63 to 75 msec of its onset.

4) Wire seen to be most volitile was Tensolite BMS 13-51 (Kapton) with the next most volitile being Filotex BMS 13-51 (Kapton). In all but one case, the Raychem BMS 13-48 (Tefzel) exhibited the least amount of damage.

5) Where the wires burned through with no breaker trip, damage was limited to the two wires involved with the arcing fault.

6.0 RECOMMENDATIONS

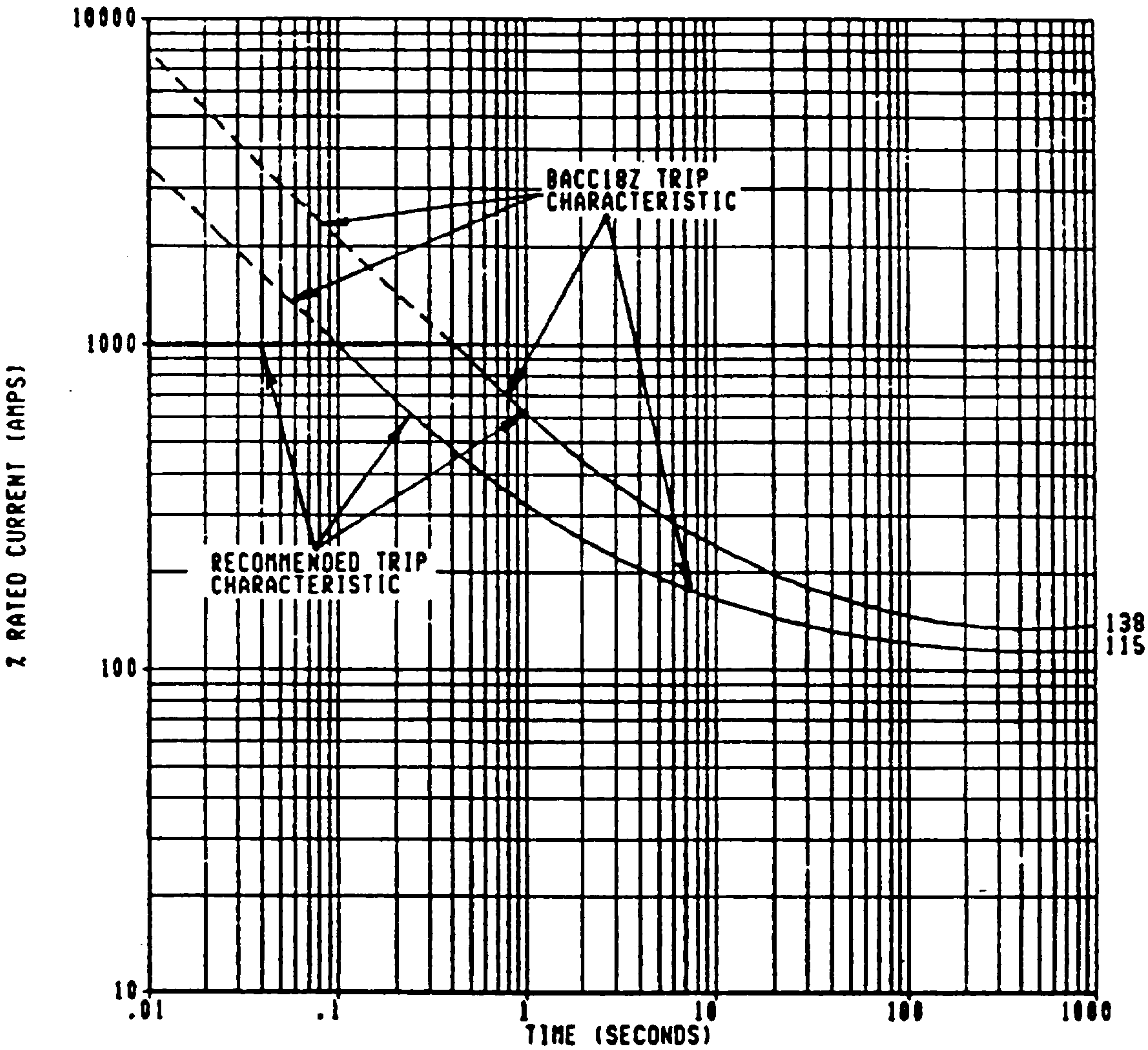
The following recommendations for 270 VDC circuit protective devices are based upon the results of this testing and conclusions drawn from it.

1) The upper limits of the trip time characteristics (1000% and above), should be faster than present AC circuit protective devices. Since significant damage done to the wires was at the higher current levels, only those need to be redefined, leaving the lower trip times the same as current AC breaker trip times. This would allow for motor inrush currents and other similar transients, while protecting the system from arcing type faults.

2) Some consideration should be given to the manual reset time allowed. It was shown significant damage occurred each time an arcing type of fault was reset. If the device is to be resettable in flight, a longer rest time should be required for 1000% faults, but allow normal reset times for lower faults. This would still allow a breaker reset for motor or inductive loads, but not allow a reset into a low impedance or arcing fault.

A recommended trip time characteristic is given in Figure 7.

RECOMMENDED TRIP CHARACTERISTIC



CALC	JACraig	24NOV86	REVISED	DATE	RECOMMENDED TRIP CHARACTERISTIC	Figure 7
CHECK						D045Y41102TR
APPD.					THE BOEING COMPANY	PAGE 32
APPD.						

APPLICATION				PART NUMBER	SYM N
NEXT ASSY	USED ON	SECT. NO.	SERIAL NUMBER		
	65B70199	12&44	R0001–R9995		

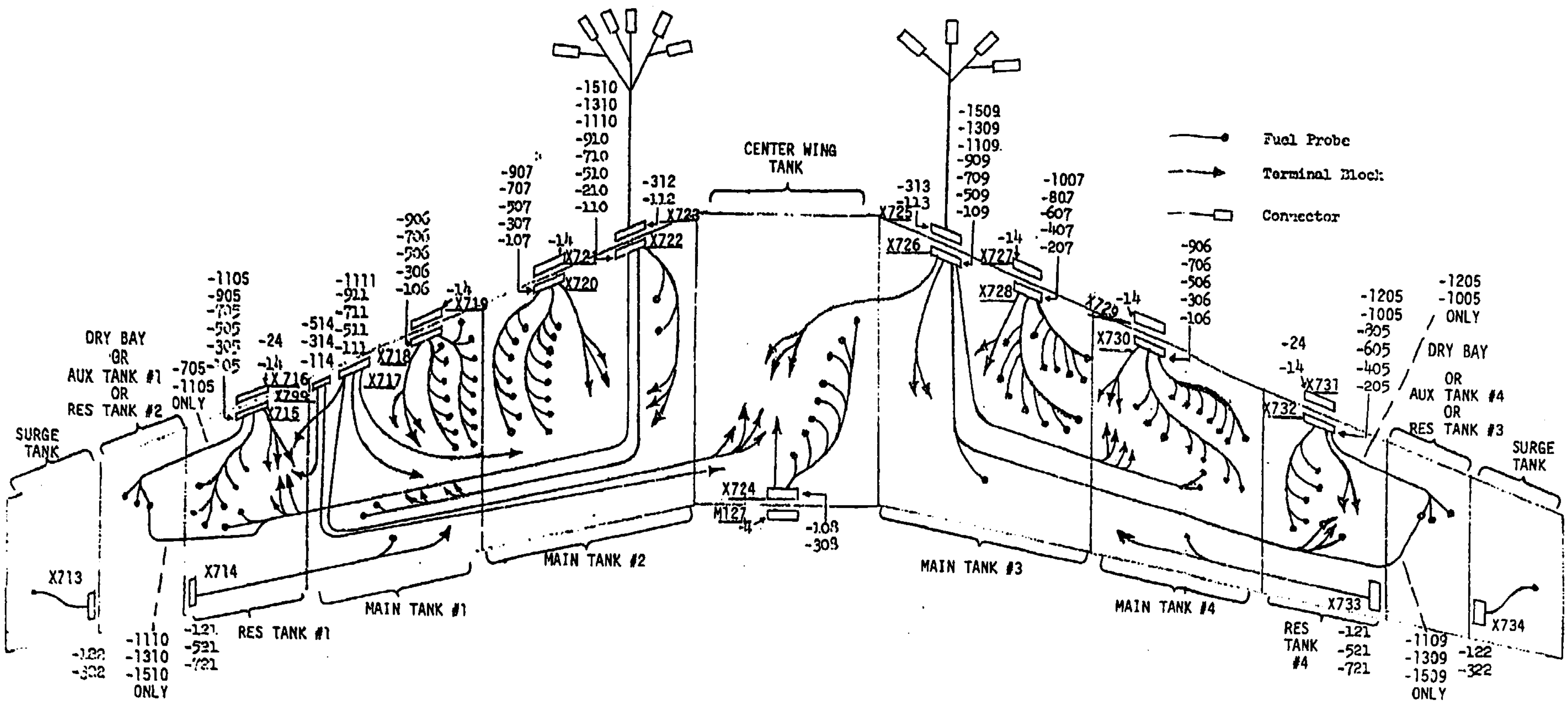
SPECIFICATION CONTROL DRAWING

DRAWN E. Simmerly	DATE 8-7-7	THE BOEING COMPANY COMMERCIAL AIRPLANE DIVISION RENTON, WASHINGTON
CHECKED	11-1-67	
STRUCT		CONNECTING COMPONENTS, FUEL QUANTITY SYSTEM - MODEL 747
ENGR.		
STAFF	11/7/67	
GROUP	11/6/7	
PROJ	11/9	CODE IDENT. NO. 81205 — SIZE A — 60B40037
		SCALE — SH 1 OF 102

AQX 4141C-R1

G7 8

Locations of [illegible] Cable Assemblies on the Airplane



NOTE: This page for RA002 and on only. See SH 43b for RA001.

THE BOEING COMPANY	CODE IDENT NO. 81205	SIZE B	60B40037
	SCALE		SH 10

SYM M

2.1.2.9	* BAC 5162-(5).	Assembly of MIL-C-26500 Solderless Connectors
2.1.2.10	D6-1100	Designing to Skydrol 500
2.1.2.11	D1655-59T	ASTM Designation, Aviation Turbine Fuels
2.1.2.12	P & WA 522	Pratt & Whitney Aircraft Specification "Fuel, Commercial".
2.1.2.13		Deleted
2.1.2.14	BAC D 2104	"O" Ring Grove Config. etc.
2.1.2.15	D6-5762-1	Reliability Guide For Suppliers
2.1.2.16	BAC 5162-6	Assembly of BAC 10-60479 and 60B40037 Connectors
2.1.2.17	10-60479	Connector Components, etc.
2.1.2.18	BAC S11W-4	Seal, Washer
2.1.2.19	BACC47CP	Contact, Electrical Socket
2.1.2.20	BACC47CN	Contact, Electrical Pin
2.1.2.21	BMS 13-10	Wire, Electric, Insulated High Temperature
2.1.2.22	BMS 13-16	Wire, Electric, Polytetrafluoroethlene Insulated Surface Treated
2.1.2.23	* BAC 5162	Assembly of Electric Connectors
2.1.2.24	* BAC 5152	Identification of Electric Wire Bundles

SYM M

3.0 DESIGN REQUIREMENTS

3.1 General

3.1.1 a) General design, data, interchangeability, material, and process requirements shall be as specified in D6-13016, "General Requirements Supplement to Specification Control Drawings for the Model 747 Airplane", except as noted herein.

b) Design and construction requirements, as well as electrical design data requirements, shall be as specified in D6-13000, "Electrical Requirements for Items of Equipment Installed on the Model 747 Airplane", except as noted herein.

c) In case of conflict, the requirements of the following documents shall apply in the priority shown:

1. Specification Control Drawing 60B40037
2. D6-13016
3. D6-13000
4. Reference Specifications

3.1.2 Performance

All parts specified in this drawing shall provide 30,000 hours of continuous, trouble-free operation when exposed to the following environmental conditions:

a) Ambient temperature extremes ranging from a low of $-65^{\circ}F$ to $250^{\circ}F$ and combined with the following:

b) Altitudes ranging from 1000 feet below sea level to 50,000 feet above sea level.

c) Vibration as defined in D6-13014 "Model 747 Equipment Vibration Test Requirements; Area 7, Category A".

d) Relative humidity varying from 0 to 100 percent.

e) Exterior contamination in the form of moisture, dust, sand and metallic particles. Moisture is defined as including salt water, Skydrol 500A hydraulic fluid as described in D6-1100, hydraulic fluid conforming to MIL-H-5606, aviation lubricating oil conforming to MIL-L-7808, and jet fuels conforming to MIL-J-5624, D1655-59 or Pratt and Whitney Aircraft Specification P & WA 522, and caustic cleaning fluid.

SYM C

3.4 Functional Test Requirements

The following Functional Tests requirements are applicable to all connectors and assemblies in this document to the extent specified herein. The conditions under which these tests are to be performed are specified under their respective Quality Assurance paragraph 4.6.

3.4.1 Physical

(a) Air Leak

There shall be no air leakage past the receptacle and no air leakage past nor through the attached cable assemblies.

(b) Vacuum Test

There shall be no change in pressure after 30 seconds of exposure to a pressure differential of 23 $\pm$ 3 inches of mercury.

(c) Fuel Leak

There shall be no fuel leakage of any amount past the O-ring, through the connector assembly, or through the connector shell.

3.4.2 Electrical

(a) Insulation Resistance

The insulation resistance shall be $\geq$ 2000 megohms. After immersion in Skydrol 500A, the insulation resistance shall be $\geq$150 megohms.

(b) Dielectric Strength

There shall be no arcing or sparking. Leakage current shall be $\leq$ 2.0 milliamperes per connector plus 2.0 milliamperes per 100 inches of cable length. C

(c) Continuity

For the Qualification Test Unit, the resistance as measured in paragraph 4.6.2 shall be 0.010 ohms as measured with a suitable bridge.

For all units other than the Qualification Test Unit, there shall be continuity (as measured with a lamp or equivalent technique) per paragraph 4.6.2.

(d) Continuity Under Vibration

There shall be no interruption of current flow in excess of 10 microseconds.

3.4.2 Electrical (Continued)

(e) Contact Resistance Test

The resistance shall be such that 5 amperes will not produce a voltage drop to exceed the following limits:

Circuit	Millivolt Limit
Inner Contact of Shielded Circuit	45
Shield Contact of Shielded Circuit	55
Size 16 (unshielded) Circuit	40

4.2 Pre-Qualification Tests

Samples 1 and 5 of Table I shall be subjected to and shall satisfactorily pass the following tests in Table IIa. B

(a) Product Examination
(b) Maintenance Aging
(c) Contact Insertion Forces
(d) Contact Retention
(e) Insert Retention
(f) Shell Air Leakage

4.2.1 Maintenance Aging

Before any environmental tests are conducted, each contact shall be inserted, removed, and reinserted using applicable insertion and removal tools. "Sample 1" and "Sample 2" per paragraph shall be mated and unmated 10 times. Twenty percent of the contacts, but not less than 3 contacts in the receptacle, shall be removed and inserted 9 times, using applicable insertion and removal tools. The forces measurement required by 4.2.2 shall be made on the third insertion of 5 contacts of each of the connectors. The purpose of the procedure is to provide accelerated maintenance aging of the contact, contact locking mechanism, and sealing provisions prior to environmental testing.

4.3 QUALIFICATION TESTING

Qualification Test Units designated Samples 1, 2, 3, 5, 6, and 7 (see Para. 4.1) shall be subjected to and shall satisfactorily pass the tests specified in Tables II and IIa. Those tests shall be performed in the order listed. Tests where previous data on similar units is submitted as "proof by similarity" must be approved by the buyer.

TABLE II

PRE-QUALIFICATION TESTS	APPLICABLE PARAGRAPHS	SAMPLE 1		SAMPLE 5	SAMPLE 8	SAMPLE 9	SAMPLE 10
		-1	-2	-3	-20	-122	-122
Product Examination	4.4	X	X	X	X	X	X
Maintenance Aging	4.2.1	X	X	X	X	X	X
Contact Insertion Forces	4.2.2	X	X	X	X	X	X
Contact Retention	4.2.3	X	X	X	X	X	X
Insert Retention	4.2.4	X	X	X	X	X	X
Shell Air Leakage	4.2.5	X	X	X	X	X	X
Contact Resistance	4.6.2(e)	X	X	X	X	X	X

TABLE IIa

	QUALIFICATION TESTS	APPLICABLE PARAGRAPHS	SAMPLE 2		SAMPLE 3		SAMPLE 6	SAMPLE 7
			-109 or -1309	-113 or -313	-109 or -1309	-113 or -313	-111 or -911	-111 or -911
	Product Examination	4.4	X	X	X	X	X	X
*	Thermal Shock	4.5.1	X	X	X	X	X	X
*	Fluid Immersion	4.5.2	X	X	X	X		
*	Insulation Resistance	4.6.2(a)	X	X	X	X	X	X
**	Dielectric Strength	4.6.2(b)	X	X	X	X	X	X
*	Continuity Test	4.6.2(c)			X	X		X
*	Vibration & F/T	4.5.3 & 4.6.2(d)	X	X	X	X	X	X
*	Physical Shock	4.5.4	X	X			X	
*	Durability	4.5.5	X	X			X	
	Insulation Resistance	4.6.2(a)	X	X	X	X	X	X
*	Corrosion	4.5.6	X	X			X	
**	Air Leakage	4.6.1(a)	X	X	X	X	X	X
	Fuel Leakage	4.6.1(c)	X		X		X	
	Hi Temp Ins. Res. Test	4.5.7 & 4.6.2(a)			X	X		X
	O Zone Exposure	4.5.8			X	X		X
	Insulation Resistance	4.6.2(a)			X	X		X
	Dielectric Strength	4.6.2(b)			X	X		X
	Altitude Immersion & F/T	4.5.9 & 4.6.2(a)			X	X		X
*	Altitude and Dielectric Strength Test (Mated)	4.5.10						X
	Altitude and Dielectric Strength Test (Unmated)	4.5.10	X	X			X	
	Product Examination	4.4	X	X	X	X	X	X

* Connectors mated for test indicated
** Test performed for both the mated and unmated configuration

SYM M

4.5 Environmental Tests

4.5.1 Thermal Shock

The wired and mated connectors shall be subjected to a test in accordance with MIL-C-26500, , Para. 4.7.6 except the upper temperature limit shall be 250 ± 5°F. M

4.5.2 Fluid Immersion

The connectors shall be suitably mounted on a fixture, mated, and then immersed in fluids as specified below for a period of 20 continuous hours with the fluid maintained at the temperature specified.

FLUID	FLUID TEMPERATURE
JP-4	68 ± 5°F
Skydrol 500A	140 ± 5°F

During immersion of the specified samples, the conditions should be such that Skydrol 500A does not contact the potting compound at the rear of the receptacle. (This potting compound is not resistant to Skydrol). After fluid immersion, the unit shall be subjected to an insulation resistance test for 4.6.2(a).

4.5.3 Vibration

The vibration conditions described herein shall be conducted at the following temperatures:

Low Temperature	-65°F
Room Ambient Temperature	+72°F
High Temperature	+250°F

The test set-up shall be as specified in MIL-C-26500, Para. 4.7.12. M
The vibration conditions shall be as specified in D6-13014, Area M
7, Category A.

Throughout each vibration test, the wired and mated connectors shall be subjected to and pass the continuity Functional Test as specified in Para. 4.6.2(d).

4.5.4 Physical Shock

The wired and mated connectors shall be subjected to a test in accordance with MIL-C-26500 B, Para. 4.7.13. M

SYM B

4.7 **Acceptance Testing**

4.7.1 **Tests and Sampling Plan**

4.7.1.1 All deliverable production cable assemblies, only, shall be subjected to the Acceptance Tests of Table IV. B

TABLE IV

ACCEPTANCE TESTS	APPLICABLE PARAGRAPHS
Product Examination	4.4
Air Leak	4.6.1(a)
Dielectric Strength	4.6.2(b)
Continuity	4.6.2(c)
Insulation Res.	4.6.2(a)

4.7.1.2 All deliverable production units, other than cable assemblies, such as contacts, brackets, and cable clamps are required to pass visual inspection and mechanical tests as applicable. B B

The number of units that are required to pass the acceptance tests are determined by the size of the lot as follows:

LOT SIZE	SAMPLE SIZE	ACCEPT	REJECT
0-14	100 Percent	0	1
15-180	15 Units	1	2
181-500	50 Units	1	2
501-800	75 Units	2	3

A lot shall consist of all units with the same part number, manufactured by the same processes during a continuous production run, not to exceed one calendar week and submitted for acceptance at one time. B B

NOTE 1:
TERMINALS ARE AMP INCORPORATED HARRISBURG, PA. ASSEMBLE PER BAC 5153, EXCEPT CRIMP WITH AMP TOOL 59071-2 USING INSULATION GRIP SETTING NO. 1.

NOTE 2:
RNF-RAYCLAD IDENTIFICATION LETTERS

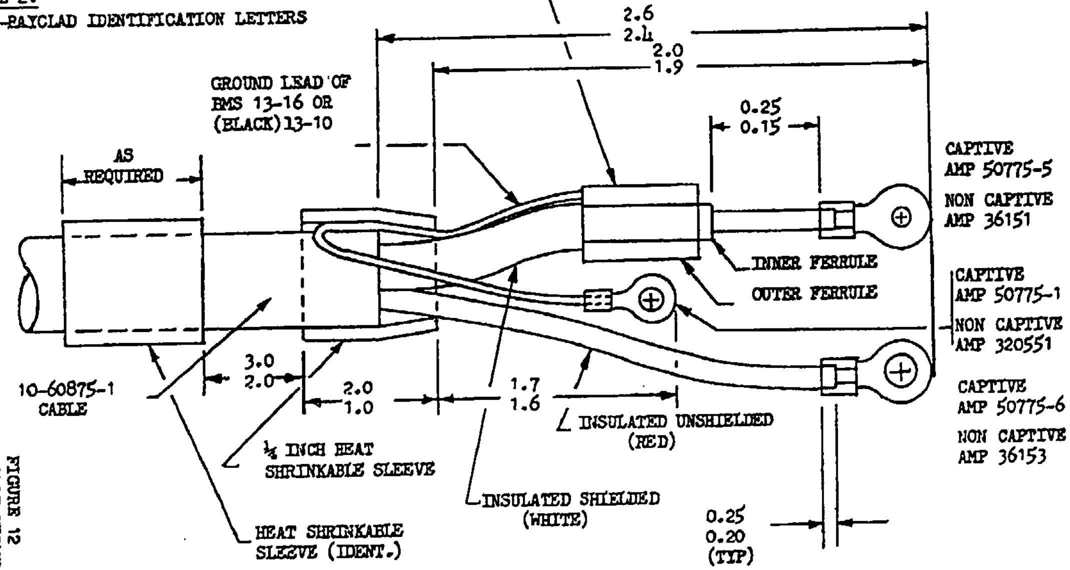


FIGURE 12
CABLE TERMINATION

THE BOEING COMPANY	CODE IDENT NO. 81205	SIZE A	60B40037
	SCALE		SH 70

SYM D

TO 4263A-R1

B-7000

NOTE 1:

TERMINALS ARE AMP INCORPORATED HARRISBURG, PA. ASSEMBLE PER BAC 5153, EXCEPT CRIMP WITH AMP TOOL 59071-2 USING INSULATION GRIP SETTING NO. 1.

NOTE 2:

RNF-RAYCLAD IDENTIFICATION LETTERS

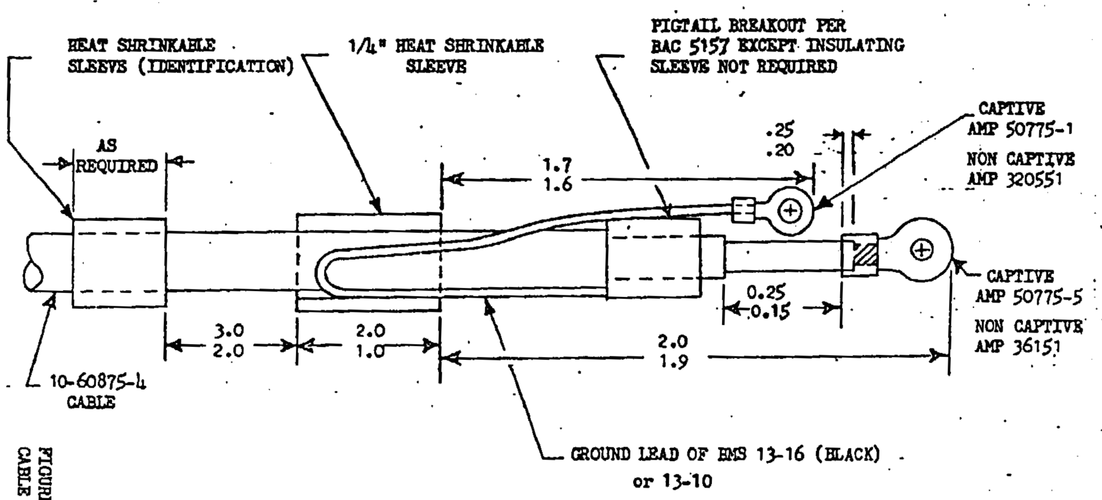


FIGURE 13
CABLE TERMINATION

THE BOEING COMPANY	CODE IDENT NO. 81205	SIZE A	60B40037
	SCALE		SH 71

SYM D

TD 4263A-R1

NOTE 1:

TERMINALS ARE AMP INCORPORATED HARRISBURG, PA. ASSEMBLE PER BAC 5153, EXCEPT CRIMP WITH AMP TOOL 59170-2 USING INSULATION GRIP SETTING NO. 1

NOTE 2:

RWF-RAYCLAD IDENTIFICATION LETTERS

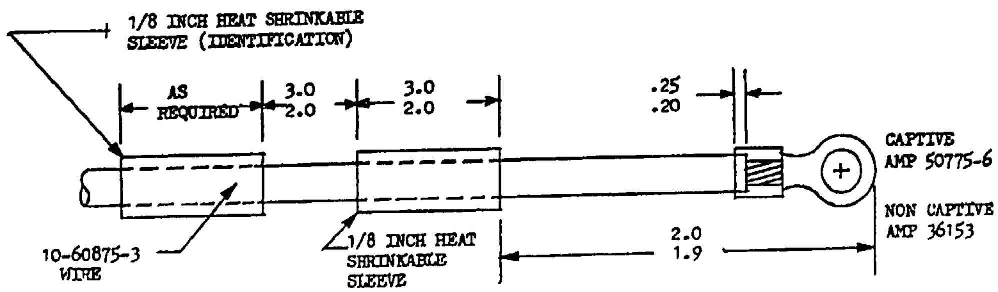
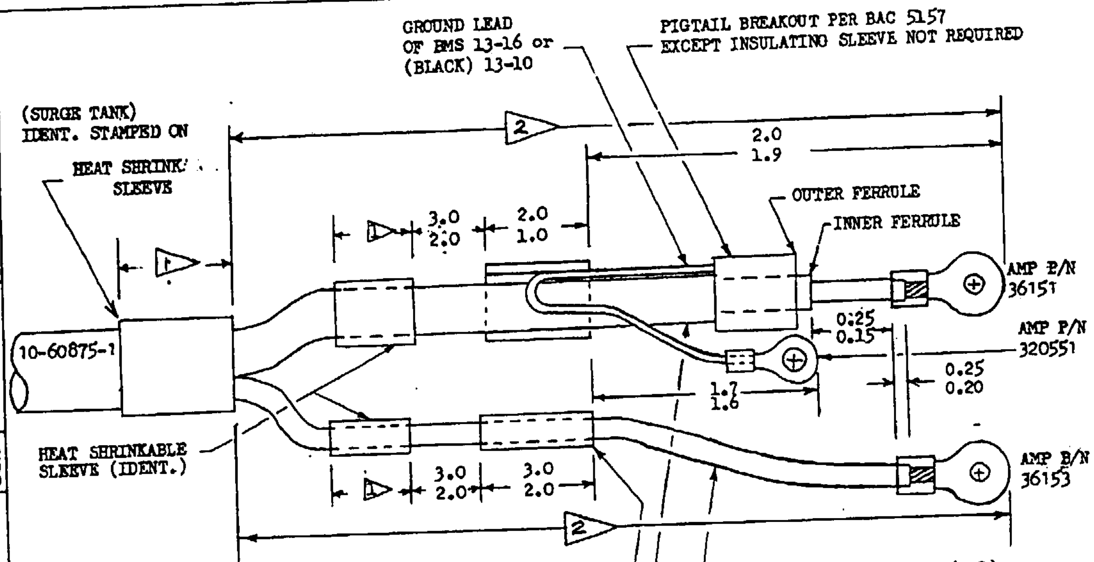


FIGURE 14
CABLE TERMINATION



NOTE 1:

TERMINALS ARE AMP, INCORPORATED
HARRISBURG, PA. ASSEMBLE PER BAC 5153
EXCEPT CRIMP WITH AMP TOOL 59170-2 USING
INSULATION GRIP SETTING NO.1.

NOTE 2:

RNF-RAYCLAD IDENTIFICATION LETTERS

△1 LENGTH AS REQUIRED

△2 SEE FIGURE 33 FOR LENGTH

SYM C

THE BOEING COMPANY	CODE IDENT NO. 81205	SIZE A	CABLE TERMINATION - 60B40037-121, FIGURE 15. 60B40037
	SCALE		SH 73

ABSTRACT

This document defines the methods and practices to be used in the electrical/electronic area for presenting circuit information and wire assembly and installation on the Model 747 aircraft.

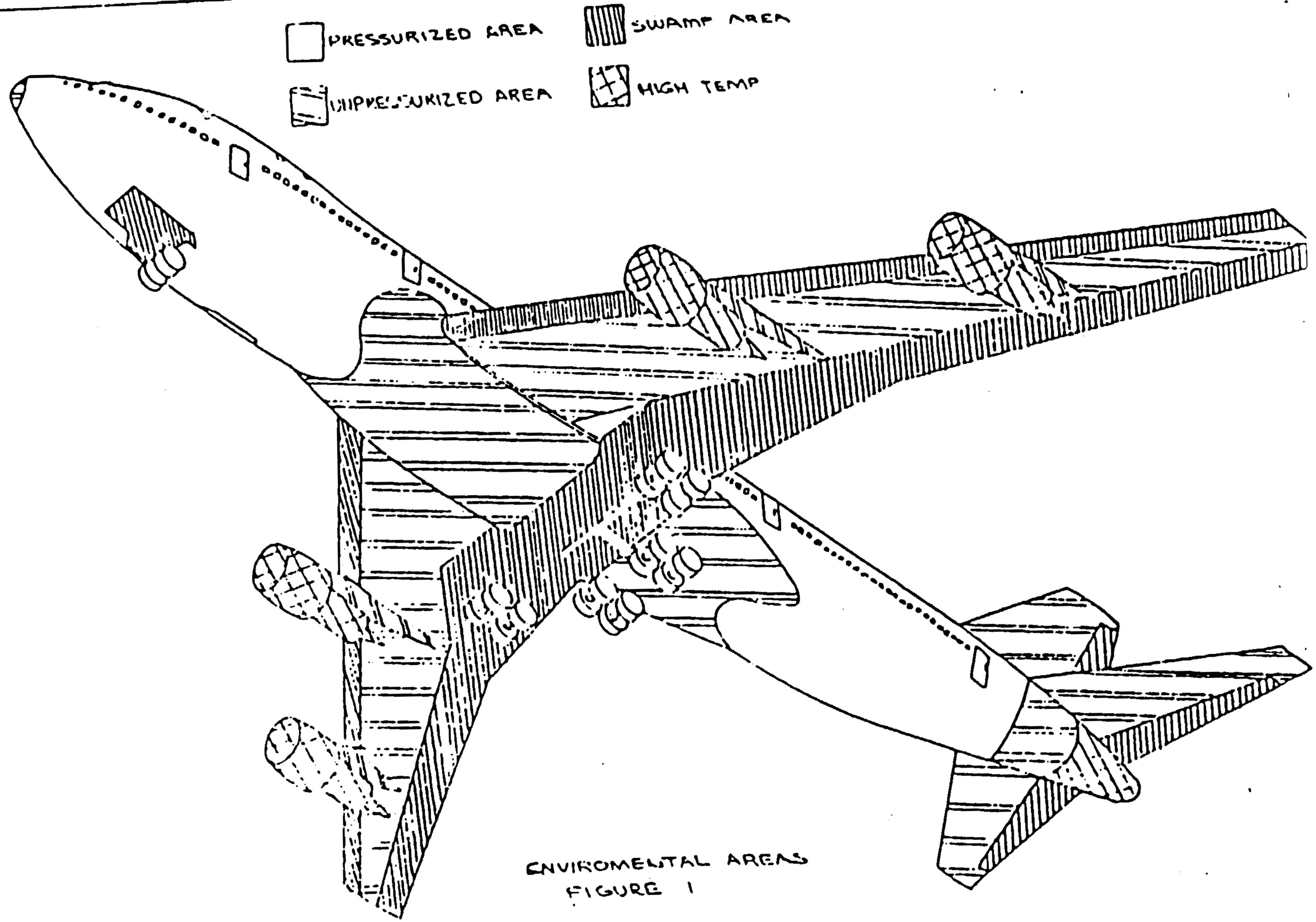
The data is intended for use during design and development by Engineering.

All hardware shall be manufactured and inspected for conformance to applicable drawings, and this document shall not be used as a substitute or supplement thereto.

KEY WORDS

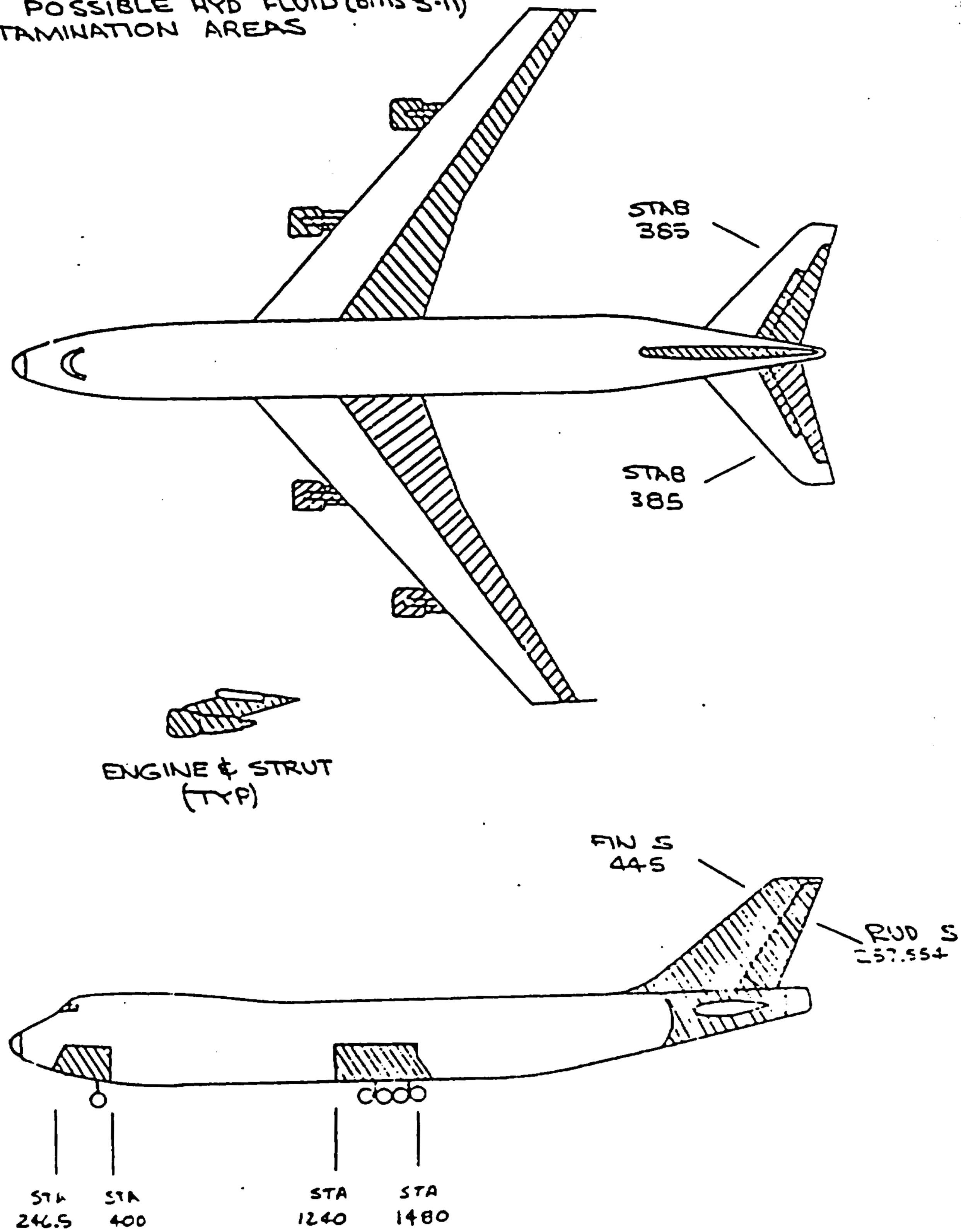
Wiring Design	Wire Size
Wire Routing	Integration Panels
Wire Bundle	Connectors
Ships' Wiring	Crimp Contact

AD 1546 D



ENVIROMENTAL AREAS
FIGURE 1

747 POSSIBLE HYD FLUID (BMS 3-11) CONTAMINATION AREAS



AD 1546 D

1.0 INTRODUCTION (Ref 4, para 42.1)

1.1 Definitions

The following definitions are for the meaning of words as they are used within this document:

A. Clamp - A device used to hold and support wire by gripping action.

B. Coaxial - A wire configuration in which there is an inner conductor surrounded by a dielectric and enclosed by an outer conductor; normally used for conducting radio frequency currents.

C. Connector - A device to make in-line connection(s) between one or more wires for continuous electrical path(s) at a location where the wires are subject to being disconnected and reconnected without mismatching circuits.

D. Contact - A device within a connector used to provide the electrical path joining two individual wires.

E. Crimp - A method of permanently joining a device to an electrical wire by mechanical pressure.

F. Drip-Loops - The loop formed by a wire bundle routed to a connector from above the level of the connector by looping below the connector in such a manner that condensed moisture will not flow along the wire to the connector.

G. Equipment Center - An area where several pieces of electrical or electronic equipment requiring interconnecting and incoming wiring are mounted.

H. Integration Panel - One or more sheet metal panels near an equipment center on which to mount connectors used for integrating the interconnecting and incoming wiring.

I. Module - The integration of an instrument and its associated switches and/or electronics into a unit.

J. Pigtails - Short wires from a piece of equipment that are not terminated in a connector.

K. Pin - A male contact within a connector that is normally round rod shaped, pointed or rounded on one end and connected to a wire on the other end.

L. Plug-to-Plug - To assemble a wire bundle from a connector on one end to a like connector on the other end without any splices, terminals, or other connectors in between.

M. Raceway - An area within the aircraft set aside for the routing of electrical wires. The area may be enclosed or open.

N. Shell - The outside structure of a connector which supports and holds together all of the parts.

1.1 Definitions (Continued)

O. Ships' Wiring - That wiring which is normally permanently mounted in the aircraft, as distinguished from wiring that may be removed with a panel or piece of equipment.

P. Splice - A device for permanently joining together the ends of two or more pieces of wire to provide a continuous electrical path in which the wires cannot be disconnected, without cutting the wire or destroying the device.

Q. Socket - A female contact within a connector normally shaped to receive the pin contacts of the mating connector.

R. Trunk Lines - A group of wire bundles routed between two equipment centers.

S. Wire - An individual insulated conductor used as a single current path.

T. Wire Bundle - Two or more individual insulated conductors tied together in a bundle.

U. Wire Harness - A wire bundle with many destinations.

1.2 General Practices

Design practices and procedures to be used for design and development of electrical and electronic wire bundles and installations shall be in accord with DM 72B1, Ref 8, Drafting Standards Manual, Ref 7, and this document. In case of conflict, this document shall take precedence.

All electrical and electronic wire bundles and installations shall be fabricated and installed in accordance with appropriate Ref 8, DM72B1 (Process Specifications), Ref 4, (D6-13053) and the engineering drawings. In case of conflict between the foregoing, the order of precedence shall be:

A. The engineering drawing

B. D6-13053

C. DM72B1 Section 2 (Process Specifications)

It is the objective of this project to produce wiring for the 747 airplane using a concept which standardizes wiring as much as possible for all airplanes with versatility for maximum accommodation of customer options. Wire bundle development and routing shall be accomplished to provide the minimum of differences between the passenger, the convertible, and the cargo aircraft.

To aid in accomplishing standardized wiring, to simplify modification capabilities, and to simplify maintenance concepts, connector integration panels shall be located in each major equipment center

1.2 General Practices (Continued)

Wire bundles between integration panels shall be considered ships' wiring and shall be treated as trunk lines constructed from connector to connector with a minimum of crossovers or multi-destinations. Wire bundles between the integration panels and the adjacent equipment center (instrument panel or electronic rack shelf) shall become the wire harness containing the cross-over interconnects and the bundle diversions. These cables shall be used to provide for customer variable with the minimum changes to the ships' wiring.

All panel instrument and module wiring shall be terminated in connectors for ease of removal. Switches, relays, indicator lamps, dial lamps, etc., shall be in modules and terminated in connectors on the module.

1.3 Engineering release of Wiring Information

Release of production electrical and electronic drawings shall be per PM 6.7 of Ref 3, (D6-13010) and Ref 7 (Drafting Standards Manual 94C1). All of the rules of PM 6.7 for release shall be followed with the following exception:

All wire bundles and wire routing drawings shall be released as variables for a particular customer block of airplanes. (Example RA001-RA009 Pan Am) Any new customer introduction (Example RA101-RA199 TWA) will be added on as they are committed if they are applicable to existing drawings. If existing drawings do not represent the needed configuration of the next customer block of airplanes then new drawings will be created using existing customer drawings as a base line.

2.1 The process specifications of D6-7281, Section Two, are applicable with the following addition:

BAC 5000 Sealing

3.0 WIRE AND CABLE SELECTION

The wire and cable details listed in D6-7281, Section Fourteen, are applicable to the wire and cable of this specification.

To assure that a minimum number of types of wire are used on the 747 airplane, wires are to be selected from the following whenever practical.

The application temperatures listed are the sum of the ambient temperature and the temperature rise of the conductor.

3.1 Wire and Cable Descriptions

A. H22-4000 (Ref 9) The Rockbestos Company, "Wire, Electrical, Insulated, Fire Resistant"

Maximum Temperature Rating - 500°F (260°C) and flame resistant per MIL-W-25038

Conductor - Nickel clad copper suitable for crimping.

Insulation - Silicone rubber, asbestos/silicone, glass braid and Nomex braid, polyimide finish

Size 18 AWG only

B. BMS 13-16 (Ref 10)

Maximum Temperature Rating - 392°F (200°C)

Conductor - Silver coated copper

Insulation - Extruded teflon (TFE) 10-mil wall

Type I in size 20 AWG

3.1 (Continued)

C. BMS 13-28 (Ref 11)

Maximum Temperature Rating - 500°F (260°C)

Conductor - Nickel coated copper suitable for crimping. Soldering is possible but not recommended.

Insulation - Mineral filled extruded TFE (28 Mil)

Type I in sizes 18 AWG through 4/0 AWG.

Type III shielded and jacketed wire in sizes 18 AWG through 12 AWG.

D. BMS 13-31 (Ref 12)

Maximum Temperature Rating - 500°F (260°C)

Conductor - Nickel coated copper suitable for crimping. Soldering is possible but not recommended.

Insulation - Mineral filled extruded TFE (22 Mil)

Types I in sizes 20 AWG through 1/0 AWG.

Type III shielded and jacketed wires in sizes 20 AWG through 12 AWG.

E. BMS 13-40 (Ref 13)

Maximum Temperature Rating - 302°F (150°C)

Conductor - E. C. grade aluminum.

Insulation - Extruded cross-linked polyalkene primary, cross-linked polyvinylidene flouride jacket, covered with dacron and fiberglas braids.

Sizes 6 AWG through 3/0 AWG.

F. BMS 13-58A (Ref 18) G

Maximum Temperature Rating - 500°F (260°C)

Conductor - Nickel coated copper suitable for crimping. Soldering is possible but not recommended.

Insulation - Composite PTFE-Kapton-glass braid, tape wrapped and fused.

Type I in sizes 6 AWG through 4/0 AWG.

3.1 (Continued)

G. BMS 13-48A (Ref 14)

Maximum Temperature Rating - 302°F (150°C)

Conductor - Tin coated copper or silver coated high strength copper alloy (size 24) suitable for crimping and soldering.

Insulation - Extruded Ethylenetetrafluoroethylene (ETFE)

Type I — 6 Mil nominal insulation in sizes 22 AWG through 12 AWG insulated conductor or two or more insulated copper conductors to make a multiconductor cable.

Type VIII — 10 Mil nominal insulation in sizes 22 AWG through 1/0 AWG, insulated copper conductor or two or more insulated conductors to make a multiconductor cable.

Type IX — 10 Mil nominal insulation in size 24 AWG, insulated, silver coated, high strength, copper alloy conductor or two or more insulated copper conductors to make a multiconductor cable.

Type XII — 8 Mil nominal insulation, shielded and jacketed single or multiconductor wire or cable in sizes 22 AWG through 12 AWG.

Type XIII — 8 Mil nominal insulation, shielded and jacketed single or multiconductor wire or cable in size 24 AWG.

Type XIV — 8 Mil nominal insulation, jacketed multiconductor cable in sizes 24 AWG through 12 AWG.

H. BMS 13-51E (Ref 17)

Maximum Temperature Rating -

Type I through Type VII - 200°C

Type VIII through Type XLIII - 150°C

Conductor - Nickel-coated copper, tin-plated copper, nickel-coated high-strength copper alloy or silver-plated high-strength copper alloy.

Insulation - Fluorocarbon coated aromatic Polyimide tapes.

3.2 Wire and Cable Applications

A. Pressurized Areas - For general application, select from the following:

1. BMS 13-16 Type I, Size 20 AWG use for wire pigtails.

2. BMS 13-48A - Shelf and Panel

   Type VIII, Size 20 AWG through 4/0 AWG, except Size 22 AWG may be used in bundles of three or more wires.

   Type IX, Size 24 AWG, may be used in bundles of three or more wires.

   Type XII, Size 22 AWG and larger

   Type XIII, Size 24 AWG.

3. BMS 13-51 - General Applications

   Type XIV, Class 1, Size 22 AWG through 18 AWG and Size 10 AWG through 1/o AWG (size 22 AWG in bundles of three or more wires only).

   Type VIII, Class 1, Size 16 AWG through 12 AWG

   Type XIV, Class 2 and greater, Size 22 AWG and larger.

   Type XI, Class 1, Size 24 AWG.

   Type XVII, Class 2 and greater, Size 24 AWG.

   Type XV, all classes, Size 22 AWG and larger, shielded and jacketed.

   Type XVIII, all classes, Size 24 AWG.

4. BMS 13-35 Wire sizes 6 AWG and larger aluminum.

B. Unpressurized Areas - For general applications excluding special wind and moisture provision areas, engine areas and landing gear areas, select from the following:

1. BMS 13-48A Type VIII, all classes, in sizes 20 AWG through 4/0 shall be used. Type XII, size 20 and larger.

2. BMS 13-35 Wire sizes 6 AWG and larger aluminum.

3.2 (Continued)

C. Landing Gear - For applications on movable portions of the landing gear, wire shall be selected from the following:

1. BMS 13-48A Types VIII and XII, size 18 AWG minimum.

2. BMS 13-31 Types I or III, size 18 AWG minimum for applications where temperature may exceed 302°F (150°C).

D. Special Wind and Moisture Provisions Areas - For applications in unpressurized areas subject to abrasion and fluids, wire shall be selected from the following:

1. BMS 13-48A Type VIII, Size 20 AWG through 4/0 AWG.

Type XII, Size 20 AWG and larger, shall be used where shielded wire is required.

2. BMS 13-35 Aluminum wire shall be used for AWG 6 and larger.

E. Engine Areas - For applications where wiring is exposed to fluids and abrasion, wire shall be selected from the following:

1. BMS 13-31 Types I and III, Size 18 AWG to 8AWG up to 500°F (260°C).
2. BMS 13-58A Type I, Size 6 AWG to 4/0 AWG up to 500°F (260°C). G
3. H22-4000 Size 18 AWG where resistance to flame is required.

F. Modules (All Areas) - Wire shall be selected from the following:

BMS 13-48A Type I, Size 22 through 18 AWG.

Type XII, Size 22 through 12 AWG.

Type IX, Size 24 AWG.

Type XIII, Size 24 AWG.

Type VIII, Size 16 AWG and larger.

3.2.1 Fire Detection and Extinguishing System

All wire for the fire detection system shall be coded red. Wire types external to electronic boxes and minimum sizes shall conform to the wire requirements for the areas in which the fire detection circuit is routed. Fire resistant wire (Ref 9) is required in the fire zone area.

3.2.2 Coaxial Cable

Applicable configurations shall be selected from MIL-C-17, Ref 16, where applicable for general usage.

For applications in areas subject to hydraulic fluid or temperatures above 105°C, select from the following:

ITT (Suprenant) BMS 3-11 hydraulic fluid resistant cables:

A. BA 5903, 125°C maximum, equivalent to RG-58C/U electrically and dimensionally only.

B. BA 6903, 125°C maximum, equivalent to RG-214/U electrically and dimensionally only.

3.2.3 Thermocouple Wire

Chromel-Alumel and Copper-Constantan pairs shall be selected from vendor special products to meet environmental and EMT requirements.

4.0 PART SELECTION

4.1 Connectors

4.1.1 Connector Wiring Design

To facilitate connector assembly, bundle maintenance and possible future design change, utilize the center contact locations of all connectors first. Use the peripherial hole locations, if not used otherwise, as spares. Each spare removable crimp type cavity in an environmental connector should be sealed with a sealing plug to resist environmental contamination. Environmental connectors installed in the unpressurized area should have spare contacts and sealing plugs installed in all unused contact cavities. Each spare contact in a potted connector should be terminated with a 5 to 7 inch long spare wire of the largest size the contact will accomodate. Spare wires should be dead ended and identified with their relationship to connector insert.

The preferred design for 350 volt wiring is to use separate connectors having all size 16 contact insert arrangements. As an option, in areas where there are only (1) or (2) 350 volt wires being routed through a connector, they may be added with other wire in a mixed insert arrangement of size 20 and 16 contacts, if the 350 volt wiring is installed in the size 16 contacts. No special connector contact arrangement is required for wiring carrying less than 350 volts.

The preferred design for 450 volt wiring is to use separate connectors having all size 16 contact insert arrangements. As an option, where it is not practical to provide separate connectors for 450 volt wire, an optional design concept of maintaining unused contacts around each 450 volt wire is acceptable.

Hermetic style connectors should not be used in aircraft applications due to poor service experience. Bent contacts and electrical interruptions have caused this style of connector to be unacceptable for new equipment design. Consult the Project Electrical/Electronic Components Group for alternatives.

The following usage provides the most desirable connector type selection for most Model 747 applications, and minimizes the variety of connector types used in order to facilitate effective logistic support of aircraft in the field. All application of electrical connectors must be coordinated with the Project Electrical/Electronic Components Group.

4.1.2 Connector Selection

A. For all applications where Boeing has a choice, connectors of the MIL-C-26500 (Ref 20) types listed below shall be used. Cases of large wire sizes and extreme environment (firewall or fuel gage) may require special consideration. Size No. 20 or larger contacts shall be used. Screw thread coupling connectors should be used in high vibration areas.

BACC45FM	Receptacle, Flange Mounted, Threaded Coupling
BACC45FN	Receptacle, Flange Mounted, Bayonet Coupling
BACC45FS	Plug, Threaded Coupling
BACC45FT	Plug, Bayonet Coupling
C0909A	Cinch Nuline Plug, Bayonet Coupling, Metal-to-Metal Shell bottoming, High Vibration Resistant

B. The connector half shall be selected to mate with equipment which has a non-standard connector, as follows:

EQUIPMENT CONNECTOR TYPE	MATING CONNECTOR
MIL-C-5015 (MS 3100-3108), (Ref 19) MS 31XXF "AN" type two-piece insert neoprene elastomer solder contacts (MS 31XXE is interchangeable callout) 255°F maximum.	BACC63 BD (Plug) or BACC63 BE (Receptacle) one-piece insert neoprene elastomer, removable crimp, gold-plated contacts, 225°F maximum.
	Bendix 10-244XXX, 10-2484XX and 10-2625XX two-piece insert, viton rhodium plated contacts -10°F to 400°F maximum; becomes brittle below -10°F.
MIL-C-26482 (MS3110-3128) (Ref 19)	Bendix "PT-SE" Burndy "LT" Cannon "KPSE"
A-MP AD Rack and Panel	A-MP AD
Cannon DPA	Cannon DPA
Cannon DPD	Cannon DPD
Cannon DPX	Cannon DPX, A-MP "AM" series are used for high density contact arrangements ie, 57 and 97 inserts.
Cannon Subminiature "D" Series	Cannon Subminiature "D" Series

5.0 WIRING ASSEMBLY AND INSTALLATION

The requirements of DM72B1 are applicable with the following exceptions and additions:

5.1 ASSEMBLY TECHNIQUES - DM72B1, PARA 124.3

5.1.1 Bundles

Wires in common routes shall be bundled, unless otherwise specified. Wire bundles shall be firmly gripped by ties and clamps at all support points to minimize vibration movement.

5.1.2 Interconnect Bundles

Basic plug-to-plug interconnect bundles between equipment centers shall be firmly gripped by ties and clamps at all support points to minimize vibration movement.

5.1.2 Interconnect Bundles

Basic plug-to-plug interconnect bundles between equipment centers shall be installed for all customers. Adequate wires (para 5.8.1) shall be provided in these bundles for operational systems and growth. Instrument panel and rack shelf wiring shall be quickly disconnectable, allowing for the majority of customer variations to be made in the local equipment center areas.

5.1.3 Production Break

When a production break is required at a pressure bulkhead, the wire bundles shall pass through a BACS45 or similar type pressure seal and connectors shall be installed within the pressurized section.

5.1.4 Splice Accessibility

Aluminum-to-copper splices at each end of aluminum conductors shall be accessible for inspection and replacement.

5.1.5 Connector and Cable Assembly

5.1.5.1 Leave sufficient excess bundle length, at or near each connector, to permit a minimum of three connector replacements. 2.25 in. excess bundle length will normally accomplish this objective. In high vibration areas the excess length shall be distributed between the first couple of clamps.

5.1.5.2 Connector cable clamps shall be used on both plug and receptacle in unpressurized areas. Connector cable clamps shall be used in pressurized areas only under the following specific conditions:

1. Connectors of front removable instruments.

5.1.6.2 (Continued)

Maximum assurance in connector mating is obtained by forming the wire on the plug side into rows across the panel. The above pattern should be adhered to when connectors with different insert arrangement or different shell size is introduced into the panel; however, each installation should be reviewed individually and revised as necessary to prevent mismating possibility.

5.1.7 Wire Breakouts

DM7231 Para 124.313 is applicable.

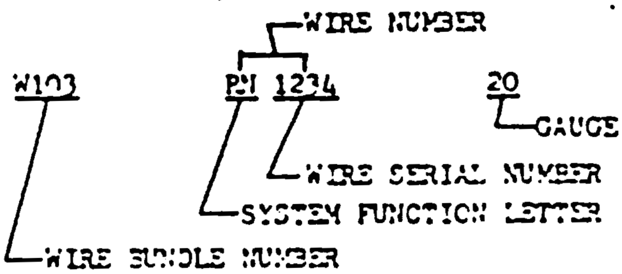
5.1.8 Wire Identification

5.1.8.1 General

The intent of the 747 wire identification system is to provide a traceable wire number to the maximum extent possible. Primary concern is to provide a reliable engineering control of circuit connection by wire identification.

The 747 wire number is an alpha-numeric combination of one or two letters and one to four digits or one digit, one letter and one to four digits. Letters indicate system function and digits establish serial wire number within the system. Use the following wire identification system.

(1)



(2) W103 - C1234-20

(3) W103 - LE1234-20

5.1.8.2 System Function Letter

A. The systems function letters portion of the wire number will be used to define a particular system in the airplane. The system is usually defined by first (single) function letter. The second letter, called circuit designation letter, provides refinement of the circuit function. It will be used with circuit function letters "R", "S", and "T" (electronic systems).

5.1.8.2 System Function Letter (Continued)

B. System function letter may be preceded by digit indicating two or more identical systems under the same circuit function letter.

5.1.8.3 Wire Serial Number

A. The wire serial number will have one, two, three or four digits and will define each wire within the system.

B. For wires with the same circuit function wire numbers shall be assigned to each wire in numerical sequence beginning with the lowest digit insofar as practical.

C. Digits 1 through 8990 shall be used in the digital part of the wire number. Digits 9000 through 9999 shall be reserved for customer use.

D. Wire with the same circuit function having a common terminal connection or junction should have a consecutive number (within the bundle) if possible.

E. A distinct block of numbers shall be provided if two or more identical systems exist under the same function letter. This separation is not required if no duality or triplicity within the overall system exists.

5.1.8.4 Shielded or Twisted Pairs, Triplets, and Quadruplets

A. Red ("R"), blue ("B"), yellow ("Y"), or green ("G") must be added in order to differentiate between hot (high), common (low) and other functions of the wires. Blue "B", is usually allocated to the common lead and red, "R", to the hot lead.

B. When assigning wire numbers to a pair, triplet, or quadruplet, proceed as follows:

Keep numbers in consecutive order.

Allocate lowest number to "red" wire.

5.1.8.5 Coaxial Cable

Wire number to a coaxial cable shall be allocated in the same manner as for ordinary wire.

5.1.8.6 ARINC Spares

Assign numbers using appropriate prefix for the system involved.

5.1.8.7 Ships" Wiring Spares

Spare wires will be designated in the wire list pages of the wiring diagram book and assigned consecutive numbers, prefixed with letter "Z". As spare wires are used out of sequence, they will appear on the appropriate wiring diagram retaining the "Z" numbers, and will be removed from the chart page. The wire number will be changed to a system number for follow-on in sequence airplanes. The chart page will always show the available spare wires by bundle and connector.

5.1.8.8 Wire Size (Gauge)

The wire size number follows the wire number and identifies the gauge of the wire. For coaxial cables and thermocouple wires, wire size entry shall not be made.

5.1.8.9 Wire Number Control

The wire number shall be controlled by the engineer responsible for the system. The engineer shall be continuously aware of the "last number used" within the system.

5.1.8.10 Phase Identification

Three-phase-power wires, which terminate in ring tongue terminals on the same piece of equipment, shall have each wire identified by phase. Phase identification sleeves shall be heat shrinkable polyolefin for temperatures 275°F or lower, and fiberglas for temperatures exceeding 275°F, and shall be installed per document D6-13053 when specified by the bundle assembly drawing. The heat shrinkable sleeves shall be red, yellow, and blue for phases "A", "B", and "C", respectively. The fiberglas sleeves shall be marked Phase "A", Phase "B", and Phase "C", as applicable.

5.1.9 Spare Wiring

5.1.9.1 General Spare Wiring

Ten percent spare wires shall be installed in the "trunk" type bundle assemblies between the equipment centers and between the cockpit and pressure seal at the end of the main cabin. Additional spare wire in each trunk shall be in accordance with each customer detail model specification. The spare wire requirements shall not apply to special bundles such as coaxial cables, power feeders and special system bundles such as critical circuits.

5.1.9.2 Power Plant Spare Wiring

Spare wiring to the engine nacelle areas varies greatly between customers and the customer model specification shall be consulted for these requirements in each case.

5.1.10 Terminations

5.1.10.1 Splices

DM72B1, para 124.321, is applicable with the following additions.

Use of splices shall be kept to a minimum and may be used only as follows:

A. Splices at general multiple wire terminations may be used in cases where other termination means are not practical.

B. Nylon pre-insulated in-line splices (NAS 1388) shall be used generally in pressurized areas except moisture-proof splices shall be used where one of the following conditions exists:

   1. The voltage exceeds 115 volts nominal.

   2. Where condensation might occur and drip shield protection is not provided.

   3. Where temperatures may exceed 221°F.

   4. Where moisture proofing is required, such as: passenger door area, cargo door area, and under the cargo deck.

C. In all unpressurized areas, moisture-proof splices shall be used.

D. Aluminum wire terminating in electrical connectors shall have an aluminum-to-copper splice, A-MP part no. 5252( ), on the end with a copper segment spliced on. The copper segment will be as short as practical, yet long enough for at least five terminal replacements. The splice shall be installed as specified in Document D6-13053, Ref 4. Ten inches additional slack length shall be provided in the aluminum segment to accomodate the terminal replacements. The slack shall be distributed evenly throughout the length of the bundle on installation.

E. Splices shall be protected from fluid contamination, flexing, and damage from structure and maintenance.

F. Splices shall not contain more than six wires per Crimp Barrel.

5.1.10.2 Terminal Blocks

DM72B1, para 124.42, is applicable except as follows:

A. BACM15C - General purpose terminal block for wire sizes 24 AWG through 16 AWG shall be used in pressurized areas or in unpressurized areas, where enclosed in a protective box and mounted to prevent the accumulation of moisture in the block. The maximum operating temperature shall be 149°F (65°C).

5.1.11 Cable Sleeving

The use of cable sleeving shall be avoided except where required to protect the wire from chafing or where it must be used to achieve wire separation. When sleeving is used, it should be secured at both ends with cable clamps, connector backshell clamps or by tying with a cord. Green sleeving shall be used only for the standby power system wiring.

Type and installation shall be per D6-13053, Ref 4.

5.1.12 Tying Cord

Tying cord shall be used as specified in D6-13053, Ref 4, and DM7231, para 124.34.

5.1.13 Sealing

Sealing at pressure bulkheads shall be done per BAC5000 (Ref 21) and BAC5103 listed under "Process Specifications" in DM7231.

5.1.14 High Vibration Area Assembly Technique

5.1.14.1 The Model 747 high vibration areas include the wing, engine strut, wheel well, landing gear and empennage. Wire bundles which route in these areas are subjected to extreme levels of mechanically induced vibrations created by the engines, flap drive motors, fuel pumps, gear mechanisms and wind turbulence. In addition, severe environmental conditions involving exposure to heat, cold, moisture, hydraulic fluid, fuel and dirt are encountered.. The combined effects of these conditions can be accelerated due to the use of stand-off's and brackets. Further problems can be introduced by the use of loosefitting clamps, improper slack distribution, incorre[illegible] forming of breakouts and insufficient bundle ties. The net res[illegible]t of the aforementioned conditions can be serious abrasi[illegible] (wear) of the wire insulation and shortened life of the wire [illegible]allation in service. E

5.1.14.2 Tie wi[illegible] groups, breakouts, and bundles using tie cord only, plasti[illegible]es shall not be used. Special loop knots secured with square [illegible] or surgical knot shall be used at all breakouts to positive[illegible] prevent slippage. The loop shall be secured around one of the wi[illegible] in the main bundle.

Wire bundl[illegible] which route in the strut and sailboat area shall have a tie spac[illegible] of 2 inches. Wire bundles which route in high vibration [illegible] other than the strut and sailboat area shall have a nominal t[illegible] spacing of 6 inches with a maximum spacing of [illegible] inches.

5.2 INSTALLATION TECHNIQUES - DM72B1, PARA 214.4

5.2.1 Routing of Wiring

DM72B1, Para 124.413, is applicable with the following exceptions and additions:

Coaxial cables, critical and emergency circuits, and generator feeders shall not have any breaks except as specifically provided by Engineering. Breaks in other wiring, in addition to the provisions of para 5.1, shall be as provided below:

A. Control cab and electronic racks to wing leading and trailing edges may be broken in the vicinity of the wing body joint.

B. Wiring from forward to the aft body (including coaxial cable) may be broken forward of the aft pressure bulkhead to permit subcontractor wiring of the empennage. Wires passing through this disconnect shall not be broken at the disconnect noted in para 5.2.1.A, above.

C. Wiring from the empennage to the body (including coaxial cable) may be broken forward of the aft pressure bulkhead to permit subcontractor wiring of the empennage. Wires passing through this disconnect shall not be broken at the disconnect noted in para 5.2.1.A, above.

D. Passenger Services wiring from Section 41 and 42 terminating in Section 44 may be broken at the Section 42-44 joint. Additional breaks in passenger services wiring will be permitted as necessary to provide the capability to achieve maximum flexibility in seat spacing and cabin configuration.

E. Breaks to provide for removal and replacement of assemblies such as landing gear, doors, etc., will be provided as necessary.

5.2.1 Installation Techniques (Continued)

F. A break may be used at the wing/body joint if one of the following conditions exist:

1. Wire size change at the wing.

2. Length of wire run in the body is greater than ninety-two feet.

3. Connector use is approved by Wiring Installation Group supervisor.

G. There shall be at least 2 in. separation between wiring and lines carrying fuel, hydraulic fluid, or oxygen, and between wiring and control cables. This separation may be reduced to less than 2 in. only with Engineering approval, in which case, positive support or mechanical protection must be provided to prevent actual contact.

H. Maintain a minimum of 1/2 in. separation between wiring and water lines, pitot static lines, etc. This separation may be reduced to less than 1/2 in. where positive support is provided to prevent actual contact.

5.2.2 Support of Wiring

DM7281, para 124.415, with the following exceptions and additions:

5.2.2.1 Support Requirements

A. Do not include wires of another circuit in clamps supporting main power feeder wires except inside junction boxes and shields.

B. Support of No. 22 and smaller wire shall be provided by routing in bundles of three or more wires. Where this cannot be achieved, special consideration must be given to the installation to provide adequate mechanical support for the wiring. In order of preference, possible design solutions are:

1. Rebundle with other wires.

2. Tie to another bundle.

3. Provide additional support by:

a. Local reroute to obtain shorter breakouts.

b. Additional clamp points (approximately six inch intervals)

c. Use of conduit or plastic rod.

d. Tie to brackets or other structure.

4. Increase wire gauge.

Shielded wire does not require these special considerations.

5.2.2.1 Support Requirements (Continued)

C. As an objective, wire support interval shall be 20 in. or less. A support spacing of 24 in. shall not be exceeded.

5.2.2.2 Wire Support Provisions

DM72B1, para 124.415, with the following exceptions and additions:

A. Where four or more wire bundles are installed at one location and the total cross sectional area of wire exceeds 1.25 sq in., use a raceway clamp (BACC10DS and BACC10DR) except in areas where temperature exceeds 160°F in the wheel wells, engines or where separation of wire bundles is required. If separation of wire bundles is required, use Multiple Tie Plate MTPH( ) and SST2 or SST4 Sta-Strap.

5.2.2.2 Wire Support Provisions (Continued)

B. For general purpose use in the pressurized area where there are three or less wire bundles and the cross sectional area of wire is less than 1.25 sq in., use standard panduit SST1.5, SST2 or SST4 Sta-Strap and TM2 or TM3 mount. Exceptions to this design practice are as follows:

1. If wire bundles have a cross sectional area between .75 and .125 sq in. and the bundles route together in long straight runs, then use the BACC10DS and BACC10DR raceway clamp.

2. In congested areas where wire weight or space is a factor, use the type of clamp that is best suited for that situation.

C. BACC10DK ( ) nylon loop clamps and BACP20BA-1 fillers, when required, may be used for general purpose clamps in pressurized areas for wire bundles less than 1.25 in. in diameter and with temperatures less than 275°F.

D. BACC10BH ( ) cushion loop clamps shall be used for general purpose clamps in non-pressurized areas and for the following special applications in pressurized areas. See 5.2.6 for high vibration area requirements.

1. Bundles in high temperature areas (275°F or greater).

2. Power Feeders.

3. Bundles 1.25 in. in diameter or larger.

4. Semi-flexible coaxial cable.

E. BACC10DK ( ) nylon loop clamps without fillers shall be used inside fuel cells.

5.2.3 Protection of Wiring

DM72B1, para 124.461 with the following addition.

5.2.3.1 Protect wiring passing through a hole in the structure with a support clamp plus secondary protection such as a grommet or fairlead.

5.2.3.2 Conduit

Conduit may be used where required to provide mechanical protection, or reduce radio noise, or to facilitate routing and maintenance in inaccessible areas. Conduit shall not be filled to more than seventy-five percent of cross sectional area.

5.2.4 Separation of Systems or Circuits

The following shall be considered as a minimum in establishing separation requirements:

A. The necessity of isolating flight critical systems or circuits.

B. The necessity of maintaining the redundant or standby capability of flight critical systems or circuits.

C. The necessity of isolating or separating EMI circuits as required by categorization for EMI.

D. Where wire is installed for Fail-Operational Autoland Systems or provisions, separation of wire bundles by Fail-Operational channel classification is requi. d. Reference DDM 9.15 and D6-13053. D

5.2.5 Flight Safety Requirements

DM72B1 Para 124.47 with the following additional exception is applicable:

5.2.5.1 Separation of Critical Circuits

Where physical separation between groups of wires is required for safety reasons (not radio noise), use the following procedures stated in the order of preference:

A. Space Separation of Bundles of Groups of Wires

This can be accomplished by using separate raceways or separate routing.

B. To achieve separation of individual groups of wires, they may be physically separated or protected with glass sleeving or plastic tubing installed per D6-13043, Ref. 4. Vinyl tubing shall not be used.

C. Separation by Group

Where groups of wires are to be separated so as to be replaceable as a group or to be separated from direct contact with specific wires in another group, separate tying of wire groups can be used.

D. No Separation or Non-Controlled System.

When no particular requirements apply or are stated by System engineers, the wires from various systems may be intermixed at random.

5.2.5.2 Seperation of Critical Circuits (Electrical)

DM72B1 Para 124.471 is applicable.

5.2.5.3 Safety Provisions

A. Wiring to Engines

Physical separation and protection of wire bundles is required to reduce the risk of damage in the turbine burst area. Outside the turbine burst area, if physical separation cannot be maintained, separation must be accomplished by use of fiberglass or plastic sleeving installed per D6-13053. Vinyl sleeving shall not be used. A detail plan to recommend wire locations and effective bundle separation is in preparation. As a minimum, the objective listed below will reduce the loss of instrumentation, control and protection from fragment impacts. These requirements are applicable from the engines to the panel integration connectors.

1. Wires to each engine fire detector should be routed in separate bundles.
2. Route fire extinguisher valve and fire detector wires so that a maximum amount of protection is provided by structures.
3. Route N1 and N2 instrument wires for each engine in separate bundles.
4. EGT wires shall be in separate bundles from the pressure ratio and fuel flow wires for each engine.
5. The inlet de-ice wires to one engine shall be a separate bundle from those of another engine.
6. On each engine the thrust reverser indication and extension control wires shall be in separate bundles.
7. On each engine, Ignition No. 1 wire must be routed separately from Ignition No. 2 wire.
8. On each engine the oil low pressure warning and oil pressure indication wires shall be in separate bundles.
9. On each engine the two engine vibration indicator wires shall be in separate bundles.
10. Vibration transducer wires shall not be routed in any connectors containing AC or pulsating DC currents.

B. Fuel Boost Pumps

DM72B1 Para 124.474 is applicable.

C. Fuel Shutoff Valve

Do not route the two Valve Close Control wires in the same bundle. Maintain separation from P5 panel to the valve.

5.2.5.3 (Continued)

D. Air Conditioning Equipment Area

1. No wiring shall be routed in the air conditioning equipment area unless it is connected to the equipment installed in this area.

2. All wiring in this area must be non-wicking insulation construction.

3. Connectors used in this area must be explosion proof.

4. Connectors shall be used to terminate or join wires wherever possible. Where other means are required, the joint shall be potted.

5. Connectors shall be mounted in the horizontal plane and drip-loops provided to minimize the presence of moisture and fuel.

5.2.5.4 Safety Provisions (Electronics)

DM72B1 Para 124.485 is applicable.

5.2.6 High Vibration Area Installation Techniques

5.2.6.1 The Model 747 high vibration areas are defined in D6-13053, Ref. 4.

5.2.6.2 Use JM44LC39S( )RG (J&M Products Inc.) loop style clamps for high vibration areas except BACC10BU( ) loop clamps shall be used on all coxial cable assemblies. Selection of the proper J&M loop clamp size shall be made using the ST2323-B clamp sizing tool. Block style clamps, Ref. 23 (69B90453), should be considered for wire bundles 3/4 inch diameter and larger.

5.2.6.3 Install vibration dampening silicone rubber sleeve on small diameter wire bundle breakouts (3 wires or less 16 AWG or smaller).

5.2.6.4 Control wire slack. Excessive slack allows movement of the wire bundle between clamps which could stress the wires or permit abrasive contact. Insufficient slack, i.e., wires installed taut between clamps will impart loads to the wire bundle stressing the wires.

5.2.6.5 Drip loops must be installed so that motion of the loop is constrained. Additional clamps or other provisions may be required.

5.2.7 Routing of Power Feeders in Proximity to Fuel Lines.

5.2.7.1 Power feeders routing in proximity to fuel lines shall comply with the applicable requirements of Paragraph 5.2.

5.2.7.2 Power feeders (AWG 8-CU/AWG 6-AL and larger) which route within 36 inches of a fuel line in the fuselage shall be shrouded by a continuous electrically insulated TFE sleeve or equivalent. Slit or overlapped insulation of any form is not to be considered as an equivalent.

8.0 ELECTRICAL INTERFERENCE

DM72B1, Section 74, is noted "To be Added Later." The following is applicable:

8.1 MAGNETIC OR ELECTROSTATIC COUPLING

Most magnetic and electrostatic coupling can be controlled by wire separation and shielding practices.

As a basic general separation philosophy for the 747 airplane, where system separation for safety is not involved, the heavy current carrying cables, power distribution, and switching cables shall be routed on the R.H. side of the fuselage and the electronic cables shall be routed on the L.H. side of the fuselage.

All items of equipment, wire bundles, etc., related to one power supply shall be separated from those related to another, insofar as practical.

9.0 ENVIRONMENTAL CRITERIA

DM 72B1, Section 180, is applicable with the following exceptions and additions:

Fig. 1 shows several major environmental areas in the 747 airplane, each requiring different types of wiring and installation treatment. These areas, and the environment with associated equipment problems to be expected in each, are defined as follows:

9.1 PRESSURIZED AREAS

Those areas inside the pressure skin which would normally be held at a low pressure altitude. This includes the airplane main body from the radome pressure bulkhead to the aft pressure bulkhead with the exception of the wheel wells.

Passenger cabin under normal conditions:

Temperature: Cool to 80°F sea level to 10,000 ft.
Cool to 70°F 20,000 ft altitude and above

Pressure: Cabin altitude of 8,000 ± 250 ft at a flight altitude of 45,100 ft.

Sea level cabin to flight altitude of 23,100 ft.

The maximum normal cabin pressure differential shall be 8.9 ± .1 psi.

Freighter cargo compartment under normal conditions:

Temperature: 40°F minimum two inches from interior lining.

Pressure: Cabin altitude of 8,000 ± 250 ft at a flight altitude of 45,100 ft.

The maximum normal cabin pressure differential shall be 8.5 ± .1 psi.

Humidity: As high as one-hundred percent, including condensation, may be encountered.

9.1.1 Condensation - Service experience has shown that in some locations moisture condensation collects and runs down wire bundles. The wire bundles must have drip-loops to stop the condensation from entering the plugs. Connectors must be oriented on equipment in a horizontal or downward direction so the condensation cannot collect in the plug backshell.

9.1.2 Fluids - A few cabin and cargo space locations, such as galleys and toilets, are designated as hydraulic fluid (BMS 3-11) exposure areas. Use of connectors in these areas should be avoided where possible; when used, wire and connectors shall be provided with moisture protection.

9.2 UNPRESSURIZED AREAS

Those areas outside the pressure skin which are normally protected from the weather elements. This includes the tail cone aft of the pressure bulkhead, the radome area, the vertical and horizontal stabilizer interiors and the fin interior.

9.2.1 Temperatures range from -54°C* to +71°C (-65°F to +160°F) with an increase to +85°C after prolonged exposure. Pressure altitudes from 1,000 ft below sea level to 45,100 ft above sea level.

NOTE: (*) The -54°C includes ram rise corrections for outside temperatures in flight which may be as low as -80°C (-112°F).

9.2.2 Vibration - Landing gear and engine areas are high vibration areas. Some tail configurations are also high vibration areas. Use of bayonet coupled connectors in high vibration areas should be avoided unless the long term high vibration capabilities of the connectors are known.

9.2.3 Moisture - Trapped air spaces in connector or equipment tend to fill with condensed moisture. Boxes shall have drain holes. During high altitude flight, the air leaks from the trapped air space in connectors. Upon returning to low altitudes, high temperature/high humidity air returns to the trapped air space. After a few flights to altitude, condensed water will fill the air space. Connectors must be oriented so water cannot accumulate in the rear of the plugs. Air pressure cycling can drive this water into the connector.

9.3 SPECIAL WIND AND MOISTURE PROVISIONS AREAS

Those areas outside the pressure skin which are exposed to the weather elements of wind, rain, sand, etc. Periodic cleaning with detergents is required. The cleaning detergents are normally applied at 140°F to 160°F under pressure.

Those areas include the wheel wells, landing gears, wing leading edge, wing trailing edge, and horizontal and vertical stabilizer trailing edges.

Temperature and altitude ranges are the same as other unpressurized areas with the addition of the above abrasive elements.

9.4 COMBUSTIBLE AREAS - REF. 2, D6-13006

Those areas in which leakage of combustible fluids and vapors may occur, such as: all wing areas, engine struts, main wheel wells, unpressurized areas of Section 46.

9.5 HIGH TEMPERATURE AREAS

9.5.1 High temperature areas are those areas in which the temperature may exceed 135°C (275°F).

The high temperature areas include:

A. Areas on the engine side of the firewalls for the main power plants.

B. Areas adjacent to bleed-air ducts in the air conditioning bay.

9.5.2 Limitation of Equipment

Both connectors and wire have limited high temperature capabilities. Long time (5,000 hours) capabilities at maximum temperature are desirable.

10.0 POTTING AND ENCAPSULATION

DM 72B1 section 190 is noted "To be Added Later". The following is applicable:

Potting of connectors shall be avoided on the 747 airplane where possible. Where potting and encapsulating are necessary, the problem should be referred to the Electrodynamic Staff Group for special consideration.

FOR COMPLETE USAGE DATA SEE ENGINEERING RECORDS

LTR	DESCRIPTION	DATE	APPROVED
A	SEE EO	10/25/??	[illegible]
B	SEE EO	7/6/7?	DAC
C	SEE EO	6-14-78	[illegible]
D	SEE EO	3-23-??	[illegible]

NEXT ASSY	USED ON
[illegible]	DC-10

NOTE TO REPRO: This is not a transparent original. Do not use bleaching equipment.

FILE COPY
NOT TO BE CHARGED OUT

ORIGINAL AT: DAC
DUPLICATE AT: *
CHANGES MUST BE MADE ON ORIGINAL ONLY

FILE COPY
NOT TO BE CHARGED OUT WHEN STAMPED IN RED

* Sundstrand, Tulsa, [illegible]
G.E., Rohr, Westinghouse, Airesearch L.A. & Pheonix

MCDONNELL DOUGLAS PROPRIETARY

RELIABILITY ENGR: [illegible] DATE: 9-25-68

SEPARATE PARTS LIST NOT REQ.

ORIG SECTION: 2200
RELEASE CODE:

DASH NUMBERS OF THIS DWG: ODD DASH NUMBERS SHOWN, EVEN DASH NUMBERS OPPOSITE

FINISH

ORIG. DATE OF DWG: FEB 26 1968
FIRST RELEASE OF PRINTS: OCT 2 1968

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: ANGLES ±2° 30' ... PLACE DEC ±.010, ... PLACE DEC ±.03

CONTR NO.
STRESS
CHECK
DESIGN
PREP. BY S.J. King
DSGN ACTIVITY APPROVAL
CUSTOMER APPROVAL

DOUGLAS AIRCRAFT COMPANY
LONG BEACH, CALIFORNIA

SPECIFICATION - AIRCRAFT WIRING INSTALLATION CLASSIFICATION

SIZE: A
CODE IDENT NO.: 88277
WZZ7002
SCALE: NONE
SHEET 1

24

PRIOR NUMBER AT13227

4.5 Category V - Isolated Wiring

Wiring in this category contains circuitry associated with specific electrical functions necessary for flight. Circuits other than coaxial cables that fall into Category V are isolated because of their extreme susceptibility or emissions characteristics. The requirements of wiring separation are extended for Category V cables in that they may not be grouped with other cables of the same classification. Each cable of this group must be isolated. Deviation from this requirement must have the approval of EMC Engineering.

Category V includes the following:

(a) All transmission lines, waveguide and coaxial types, associated with radio and radar equipment.

(b) Electro-explosive devices (EED) that affect flight safety, passenger safety, crew safety, or mission success.

(c) Fire warning, fuel and LOX quantity systems.

(d) Primary generator output feeders.

4.5.1 Separation Requirements

(a) Individual wires, with the exception of primary power feeders, shall be spaced a minimum of three inches from each other, and all other categories.

(b) Receiver coaxial cables may be grouped together. Transmitter coaxial cables may be grouped together. These two types shall not be mixed in a group; neither shall dissimilar groups be bundled. Transceiver coaxial cables shall not be grouped, nor shall any others used for the dual purposes of receiving and transmitting.

(c) Primary generator output feeders shall be routed as described in Paragraph 4.5.4.

4.5.2 Special Wire Treatment

(a) Multiple point grounding shall be used for coaxial cables with a minimum of a ground at each end of the run, and the shield making circumferential contact at its termination.

(b) Other wiring in this category shall be shielded and ground as provided for by the designer.

(c) Primary power feeders are not to be shielded or twisted.

(d) Twist wires as indicated by the system designer.

FORM 20-1972 (3-70)

4.5.3 Safety of Flight Requirements for Separation

Separation of this category wiring into two or more groups for the purpose of physical isolation for damage control reasons will be suitably identified with an appropriate code.

4.5.4 Primary Power Feeder Cables

The primary power feeder cables connecting the primary AC power generators to load center shall be routed as Category V. The primary feeder cables shall be spaced a minimum of 12 inches from any other category and between feeder runs from separate generators.

DOUGLAS AIRCRAFT COMPANY

DESIGN HANDBOOK

Compiled and Edited by
M. A. Delgado
Producibility Engineering

Authorized by
W. R. Johnson
Manager
Profitability Engineering

Published by
Product Support Publications
Technical and Training Services
Long Beach, California. 1989

Table 4. WIRE SEPARATION SUMMARY - WZZ7002

CAT	SCOPE	DESCRIPTION	EXAMPLES	SEPARATION FROM WIRES OF OTHER CATS	SPECIAL WIRE TREATMENT
I	Elec. Power Wiring	115vac and 28vac & DC to elec. loads Higher EMI sources. Spike & transient originators such as relay coils motors, or transformers (power feeders excluded, see Cat V)	AC motors, heaters, general lighting, relays and other solenoid devices, synchro excitation	6 inches	No shielding except as approved by EMC Eng. Twist with return permitted
II	Electronics Power and Instrumentation	28vac & DC to electronic loads, less offensive than CAT I - not as high current loads, not spike producing	Solid state radio interphone, auto-pilot, computer, anti-skid, shots, squibs, filtered 28VDC, LVDT excitation	3 inches	Shield may be required. May use Twisted Pair
IV	Sensitive Circuits & Low Level Sources	a. Circuits susceptible to low level EMI but not as extreme or critical as CAT V	a. Analog audio synchro signals & bridge circuits Microphone & demodulator circuits, LVDT signals	3 inches	a. Protective shielding single point gnd. Twisted and shielded as required.
		b. Lower level pulse source	b. Analog video and digital circuits		b. Containment shielding multiple point gnd.
V	Safety of Flight Isolation Wiring	Extended separate requirements for coax and for wiring of extreme offensive and defensive character - associated with safety of flight and mission success	Transmission lines, waveguide & coax (radio & radar), fire warning, EED's primary generator feeders	3 in. from each other wire in CAT and other CAT's. Gen. feeders 12" from other gen. feeder runs.	Multi, gnd. coax, Shielded and Twisted as reqd. May group recorder or transformer-coax but don't mix. Transceiver coax not to be grouped.
VI	Sub-system Wiring	Special latitude permitted to mix categories of one and only one sub-system in dense wiring areas for a max. of three feet from connector if possible (Requires Wire Instl. group coordination)	a. Wiring between equip. of same subsystem. May contain CAT I, II, IV & V. b. Generator control and regulation	3 in. from all CAT's including other CAT VI. Do not combine CAT VI subsystems.	As applicable to CAT II & IV

THE **BOEING** COMPANY

COMMERCIAL AIRPLANE DIVISION

RENTON, WASHINGTON

DOCUMENT NO. D6-24391

TITLE: CRITERIA FOR SEPARATION OF CRITICAL ELECTRIC CIRCUITS

MODEL All

ISSUE NO. ______ TO: ______ ______ (DATE)

PREPARED BY	R. B. Martin	2-12-70
SUPERVISED BY	C. B. Tenning	2-12-70
APPROVED BY	R. L. Solem	3-9-70
APPROVED BY	E. C. Brown	3-17-70
		(DATE)

AD 1546 A

REV SYM

6-7000

ABSTRACT

This document provides the guidelines for wire routing separation and power sources separation necessary for isolation of critical systems. The object of the circuit separation is to prevent hazardous malfunctions or simultaneous loss of redundant power supplies or redundant equipment functions due to failures such as:

1) Fire or damage to any wire bundle,

2) Loss of any single connector,

3) Fire in a junction box, or

4) Engine turbine burst.

These requirements apply to any electrical equipment or system for which the proper functioning is considered essential to safe operation.

To insure that these requirements are met, it is recommended that a project wire separation group be established, with the prime responsibility for controlling separation. Wire separation would be implemented by this group concurrent with system design and followed up through airplane construction.

KEY WORDS

Critical Circuits	Wire Separation
Circuit Separation	Wire Routing
Power Isolation	Wire Integration
Redundant Systems	Safety

TABLE OF CONTENTS

CRITERIA FOR SEPARATION OF CRITICAL ELECTRIC CIRCUITS

1.0 WHY SEPARATE?

1.1 Certain wire separation requirements are necessary to meet safety, dependability and certification requirements. Basic separation criteria has been established by the Boeing Design Manual, Federal Aviation Regulations and the British Civil Airworthiness Requirements. The extent of separation requirements are not the same for all types of aircraft due to the varying degree of reliance on electrically operated equipment. However, this document provides a detailed guide to what should be considered. This document is thus intended to serve as a checklist for future design, but may not be absolutely applicable in all cases. Each case must still be judged in terms of the safety of its particular design and the criticality of the system.

1.2 The basic objective of design safety is the prevention of any single probable malfunction or failure from creating a hazard. Each system or equipment is designed to prevent hazards if they malfunction or fail because no individual equipment, system component, or installation is considered immune to failure. Each equipment and component failure mode is considered in the initial design. Sometimes overlooked, however, is the installation of electric wiring and the selection of power sources. Where equipment redundancy and isolation are necessary for airplane safety, then the wire installation and electrical power sources must also be sufficiently redundant and isolated.

Critical circuit wiring should be checked for the following:

1) A single failure of the wiring or electrical system shall not render inoperative any functions (or groups of functions) considered necessary for safe operation.

2) A single failure of the wiring or electrical system shall not adversely affect critical systems (or groups of systems) which, if they malfunctioned, could create a hazard.

3) Where systems or functions make use of redundant equipment to achieve the necessary safety and reliability, then the redundant wiring must be separated and the power sources for each unit(s) must be independent.

4) If an essential function requires two independent power sources, then the power supply and wires must be separated.

1.3 Wiring associated with redundant systems must be sufficiently separated or protected so that hazards such as the following will not result in failure of both systems.

1. Wire bundle fire,
2. Equipment or junction box fire,
3. Connector shorting or decoupling,
4. Fuel Fire,
5. Engine case burn through,
6. Turbine burst fragments(including turbofans and starter turbines),
7. Battery chemical leakage,
8. Abrasion from rocks, ice and mud,
9. Burst hot air ducting.

2.0 HOW TO SEPARATE

2.1 For circuits which are to be separated from one another for safety reasons, not for EMI, adequate separation can be achieved by:

1. Physical separation by either 1/2 inch air spacing when other constraints (such as burst area protection) do not apply, or other suitable means.
2. Routing redundant wires through separate connectors.
3. Providing additional protection in areas where mechanical failures such as turbine burst, pneumatic duct ruptures, etc., may damage primary and redundant wiring.

2.2 General rules for installation of wiring and equipment are given in the Boeing Design Manual 72B1, Section 124. General Installation Requirements, based on Section 124, are provided for reference in Appendix 1.

3.0 **WHAT TO SEPARATE**

This section gives a checklist of what circuits may require separation. This is only a guide since it cannot be applicable to every airplane and every situation. Each particular design must be analyzed in light of the system criticality to the aircraft.

3.1 Air Conditioning

3.1.1 Gasper Fan

No special separation requirements.

3.1.2 Zone Recirculation Fan Control

No special separation requirements.

3.1.3 Cabin Pressure Relief Valve Indicator

No special separation requirements.

3.1.4 Cabin Pressurization System

Separate right hand manual control wiring from left hand manual control wiring including separate connectors. Keep manual control wiring separate from automatic control wiring.

3.1.5 Equipment Cooling System

Ensure that no single failure or fault can result in the loss of cooling air required by essential equipment. Separate wiring to redundant fans and air flow sensors.

3.1.6 Aft Cargo Compartment Heating

No special wire separation requirements.

3.1.7 Stateroom Heat Control Systems

No special wire separation requirements.

3.1.8 Pack Shutoff and Flow Control

Wiring to each pack shutoff valve to be separately routed from other pack shutoff valve wiring as well as from the rest of its own pack wiring.

3.1.9 Compressor Discharge and ACM Outlet Temperature Indicator

No special separation requirement.

3.7 Fuel

3.7.1 Fuel Boost Pumps

Wiring for the two boost pumps on each of the main tanks should be separately routed. Wiring for the aft boost pumps should be routed along the aft wing spars and wiring to the forward boost pumps should be routed along the forward wing spars.

3.7.2 Fuel Jettison Pumps

Wiring for outboard and center left combination jettison and over-ride pumps should be routed separately from the wiring for the inboard and center right combination jettison and over-ride pumps.

3.7.3 APU DC Boost Pump

No separation requirements.

3.7.4 Scavange Pump

No separation requirements.

3.7.5 Fuel Jettison Valves

There shall be separation between the right and left valves.

3.7.6 Fuel Manifold Valves

The wiring to each cross feed valve shall be separate.

3.7.7 Engine Fuel Shut-off Control

Normal wiring for any one fuel shut-off valve shall not be in the same wire bundle as that for any other engine fuel shut-off valve. This wiring should be separately routed or located in a bundle which does not connect to an engine so that loss of an engine (physical separation from the wing) does not sever the bundle and, hence the means to shut off fuel to the missing engine. A redundant "close" wire should run direct from each engine fire switch to its associated fuel shut-off valve. This wire shall be in a different wire bundle from the normal "close" wire that goes through the engine fuel valve switch. The widest possible separation should be maintained between these two bundles through the turbine burst area. Neither "close" wire should be spliced. This can be accomplished by providing another pin at the valve, internally connected to the "close" pin.

3.7.8 Fuel Transfer Valves

Separation will depend upon the system criticallity.

3.7.9 Fuel Low Pressure Warning

Separate from fuel quantity and fuel flow meter.

3.7.10 Jettison Pumps Fuel Low Pressure Warning

Outboard and center left pump's wiring must be separated from the inboard and center right pumps.

3.7.11 Ground Refueling

No special separation requirements

3.7.12 Fuel Quantity Probes and Interconnecting Cabling

No special separation required except for EMI.

3.7.13 Fuel Quantity Gages and Signal System

No special separation required except for EMI.

3.10 Instruments

Instruments required by Federal Aviation Regulations, Part 25.1303, including flight and navigation instruments, shall have separate power sources, separate connectors and separate wiring. All dual flight instrument configurations as well as fail-operative configurations shall also meet the following requirements:

3.10.1 Power

a) Separate power sources must be provided:

1. for each of the two instrument sets, and
2. for each of the three sets of sensor sources.

b) Each sensor source or instrument set and its related power supply must be designed and installed so that failure of one sensor source or instrument set or failure of its power supply or a fault in any part of its power distribution system does not interfere with the proper supply of power to the other instrument set or other sensor power sources.

3.10.2 Wiring

Separation and routing must be such that a functional failure or a fault in any part of one required flight instrument or its associated source sensor will not result in a malfunction to a similar function of the other instrument set or other set of sensor sources. Such failures shall also not affect any other required flight instrument within the same set of flight instruments. This implies the following measures.

a) Separate wires of each instrument and each sensor source into physically independent connectors, relays, switches and wire bundles to assure independence.

b) Route wire bundles of each instrument and each sensor source wiring through separate clamps and cable raceways.

1. A function of one required instrument may be routed together with non-required systems functions but should be isolated from power wiring especially heavy current carrying conductors.

2. Functions of each required instrument set on the same panel must be isolated from each other.

3.10.2 (Continued)

c) In an integration area, provide physical separation of wiring pertaining to each instrument and each sensor source component by routing wire bundles along different stanchion raceways and by the use of separate disconnects. When wire bundle routing in separate raceways is not possible, route critical wire bundles in opposite sides of the same raceway.

d) Behind panels and other confined areas an individual wire or wire bundle may be protected from an adjacent wire or wire bundle by either physical separation or by enclosure of the critical wire in fiberglas sleeving. A critical wire is a signal, control, or power lead associated with required instrument set or a corresponding sensor source.

e) Isolation of critical wires by connector contact assignment must consider the effect of the loss of a connector on the other instrument set or other sensor sources. The loss of a connector must <u>not</u> result in a malfunction of <u>more than one</u> required instrument function or sensor source function.

f) Isolation of critical wires within a relay by internal wafer selection must consider the effect of the malfunction or failure of the relay on the other instrument set or other sensor sources. The malfunction or failure of a relay, internal wafer or wire bundle must not result in a malfunction to any part of the other instrument set or other sensor sources.

g) Signal and control wires should be routed separately and isolated from wires carrying power.

3.10.3 Monitoring

Each instrument or its associated sensors must have a visual device to indicate when a malfunction or power failure is detected by its internal in-line monitor.

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Wire separation is required to comply with existing certification requirements and Boeing safety practices.

The problem involving wire separation is not one of lack of information, but rather of implementation of known requirements.

4.2 Recommendation

Wire separation control to prevent the need for expensive later date changes can be accomplished by establishing prime responsibility for this control.

It is recommended that a wire separation group be established in the project. This Group would:

1. Be knowledgeable with the latest requirements for critical system wire separation and separation for EMI requirements.
2. Be a part of the systems group so that wire separation will be initiated at the concept of a system.
3. Ensure that satisfactory call outs relating to wire separation be incorporated in the appropriate drawings.
4. Coordinate between the systems group and wire integration group to ensure continuance of communication.
5. Consist of more than one person so that group integrity and thus continuance of communication is maintained should personnel change.
6. Be concerned with separation from the time of system concept through to the installation on the airplane.
7. Document the means used to achieve the required separation.

Separation requirements should be adequately defined on the Design Group's system schematics. It is the systems group responsibility to determine the requirements in conjunction with the applicable staff D.E.R. This should be determined and released at the earliest possible date for incorporation into the bundle releases.

APPENDIX I

GENERAL INSTALLATION GUIDE

This section lists the requirements for wire installation and circuit design pertaining to all critical systems and equipment. Although these general requirements are specifically for critical functions, they may also be applied to all circuits for reliability and good service life.

1.0 Emergency Power Sources

Emergency circuits should be fed from the most reliable bus of the airplane. The reliability of this bus can be improved by designing so that it can be connected to an alternate source or sources of power and isolated from other busses by sectionalizing.

2.0 Essential Load Grouping

Special consideration should be given to ensure against the loss of more than one group of instruments or control units due to opening of a single circuit protector; e.g., instruments or control units for one engine should not be connected to the protector used for the corresponding equipment of another engine. Similarly, duplicate systems used to provide reliability, should not be operated from a common protector, i.e., duplicate fire extinguishers or flight instrument systems should be provided with separate protectors.

3.0 Secondary Load Grouping

Consideration should be given to grouping the controls for loads not classified as essential or emergency, so that they can be conveniently and quickly disconnected in the event of a critical reduction of available electric power.

4.0 Overload Protection

All distribution wires must have circuit breakers or other means to protect the wire from overloads. The circuit breaker rating corresponding to wire size is given in D-7900. Each critical circuit must have individual circuit protection, i.e., no other loads ahall be on the same circuit breaker. Remote circuit breakers should be designed to give an indication in the control cabin when in the tripped condition.

5.0 Sequence Operation of Relays and Switches

When it is necessary to design essential circuits so that two or more sets of contacts must operate in a given sequence, provide a positive interlocking means to assure the proper sequence of operation.

6.0 Redundant Equipment Installation

Where redundant essential systems are installed, arrange and interconnect them so that a failure or malfunction of any one component in one system cannot impair the ability of the remaining system or systems to operate. In general, such systems should have separate power connections or sources, separate grounds, and physical separation of wiring and components.

7.0 Routing Requirements

7.1 Route and install wiring to protect against:

a. Chafing.

b. Being stepped upon, used as handholds, or support for equipment, etc.

c. Damage by personnel movement.

d. Damage from cargo stowage and shifting.

e. Damage from heat, acids, fumes and fluids.

f. Abrasion in wheel wells from rocks, ice, mud, etc.

7.2 Do not bundle or route low temperature general purpose wire in contact with high temperature wire which may reach temperatures above 200°F.

7.3 Provide clearance, thermal insulation or baffles between wiring and heat generating parts such as electron tubes and power resistors to prevent deterioration of the wire insulation.

7.4 Route wiring at least three inches away from control cables if possible. If this cannot be done, rigidly support the wiring and specify the minimum allowable spacing on the engineering drawing. If necessary, provide mechanical protection.

NOTE: In addition to damaging wiring, an arcing fault may seriously impair the operation of control cables.

7.5 Do not route wiring under batteries, fluid lines, sumps, pumps, nor fluid line connections. If such routing cannot be avoided, adequate protection must be provided against contamination and degradation. (Ref. BAC 5157 and BAC 5158).

7.6 Route wiring at least three inches away from hydraulic lines.

7.7 Locate wiring at least six inches from fuel and oxygen lines. If this spacing is impossible, a minimum separation of two inches is allowable provided both the wiring and lines are separately secured and clamped and adequate electrical protection is used for the wiring. (Ref. BAC 5157, 5158 and D6-19868).

7.8 Route wiring so that electric terminations will not occur adjacent to lines carrying oxygen or flammable substances.

7.9 Route wiring to each engine separately from the wiring to the other engines.

7.10 Route essential engine circuit wiring so that damage to any bundle will not affect the operation of more than one engine. A minimum perpendicular distance of 16 inches should be maintained from the possible fragmentation path of ejected engine components as defined by model documentation.

7.11 Avoid routing wiring through areas of thermal extremes. If this is not possible, use compatible materials and protection.

7.12 Provide sufficient clearance to prevent the chafing of wiring against any object in the maximum movement due to gravity, acceleration or vibration.

7.13 Do not route electromagnetically incompatible wires in the same group or harness.

7.14 Route wiring for equipment essential to flight separately from other wiring.

7.15 Route wiring to the pilot's instruments separately from the copilot's instruments.

7.16 Separate wiring supplying power to a distribution center from the wiring transmitting power to the use center in order to prevent the possibility of short circuits bypassing the protective devices. If design requirements do not permit this, provide supplementary protection and use high temperature and fire resistant wire.

7.17 Do not route aluminum wiring through areas of excessive vibration. Such wiring should be carefully supported and clamped to minimize relative motion between the wire and the termination. It is sometimes more practicable to splice a short length of copper wire to the aluminum wire and then terminate. Consult the applicable Technical Staff organization.

7.18 Route the wiring for multiple systems such as engines, generators, water pumps, fuel pumps, etc., separately wherever possible.

7.19 Do not route wiring in emergency exits.

7.20 Route the individual phase wires of three power feeders in the same bundle or bundles whenever possible.

7.21 Route the load and line wires for radio noise filters so as to maintain a minimum separation of six (6) inches, except:

a. Where wires terminate on the radio noise filters, the load and line wires should diverge from the terminals to provide a minimum separation of six (6) inches within ten (10) inches of closest terminal.

b. In cases of absolute necessity, the load and line wires may cross at right angles, providing the wires are more than one (1) inch apart at the cross over point, and the wires continue to diverge so that a six (6) inch separation is affected within eight (8) inches of the point of crossing.

c. Ground leads should be as short as possible, and maintain maximum separation from line wires.

7.22 Several cable bundles may be routed in the same raceway or held by one clamp, but should be tied together only at such places as are necessary for bundle integrity or mechanical strength.

7.23 When routing wires or wire bundles in areas where there is heated equipment, thermal anti-icing ducts or cabin air conditioning ducts, the maximum spacing possible should be maintained between the wiring and the heated equipment.

8.0 Methods of Protection

Protect wiring as necessary from natural and induced environmental conditions which could lead to physical and electrical failure. The need for the application of protective materials should be minimized in preliminary planning by the careful design of equipment locations, wire routing and support.

The following design objectives should be observed for the protection of wiring.

8.1 Call out on engineering drawings all protective measures and materials required. Economize time, weight and money by minimizing the amount of protective material used compatible with safe design.

8.2 Bundle Installation Drawings should specify only protective material which cannot be incorporated in the assembly stages.

8.3 Safeguard power busses as follows:

a. Provide strong and rigid support for power busses and bus extensions. Keep bus extensions as short as practical.

b. Provide enclosures, barriers, and insulation needed to protect busses against loose or falling objects, which may cause shorts and grounds.

c. Conductors directly attached to a bus should have protection similar to the bus.

d. Arrange and secure all adjacent ground leads, such as those required for the operation of control equipment, so they will not contact the busses.

e. Protective measures applied to busses must not prevent their necessary heat dissipation or accessibility for adequate inspection.

8.4 Protect exposed terminals on power and other critical equipment with enclosures or insulating materials. Equipment located entirely within enclosures containing only electrical equipment is not considered exposed.

8.5 Direct special attention to preventing the possibility of live electric conductors, terminals, or associated maintenance tools contacting metallic pipes or tanks containing flammable materials. (NOTE: Oxygen is classified as flammable and potentially dangerous.)

8.6 Direct special attention to the protection of exposed (open) terminations in fuel vapor areas. Do not use components which have exposed terminals in these areas. Provide protection as necessary. Note the following:

a. Preinsulated terminals and splices are not considered exposed.

b. Lamp terminals covered by a rubber sleeve or boot are considered exposed.

c. Indicate clearly on the system schematic which terminals are classified as exposed terminations. Call out the applicable engineering drawings, the specific protective materials and Manufacturing Process Specifications involved.

8.7 Protect wire, wiring harnesses, and cables from sharp edges or rough surfaces which could cause chafing. Places where abrasion damage is likely are:

a. Bends around the corner of a shelf, bracket, component or structure.

b. Routings through holes, slots and cutouts.

NOTE: Specifiy that .25 inch minimum clearance be maintained or provide protection as necessary.

c. Where considerable unsupported wire bundle or cable must be provided to allow for disconnecting a plug or removing a component or panel.

d. Where subject to movement or contact by personnel and equipment.

e. Where exposed to rocks, ice, mud, rain or severe wind action.

NOTE: The use of protective tape sleeving, etc., is not a substitute for good basic design.

8.8 Protect wires against breakage at electrical connections by providing sufficient slack, and by using insulation gripping terminals and mechanical clamping as necessary to relieve strain.

8.9 Design each wiring installation to prevent its possible use as a hand hold or lifting aid.

8.10 Unprotected coaxial cables must not be located in hot areas exceeding the safe temperature characteristics of their dielectrics. Conductors may migrate. Particular attention must be given to this in the vicinity of engines, heaters, air conditioners, hot spot skin zones, etc.

NOTE: Polythylene dielectric frequently used in coaxial cables softens at approximately 160°F.

8.11 Consult D6-1100 and the applicable Technical Staff organization for protective electrical materials to use in hydraulic fluid exposure areas.

8.12 Refer to D6-19868, Electrical Design Practices for Fire Prevention.

APPENDIX II

FAA REQUIREMENTS FOR WIRE SEPARATION

Federal Aviation Regulations Part 25 (dated 11/16/68) reads:

25.1309 (a) The equipment, systems, and installations whose functioning is required by this subchapter, must be designed and installed to ensure that they perform their intended functions under any foreseeable operating condition.

(b) The equipment, systems, and installations must be designed to prevent hazards to the airplane if they malfunction or fail.

25.1309 (e) For electrical generation, distribution, and utilization equipment required by or used in complying with this chapter, except equipment covered by Technical Standard Orders containing environmental test procedures, the ability to provide continuous, safe service under foreseeable environmental conditions may be shown by environmental tests, design analysis, or reference to previous comparable service experience on other aircraft.

25.1333 (a) Each operating system for flight instruments for the first pilot, and required to be duplicated at other flight crew stations, must be independent of the operating system for other flight crew stations.

25.1353 (a) Electrical equipment, controls, and wiring must be installed so that operation of any one unit or system of units will not adversely affect the simultaneous operation of any other electrical unit or system essential to the safe operation.

(b) Cables must be grouped, routed, and spaced so that damage to essential circuits will be minimized if there are faults in heavy current-carrying cables.

25.1355 (b) Each system must be designed so that essential load circuits can be supplied in the event of reasonably probable faults or open circuits.

(c) If two independent sources of electrical power for particular equipment or systems are required for this chapter, their electrical energy supply must be ensured by means such as duplicate electrical equipment, throw-over switching, or multi-channel or loop circuits separately routed.

Civil Aeronautic Regulations

CAR 4B, although not applicable after 1964 for new design, may be considered for interpretation of a probable malfunction.

4b.622-(b) Generating system malfunctions. No probable malfunction[40] in the generating system, or in the generator drive system, should result in the permanent loss of service to electric utilization systems, which are necessary to maintain controlled flight and to effect a safe landing, unless the aircraft is equipped with an independent source of electric power capable of supplying continuous emergency service to these utilization systems.

Note 40: A probable malfunction is any single electrical or mechanical malfunction or failure which is considered probable on the basis of past service experience with similar components in aircraft applications. This definition should be extended to multiple malfunctions when: (1) the first malfunction would not be detected during normal operation of the system, including periodic checks established at intervals which are consistent with the degree of hazard involved, or (2) the first malfunction would inevitably lead to other malfunctions.

In addition to the above requirements, and in lieu of the previously imposed five minute power off flight requirement, FAA letter of January 14, 1969 requests, as part of certification of the electrical system, a failure analysis including -

1. The effects of wire bundle fires,
2. The effect of the loss of connectors, and
3. The effect of a fire in a junction box.

The above requirements do not specifically require separation of redundant circuits; however, it is quite clear that no probable malfunction should result in the loss of essential circuits. The failure of a wire bundle due to localized fire, connector failure, turbine burst, or damage due to prolonged moisture exposure, or a faulty circuit has occurred a sufficient number of times in the past to be considered a possible malfunction. The above interpretation of the regulations is the basis for considering the wire separation a FAA requirement.

MANUFACTURING DEVELOPMENT REPORT

POLY-X WIRE BUNDLE MANUFACTURING PROCESSES	MDR 6-27037

MODEL NUMBER: 747 PROGRAM NUMBER: 627-037

WORK ORDER: 9-E9631-3033-627037 PAGE: 1 of 8

MDSR NUMBER:

SUMMARY STANDARD

The purpose of this investigation was to develop manufacturing processes and tooling for the production implementation of the new Raychem Poly-X wire procured under Boeing Materiel Specification BMS 13-42. Employment of the new wire was designated by 747 Engineering Project because its thinner insulation provided a potential weight saving of approximately 400 to 600 pounds per airplane over that achieved with the existing BMS 13-38 and BMS 13-39 wire. Preliminary evaluation of experimental samples of the new Poly-X wire was reported in MDR 6-27028 titled: "Raychem Poly-X Wire Bundles" and MDR 6-27042 titled: "Development of Marking Process for Natural-Brown Poly-X Wire."

This investigation provided necessary support and feedback data to termination manufacturers to satisfy the development of new terminations for use with the thinner insulated Poly-X wire. It also provided sufficient information to Raychem to improve wire solderability and resistance to apparent disfiguration. The pigmentation of the insulation layers in the original production wire did not offer Manufacturing or Quality Control a satisfactory means of determining the extent of visible disfigurations incurred in the thin wire insulation during bundle fabrication and installation operations. The construction of the final production wire eliminated arbitrary decisions by providing visible easily recognizable color levels. The color levels can then be used to determine if the insulation damage was superficial and confined to the outer imide dip coating only or had degraded the wire by extending into the primary insulation layers.

The investigation resulted in the development and implementation of production processes and tooling to accomplish marking, stripping, terminating, soldering, potting, etc., operations on Poly-X wire. New tooling and settings required by Manufacturing to strip the new Poly-X wire were provided in addition to an interim modification recommended by the Raychem Company to improve the performance of existing "IDEAL" hand strippers when used on Poly-X wire.

The investigation also included tests and evaluations necessary to qualify and implement new series of "AMP" lug terminations and "BURNDY" modular block contacts containing smaller diameter insulation grip barrels, for use with the new Poly-X wire.

It is recommended that BMS 13-42 (Poly-X) wire be processed by electrical sub-assembly and installation shops using the production tools and techniques developed under this investigation.

ADX 10224

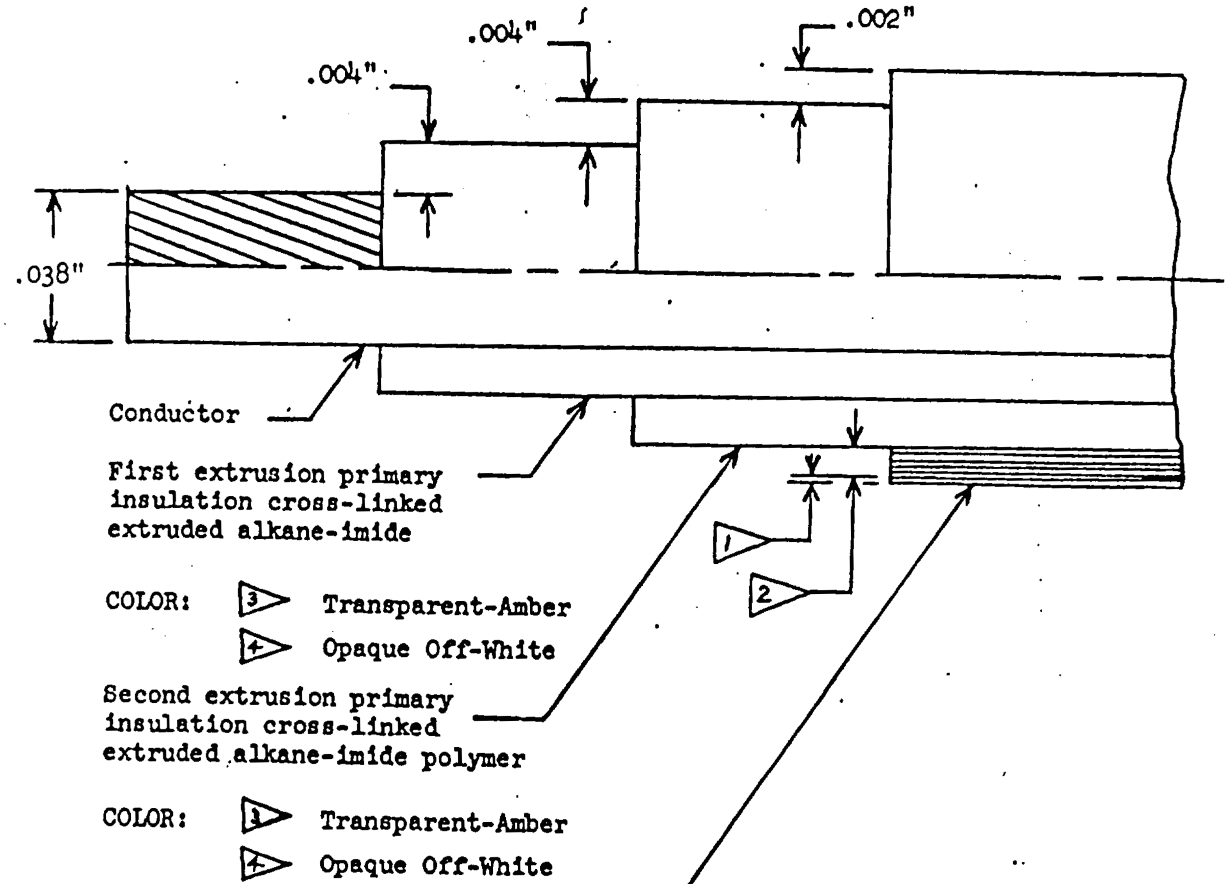
Warren F. Vaupel — PREPARED BY — DATE 3-19-70

D. W. Allen — APPROVED BY — DATE 3/19/70

R. Christy — APPROVED BY — DATE 4/6/7?

Attachment (a)

BMS 13-42 WIRE CONSTRUCTION



COATING OF MODIFIED IMIDE POLYMER COATING CONSISTS OF APPROXIMATELY EIGHT TO TWELVE LAYERS OF A MODIFIED IMIDE MELT DIP POLYMER. OUTER TWO TO THREE LAYERS OF COATING CONTAIN THE COLOR PIGMENTATION OF THE WIRE (WHITE FOR CLASS 1 WIRE). THE REMAINING NINE TO TEN LAYERS, UNDER THE PIGMENTED LAYERS, ARE GOLDEN BROWN - THE NATURAL COLOR OF THE IMIDE DIP.

1 Color Pigmented Layers

2 Golden Brown Layers

3 Original Color of Primary Insulation Layer

4 Final Color of Production Wire Primary Insulation Layer Pigmented with Titanium Dioxide Filler Material

AD 19 6-3020 8.6

Attachment (b)

October 10, 1969
6-3021-5-143

To:	S. Carlson	E-4855	OF-04
	R. Harris	E-4540	OM-49
	T. Dennis	E-4544	OE-58
	H. Fisk	E-5771	27-18
	P. Higgins	E-4810	OF-37
	K. Kingston	E-4210	02-18
	J. Morris	E-3710	OW-33
cc:	D. Cruze	E-5100	OM-21
	J. Krezak	6-3020	OK-62
	R. Leckie	6-3020	OT-67
	D. McChesney	E-4530	OE-56
	B. McMahill	E-1834	OW-05
	J. Phillips	6-3020	62-02
	R. Powell	E-5100	OY-43
	F. Starsinic	E-4541	OE-58
	T. Stensen	E-4550	OM-43

Subject: New ST Wire Strippers Required for BMS 13-42 Wire

Reference: Memo 6-3021-5-129, E. Gruel/W. Kau to D. Cruze et al, dated August 11, 1969, same subject.

The purpose of this memo is to emphasize that different hand strippers are required to prepare the new BMS 13-42 (Poly-X) wire for terminations. The new wire is scheduled for formal implementation on airplane #55; however, Engineering has already called out approximately 1800 feet of the new wire for use on the passenger doors of 747 airplanes number one and on. Reference memo listed the Ideal part numbers of the new stripper blades required. These have now been assigned Standard Tool numbers.

Hand strippers incorporating the new blades have been assigned Standard Tool numbers as follows: ST-2222-28 for wire guages AWG-26 through AWG-16 with 6 mil insulation; ST-2222-26 for wire guages AWG-26 through AWG-16 with 10 mil insulation; and ST-2222-27 for wire guages AWG-14 through AWG-10.

The use of any other strippers on the new BMS 13-42 wire, other than those specified above will result in rejections due to damage to conductor or insulation.

Should additional information be required regarding the use of the new strippers and other tooling required for BMS 13-42 wire, please contact T. Johnson or W. Vaupel on Ext. 342-4941 or G. Blevins on Ext. 342-3251.

E. Gruel
Electrical/Electronics
Mfg. Research & Development
6-3020 62-01

W. J. Kau
747 Liaison
Mfg. Research & Development
6-3020 OK-62

WJK/EG/WFV:ff

Attachment (d)

November 11, 1969
6-3021-5-154

To:	C. Peterson	E-3800	49-40
cc:	M. Bailey	E-4544	OE-58
	G. Gabrielson	E-6860	OM-49
	K. Stidell	A-5851	48-46
	T. Dennis	E-4546	OE-58
	T. Kenney	E-8523	OT-06
	J. Krezak	6-3020	OK-62
	J. MacDonald	E-4500	OM-43
	J. Phillips	6-3020	62-02
	F. Starsinic	E-4541	OE-58

Subject: Springs to be Installed on ST 2222-26, ST 2222-27, and ST 2222-28 Ideal Wire Strippers.

The purpose of this memo is to furnish the Tool Design Group, E-3800, with information regarding the ST 2222-26, -27, and -28 Ideal hand held wire strippers.

The Ideal Company, in conjunction with the Raychem Corporation, has recommended that an external spring be attached to the existing ST 2222-26, -27, and -28 Ideal strippers when they are used to strip the new BMS 13-42 Poly-X wire. This recommendation was made to alleviate possible extruding of the innermost insulation during the stripping operation.

The extruding of the insulation, during stripping, is due primarily to the toughness of the alkene-imide insulation construction and the close tolerance (± .002") of the cutter blades. Stripping difficulty on this insulation is due to the cutter blades not closing and completely cutting through the innermost extrusion layer of the insulation. This results in the layer being torn off instead of cleanly cut off.

The spring recommended for use will produce a tighter grip on the wire and force the cutter blades to close completely. This will result in a cleaner strip with little or no extrusion of the innermost insulation.

The springs, which will be supplied by Raychem at no cost to Boeing, are intended to be installed externally on the Ideal hand stripper frame using screws threaded into existing threaded holes in the frame. A sample stripper frame with spring installed and a package containing a loose spring and associated mounting hardware has been submitted to you.

New stripper assemblies ordered from the Ideal Company will be constructed with the additional spring mounted internally.

We therefore recommend that the present ST 2222 drawings be revised to include the additional spring modification. Should further information be required on this subject please contact T. Johnson or W. Vaupel on extension 342-5492, or G. Blevins on extension 342-3251.

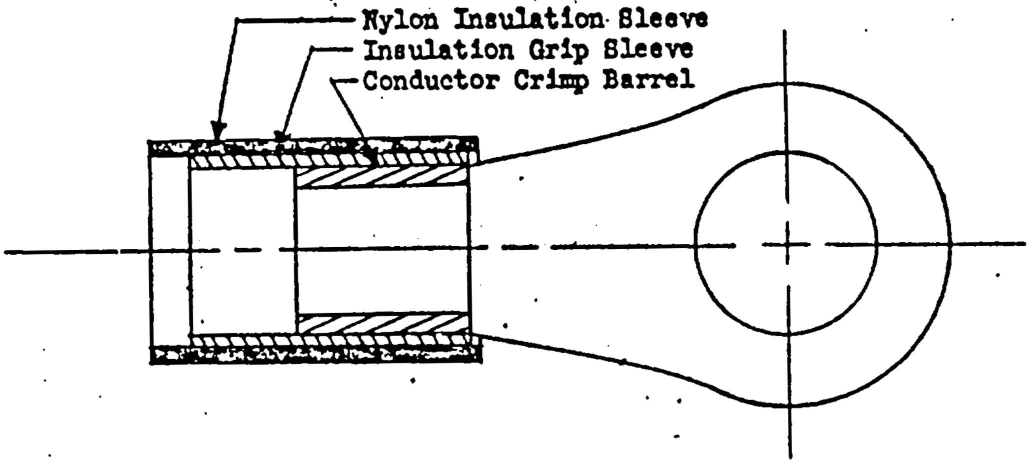
W. Kau, General Supervisor
Everett - Liaison
Mfg. Res. & Development
6-3020 M/S OK-62

E. Gruel, General Supervisor
Electrical/Electronics Group
Mfg. Res. & Development, 6-3020
Ext. 237-7155 M/S 62-01

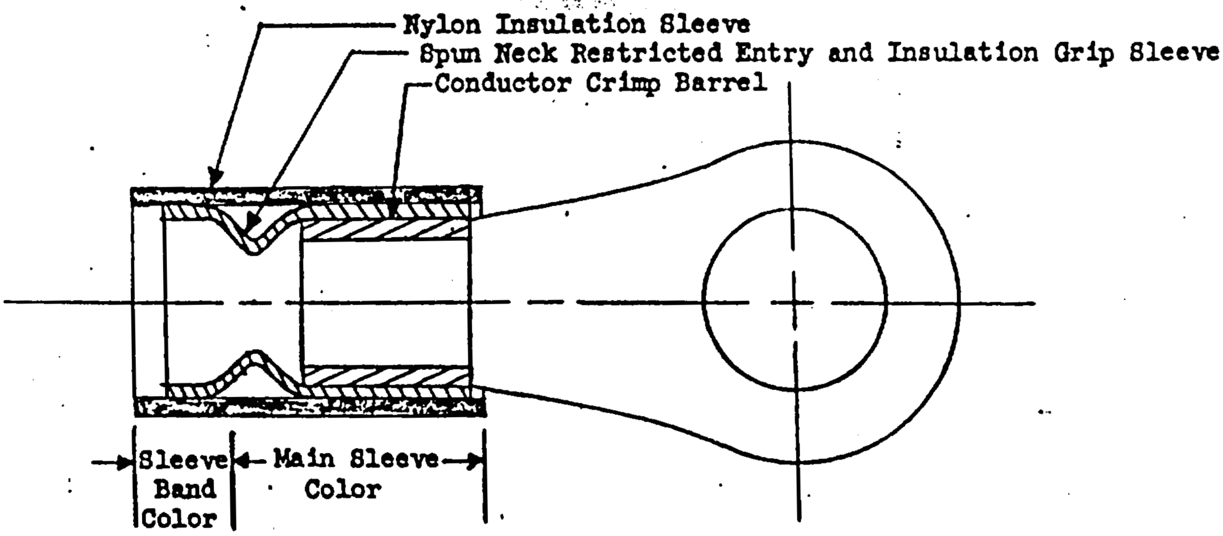
TJ:dt

Attachment (e)

AMP TERMINALS



Conventional MS type preinsulated terminal for use with previously used wire insulation thicknesses of 14 mil and above.



New restrictive entry terminal for use with thin wall insulation (6 mil to 10 mil) BMS 13-42 (Poly-X) wire.

NOTE: Spun neck restricted entry section of terminal prevents the thin insulation portion of stripped wire ends from entering the conductor crimp barrel area.

OPERATIONS TECHNOLOGY DEVELOPMENT REPORT

TITLE		
BULKHEAD SEALED WIRE FITTING, CHANGE PROVISIONS		
OTDR NUMBER	CHARGELINE	
6-30570	9-E9654-2029-630570-MR1	
IDENTIFICATION	MODEL(S)	PAGE NUMBER
STANDARD	737,747,757,767,777	1 OF 5

SUMMARY:

It is often necessary to route wires through a previously potted Electric Wire Bundle Seal (Wire Seal: BACS45A-, BACS45B-, 287T0031). A variety of unsatisfactory methods are used to penetrate the potting compound for this routing. These include the use of screw drivers, drill bits, and X-Acto knives. These methods can and usually do cause damage to the existing wires, resulting in costly, time consuming rework. The only other safe method is the complete removal and resealing of the Wire Seal. This can take hours to accomplish and is the reason behind the use of the before mentioned methods.

The Wire Change Provision provides a method for the addition of wires through a previously potted seal fitting, caused by changes made to the current wiring. A short length of spiral tubing is included with routed wires internal to the seal fitting. When the interior of the seal fitting is potted the spiral tubing becomes entrapped with the wires. The Wire Change Provision is created by pulling on the exposed end of the spiral tubing. The spiral tubing shears out a core of potting compound as it is removed, creating a hollow passageway through the seal fitting. This method will not compromise the integrity of the seal fitting or contribute to wire damage.

Currently this method is being included on two PRR's for implementation on the 767 and 747. This was accomplished through coordination with Producibility and 767 Wire Installation Engineering. Coordination with Renton is being made by the Everett DER and Project Engineering.

R.K. JARVIS 2/3/94

Prepared By Date

L.A. ANDERSON 2/7/94

Approved By Date

This program was begun based on an Employee Suggestion (E60408). The Suggestion outlined a way to install additional wires through potted wire bundle seals. Operations Technology was given the suggestion to evaluate. A program was initiated to develop the concept, establish whether there was a need for this method and coordinate with Engineering for possible implementation. A name was given to this method; Wire Change Provision (see Fig. 1).

The suggestion described the use of a hollow length of TFE (Teflon) tubing sealed at both ends to create the provision. To access it would only require the ends to be cut off. The wire would be routed through the tube and the added wire would be potted with sealant. There is no formal procedure in place at this time to provide for the addition of wiring to potted seal fittings other than complete removal of the seal fitting/wire/sealant assembly from the airplane structure. This is not easy. Each seal fitting is fillet sealed to the structure with BMS 5-95. Other undesirable methods are used to create a provision in the seal fitting. These methods include the use of sharp objects such as screw drivers, drill bits, and X-Acto knives. The use of these tools often damage existing wires. This damage is not evident until there is a systems failure. Repairing the failure is costly.

The concept of creating an easily penetrable seal fitting is valuable. Using a hollow TFE tube to do it is not. This would be purposely creating a void in the seal fitting. Pressure cycling would occur inside the tubing as the airplane changed altitudes. This could eventually cause the sealant plugs at both ends to blow out or cause shrinkage of the outside diameter of the tubing so it could be blown out. Teflon is an inherently slippery material. Air pressure breaks any adhesion the Teflon might have with the sealant material allowing air to leak past the tubing. Solid rods perform better but can still leak air past the rod. Rod materials, if not susceptible to leaks, are difficult to remove from the sealant mass.

Different materials and configurations were considered. These included nylon rod, silicone rod, rigid Teflon tubing, and coil spacer (plastic coils placed on wires to separate them from each other allowing sealant to surround each wire during potting). These were materials that could be obtained off-the-shelf. There were also design ideas of special shapes. These shapes would be able to be removable but provide an air tight seal when potted into the wire seal. These designs would require the generation of part drawings and custom molding.

Another material was spiral tubing. Spiral tubing is an off-the-shelf item, usually made from nylon, polyethylene, or Teflon tubing. The tubing is slit helically to make long coils of spiral tubing. Spiral tubing is normally used for bundling and abrasion protection of wires. It's spiral shape allows it to be applied to the wire in the middle of the bundle rather than the wire having to be routed through it. The shape also makes it flexible allowing it to bend with the wire.

The Change Provision uses other characteristics. The slits in the spiral tubing allow potting compound to penetrate the interior of the tubing, entrapping it in the voidless mass of potting compound and wire. The slits must be large enough to allow this. The viscosity of the potting compound and injection pressure will dictate the slit size. The diameter of the spiral tubing decreases when pulled, decreasing the surface tension, making it easier to remove than a solid rod.

The Wire Change Provision is created when a short length of spiral tubing is included with (not around) routed wires internal to the Wire Seal. When the interior of the Wire Seal is potted the spiral tubing becomes entrapped along with the wires inside the Wire Seal. The length of spiral tubing should be long enough to allow the ends to be exposed beyond the potting compound. This will allow for the removal of the spiral tubing and assure that the routing pathway is continuous through the Wire Seal.

The spiral tubing can be removed by hand or with the help of a pair of pliers, by grasping an exposed end and pulling. A core of potting compound is removed with the spiral tubing to create a hollow pathway through the Wire Seal. The spiral tubing must be made of a rigid material able to shear the potting compound. New wires can now be routed through the Wire Seal. Once the wires are routed the pathway is injected with potting compound, sealing the wires and filling the pathway. The spiral tubing is not reinserted into Wire Seal it is removed from. If there is excess room with the wires, a smaller diameter spiral tubing could be potted into the Wire Seal along with the newly inserted wires creating another change provision. The spiral tubing is meant to be a fly away part. It will be removed only when needed. Installation of the spiral tubing displaces its volume in sealant making the weight penalty negligible.

Pressure tests were performed using different materials. Five lengths of each material were potted inside BACS45B-4 seal fittings. Materials used were: nylon spiral tubing, Teflon spiral tubing, BMS 13-48 T8C1G14 Tefzel jacketed wire, and extruded silicone rod. All samples were tested at 5, 13, 25, and 50 psi. The 5 and 13 psi numbers are representative of low pressure test and maximum plane pressure. The 25 and 50 psi tests are unrealistic pressures but were intended to precipitate a complete failure or "blowout" of the Wire Change Provisions. No complete failures were observed.

The tests were done using a simple pressure chamber. A flange attached to the chamber held the BACS45B-4 seal fittings. Regulated air pressure was applied to one side of the seal fitting. A liquid leak detection fluid was used to amplify small leaks. Any amount of leakage was considered to be unsatisfactory and was recorded.

The wire produced one leak out of five samples. The nylon spiral tubing samples produced no leaks. The other two materials showed unsatisfactory results. Cross sections of the Teflon samples did not show any voids to provide a reason for their poor performance. Teflon's natural non-stick property allowed propagation of air between the surface of the spiral tubing and the potting compound. The silicone did the same. Some of the silicone samples leaked less as the pressure was increased. The low durometer of the silicone allowed the rod to deform and plug the hole. Air leakage at the lower pressures disqualified this material even though it possesses this self sealing property. The recommended material is nylon spiral tubing. Its stiffness is also a benefit for creep resistance and aids in shearing the potting compound upon removal.

Recent thrust reverser modifications required the creation of a new penetration in the strut to route additional wiring. This may have been unnecessary had a wire change provision been installed in the existing wire seal at that location. The Wire Provision would also allow the customer airlines to add systems to the airplane after delivery. It is also possible that some spare wires could be eliminated. This would allow the addition of wires when needed, instead of having wires pre-installed just in case.

The design of the Wire Change Provision was coordinated with Producibility and 767 Wire Installation. Currently this new method is being included on two PRR's for implementation on 747 and 767 (PRR 82987, PRR B12535). Coordination with Renton is being made by the Everett DER and Project Engineering. The PRR's have been approved, but an implementation date is not yet known.

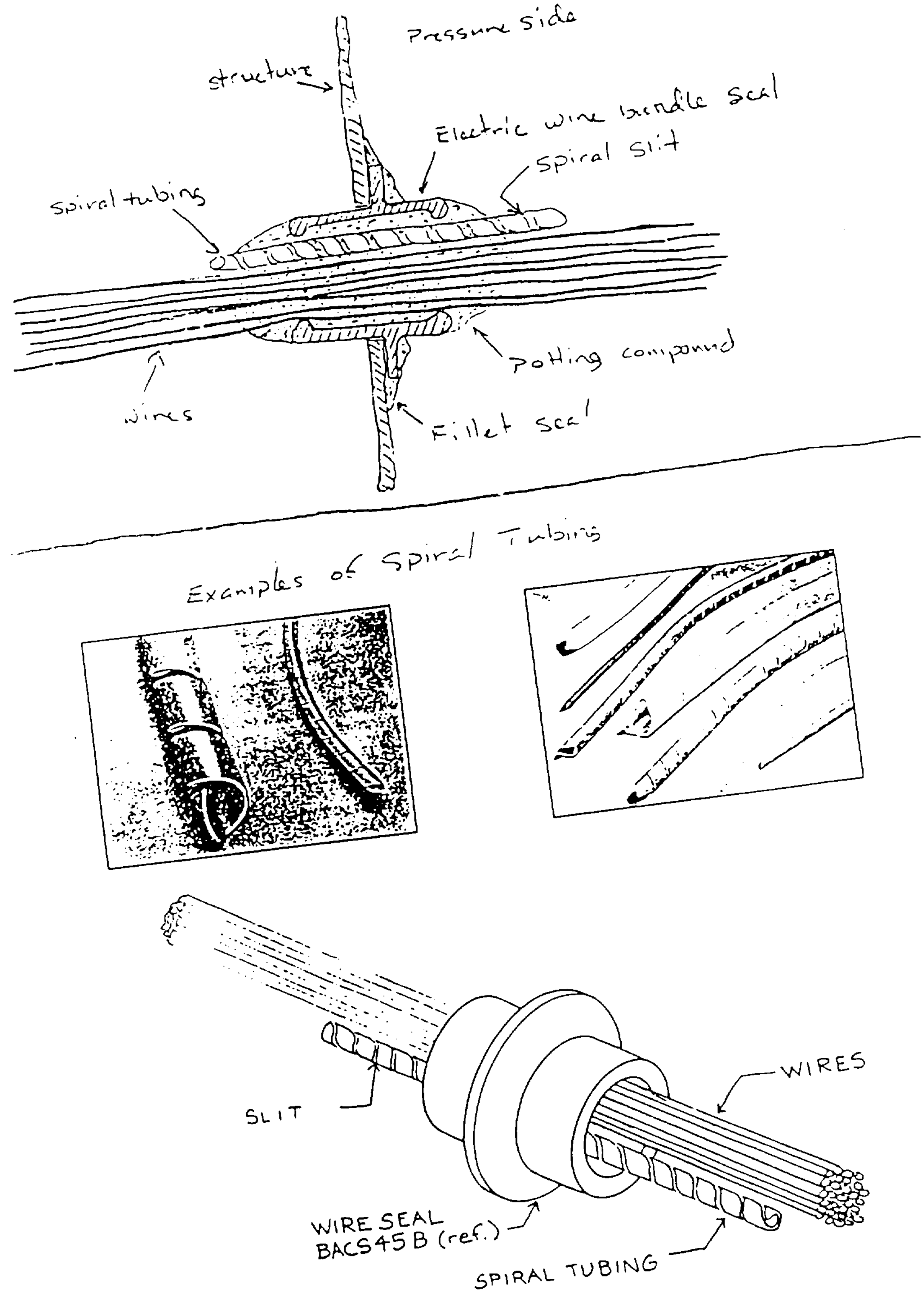

Pressure side
structure
Electric wire bundle seal
Spiral slit
Spiral tubing
Potting compound
wires
Fillet seal
Examples of Spiral Tubing
WIRES
SLIT
WIRE SEAL
BACS45B (ref.)
SPIRAL TUBING

Fig. 1

THE **BOEING** COMPANY

COMMERCIAL AIRPLANE DIVISION

RENTON, WASHINGTON

DOCUMENT NO. D6-40359

TITLE: IMPACT OF ELECTRICAL OVERLOADS ON WIRE AND KLIXON D6760 SERIES CIRCUIT BREAKERS USED ON 707, 727 and 737 AIRPLANES

MODEL 707, 727, 737

ISSUE NO. ______ TO: ______ (DATE)

PREPARED BY A.C.Blickfeldt 1/31/72

SUPERVISED BY A. M. Taylor 1/31/72

APPROVED BY H. L. Ernst 2/1/72

APPROVED BY D. R. Clifford 2/4/72

(DATE)

REV SYM

LIST OF ACTIVE PAGES

SECTION	PAGE NUMBER	REV SYM	ADDED PAGES						SECTION	PAGE NUMBER	REV SYM	ADDED PAGES					
			PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM				PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM
	1																
	2																
	3																
	4																
	5																
	6																
	7																
	8																
	9																
	10																
	11																
	12																
	13																
	14																
	15																
	16																
	17																
	18																
	19																
	20																
	21																
	22																

AD 1546B

REV SYM

REVISIONS			
REV SYM	DESCRIPTION	DATE	APPROVAL

D 1546 C

TABLE OF CONTENTS

TABLE OF FIGURES

ABSTRACT

Discusses the impact of electrical overloads on wire and circuit breaker combinations used on the model 707, 727 and 737 airplanes. Shows that a combination of an overload and an out-of-calibration (trip time vs. overload) circuit breaker can result in damage to the bimetal of the circuit breaker before damage occurs to the wire.

Concludes that a realistic trip time versus overload calibration characteristic for in-service circuit breakers can follow the 600° bimetal temperature vs. time vs. overload curve.

The study and the tests performed to derive the data used in the study were undertaken as part of an FAA program to determine the impact of circuit breaker anomolies on the life of wire bundles on the 707, 727, 737 airplanes.

SUMMARY

A study has been undertaken to establish:

1. The necessity and validity of on-board testing of [redacted] D6760 (BACC18L) circuit breakers on Boeing 707, 727 or 737 airplanes.

2. A realistic trip time versus overload calibration acceptance criteria for in-service circuit breakers.

3. The applied overload level(s) to use for on-board testing of circuit breakers.

The study uses wire protection curve data derived as a result of a companion program discussed in Boeing Document D6-40254 "Derivation of Wire Protection Curves and Comparison with Trip Time Versus Overload Characteristics of the BACC18L Circuit Breaker". In addition, bimetal temperature versus overload versus time curves [redacted] and trip time versus overload data supplied by various airlines as a result of sample testing of approximately 1200 in-service circuit breakers are used. These data are compared and as a result it is concluded that:

1. A realistic trip time versus overload calibration acceptance criteria should be, a curve which follows the 600°F bimetal temperature versus time/overload curve.

2. A combination of an overload and an out-of-calibration circuit breaker can result in damage to the circuit breaker bimetal. This bimetal damage will occur before damage to the wire.

3. On-board testing indicated that only 72.1% of all breakers tested had trip time versus overload characteristics within the procurement specification for the D6760 circuit breaker.

4. Subsequent laboratory testing showed that 34% of the breakers which had "failed" the on-board testing actually met the trip time versus overload requirements of the specification.

5. Based on (3) and (4), 81.3% of all circuit breakers tested had trip time versus overload characteristics within the tolerance limits of the D6760 procurement specification.

6. In case of an electrical fault in the wiring of the equipment 96.4% of all breakers tested would have tripped in time to protect the aircraft wiring and would have not compromised the integrity of the circuit breaker bimetal.

7. 2.6% of all breakers tested would have protected the wire but the circuit breaker bimetal may have been compromised.

8. .82% of all breakers tested at 400% overload in the laboratory failed to trip in time to protect the wire. All such breakers were 7.5 amp rated. There is evidence that some or all of these 7.5 amp circuit breakers may have been damaged during on-board testing.

9. On the basis of the approximately 1200 circuit breakers tested with less than 1% failing to trip, a circuit breaker on-board testing program is considered undesirable for the following reasons:

   (a) Only one incident has been reported with the D6760 series circuit breakers in over 13 years of operation with over 45,000 of this type circuit breaker involved.

   (b) Presently available portable test equipment and test methods used for on-board testing lead to an excessively high rate of unjustified removal of D6760 circuit breakers and may damage otherwise good circuit breakers, unless techniques requiring extremely high skill level are used.

(c) Further damage or hazards may be introduced and remain initially undetected by unnecessarily disturbing circuit breaker panels and wire bundles.

(d) The cost of replacing only the 7 1/2 amp circuit breakers would be approximately $1,600,000 world-wide.

(e) The recurring cost of testing all D6760 circuit breakers would be approximately $225,000 based on an optimistic labor rate of $10.00/manhour.

I. INTRODUCTION

Early in April 1971, [redacted] reported a failure of a Texas Instruments D6760 (BACC18L) circuit breaker. As a result of this failure and subsequent investigations, there has been consideration given to the need for electrically checking all D6760 circuit breakers which are in service. Before such a program could be undertaken, however, it is necessary to establish the following testing criteria:

1. Levels of overload current which could be used for on-board testing.

2. Overload current versus trip time calibration curves for in-service D6760 circuit breakers.

Since the circuit breakers under consideration are breakers which have been in service, they could not reasonably be expected to meet the overload current versus trip time calibration curves of a new breaker. To establish new trip limits for in-service breakers, one has to consider not only the time involved for any given fault current to damage wire but also the effect the fault current will have on the bimetal of the circuit breaker. Each circuit breaker bimetal has a critical temperature which should not be exceeded. Should this temperature be exceeded the bimetal begins to lose its integrity and degradation of the circuit breaker results. Therefore, to establish new trip limits for in-service breakers it is necessary to derive the bimetal temperature curves of the D6760 series circuit breaker. An analysis of these curves and how they relate to the protection curves of the wire to which the circuit breakers are required to protect must then be made.

[redacted]

and schedule was initiated to determine if a safety problem existed with the Texas Instrument Klixon D6760 circuit breaker. As part of this program, Boeing was to "continue development of an IBM program for determining circuit breaker trip times for different wire types". Texas Instruments was to establish bimetal temperature curves for all ampere ratings of the D6760 series circuit breaker. Airline operators (TWA, PAA, UAL, EAL and AAL) were to test all the Texas Instrument D6760 series circuit breakers on approximately 50 aircraft. Those breakers that took longer than 10 seconds to trip while carrying a 400% overload current were to be removed from the airplane and rechecked in the shop. All trip times were to be recorded and forwarded to Mr. Ken Craycraft of TWA who would act as program coordinator.

II TEST PROGRAM RESULTS

Boeing Document D6-40254 "Derivation of Wire Protection Curves and Comparison with Trip Time versus Overload Characteristics of the BACC18L Circuit Breaker" was released by Boeing on 17 November 1971. The release of this document completed Boeing's task on the derivation of the wire protection curves. Texas Instruments also completed their testing of the D6760 series circuit breaker to establish the bimetal temperature curves for these parts. The curves were forwarded to Boeing and have been combined with the wire protection curves extracted from Boeing Document D6-40254. The composite curves derived from the two sets of curves are contained in Figures 1-6 of this Report.

Review of the composite curves of bimetal temperature versus wire protection shows that for all levels of overload current, the critical circuit breaker bimetal temperature will be reached before damage occurs to the wire. Therefore, in determining the trip time versus overload characteristics for in-service D6760 circuit breakers, the maximum trip time of the breaker will need to be limited to its critical bimetal temperature. Texas Instruments reports that tests which have been conducted on the D6760 series curcuit breakers show that the integrity of the circuit breaker begins to degrade on those breakers whose bimetal temperatures have reached 700°F. Texas Instruments has therefore stipulated that the maximum temperature which the circuit breaker bimetal can obtain without adversely affecting the calibration of the circuit breaker is 600°F. This temperature corresponds to the heat-treat temperature of the bimetal.

The amount of electrical overload to be applied as a test overload can also only be chosen to ensure that the bimetal will not be compromised. As a result of the overlap of the bimetal curves with the trip time versus overload curves for the 25 and 50 amp, the test overload should be as follows:

Breakers up to and including 20 amp - 400% of rated current
Breakers 25 amp and above - 200% of rated current

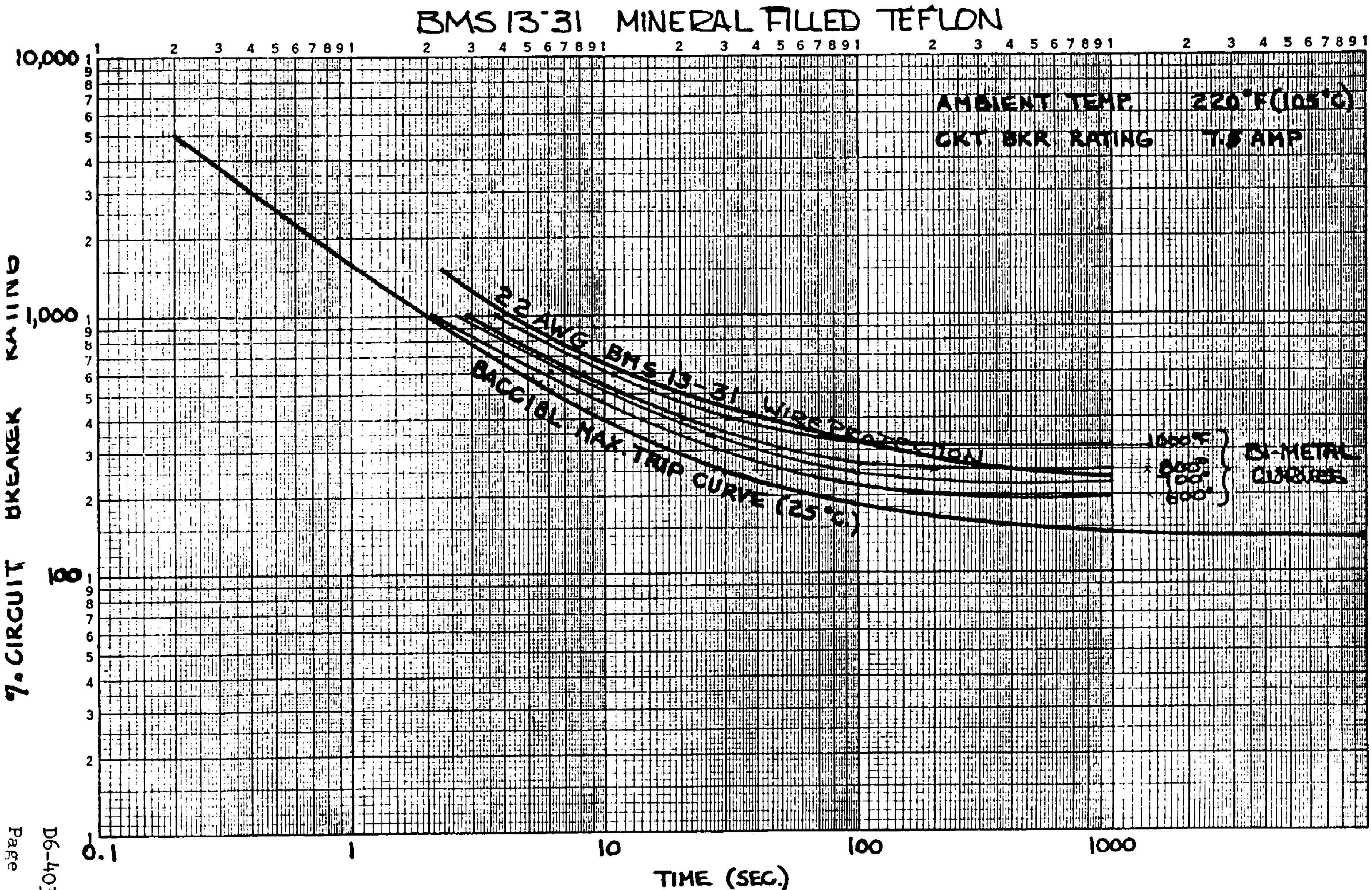
In addition to the above, the airlines have completed testing of approximately 1200 D6760 circuit breakers. Those breakers which have been tested on the airplanes and which took longer than 10 seconds to trip when carrying a 400% overload current were rechecked in the shop.

Figure 7 shows the number of circuit breakers of each rating tested by the various airlines and Figures 8 and 9 show the results of the tests with respect to the total number of circuit breakers tested. Initial results of the on-board testing showed that 72% of all breakers tested fell within the procurement specification. However, laboratory testing of the 28% which failed showed that a further 9% of all breakers tested actually fell within the procurement specification, making a total of 81%. In addition, using the 600° bimetal temperature as the acceptance criterion, a further 15% could be classified as passing the test, raising the overall total of circuit breakers which would protect the wire and not compromise the circuit breaker bimetal integrity to 96.4%.

It is possible that the circuit breakers which exhibited trip times in excess of that required to protect the wire (0.82% of the total) during laboratory test, were damaged during the initial on-board testing. This postulate is supported by the fact that during on-board testing, three of the circuit breakers from one airplane were exposed to the overloads for excessive time periods.

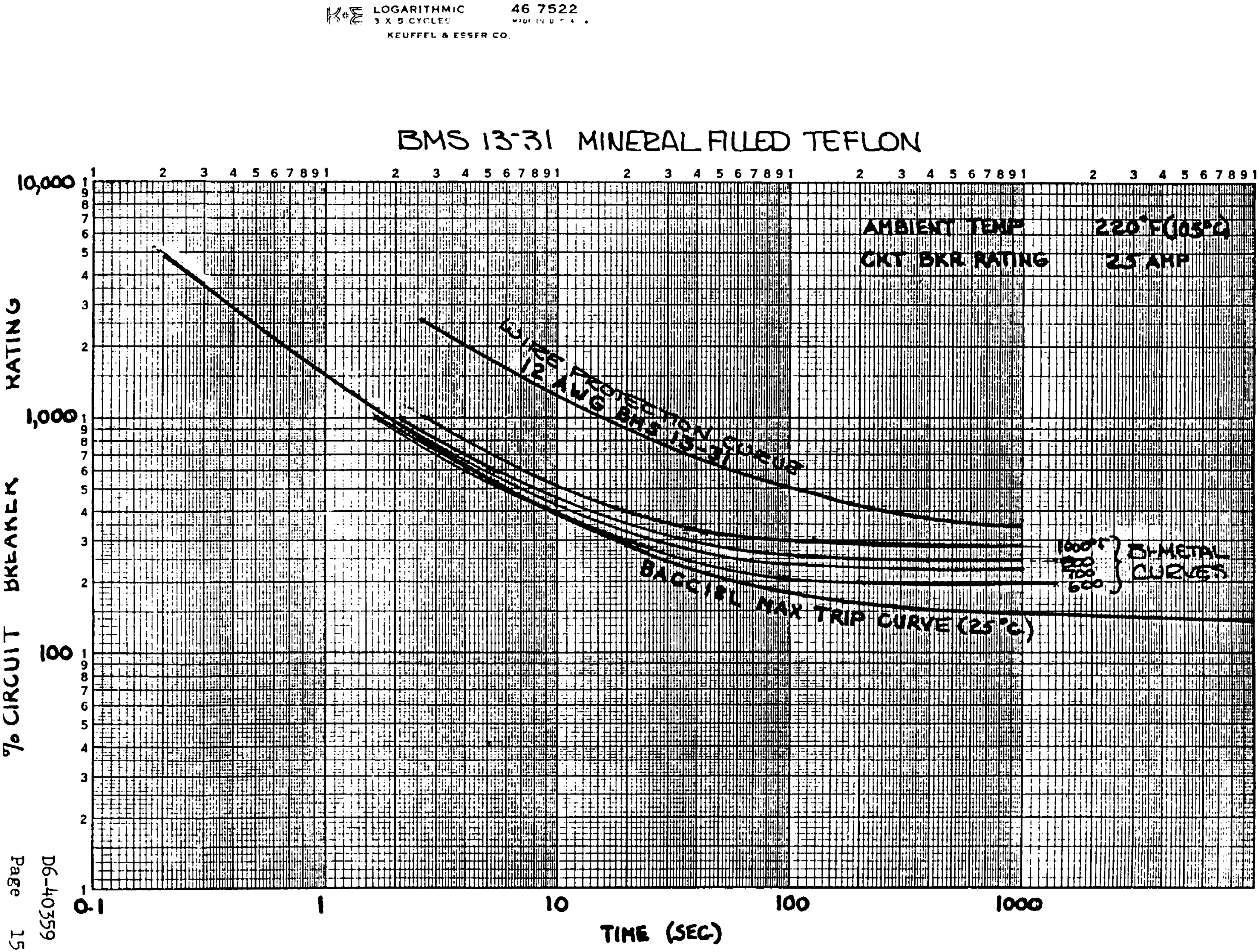
The rejection of 9% of the breakers which were actually within tolerance and the possible damaging of the 7.5 amp breakers can be attributed to the test equipment and the test methods employed for on-board testing of circuit breakers. The results obtained from the test set and test probes are entirely dependent on operator performance and skill.

Failure of the operator to adhere very closely to test requirements can result in further degradation of marginally acceptable circuit breakers. Such breakers remaining in the aircraft may not be able to trip if an equipment or wiring fault subsequently occurs.



COMPOSITE WIRE AND CIRCUIT BREAKER PROTECTION LIMITS

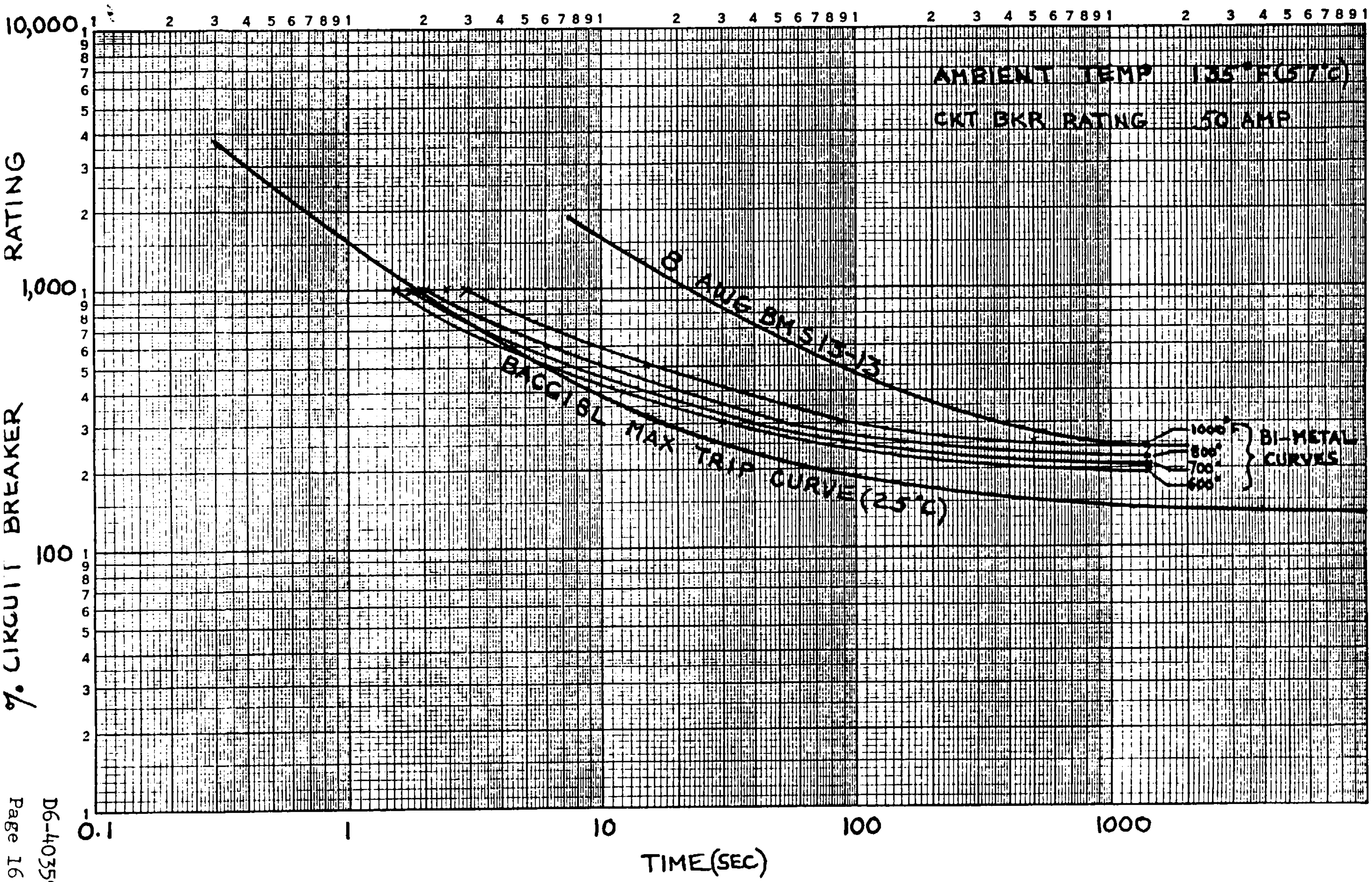
FIGURE 1



COMPOSITE WIRE AND CIRCUIT BREAKER PROTECTION LIMITS

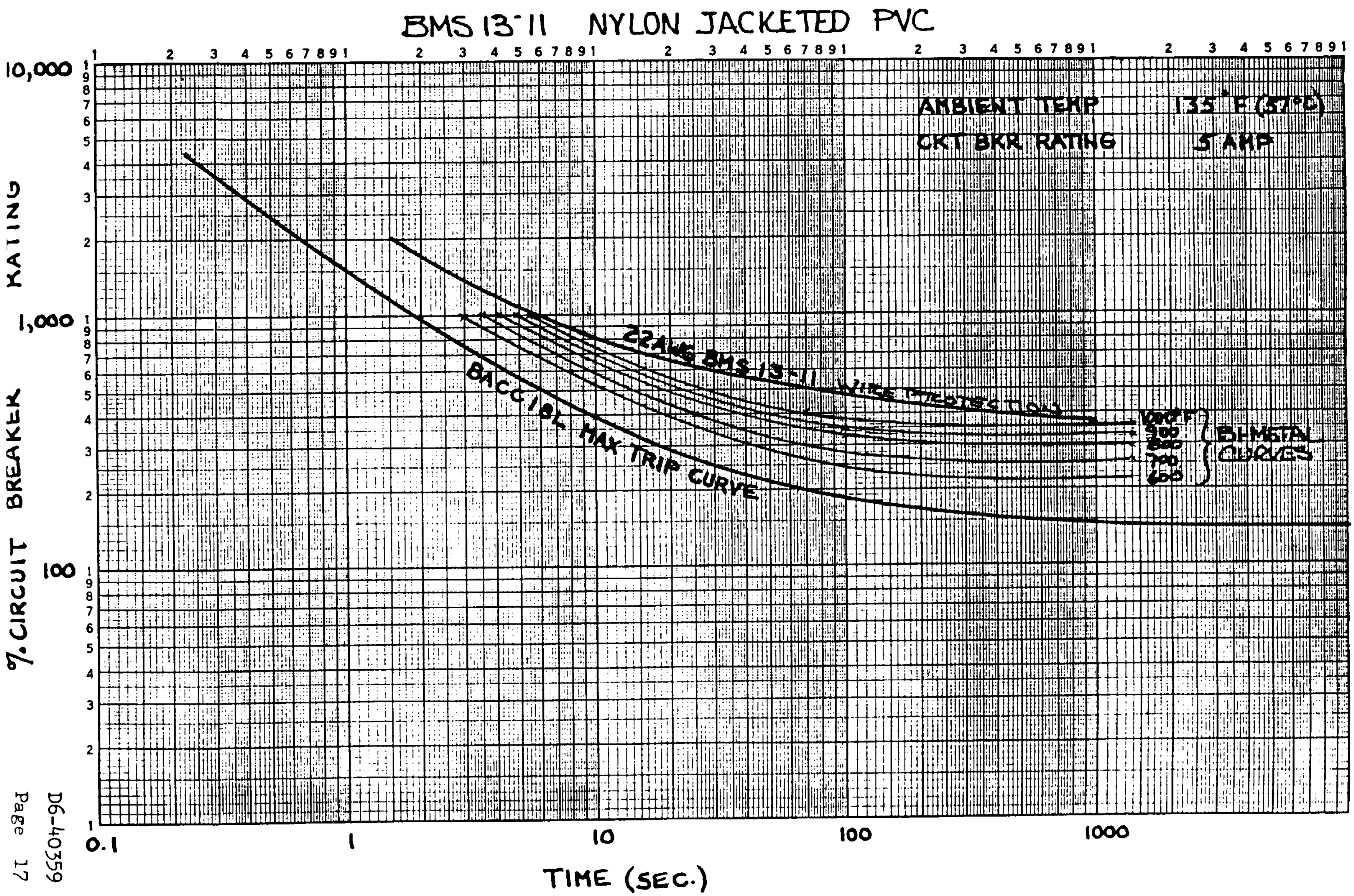
FIGURE 2

BMS 13-13 NYLON JACKETED PVC



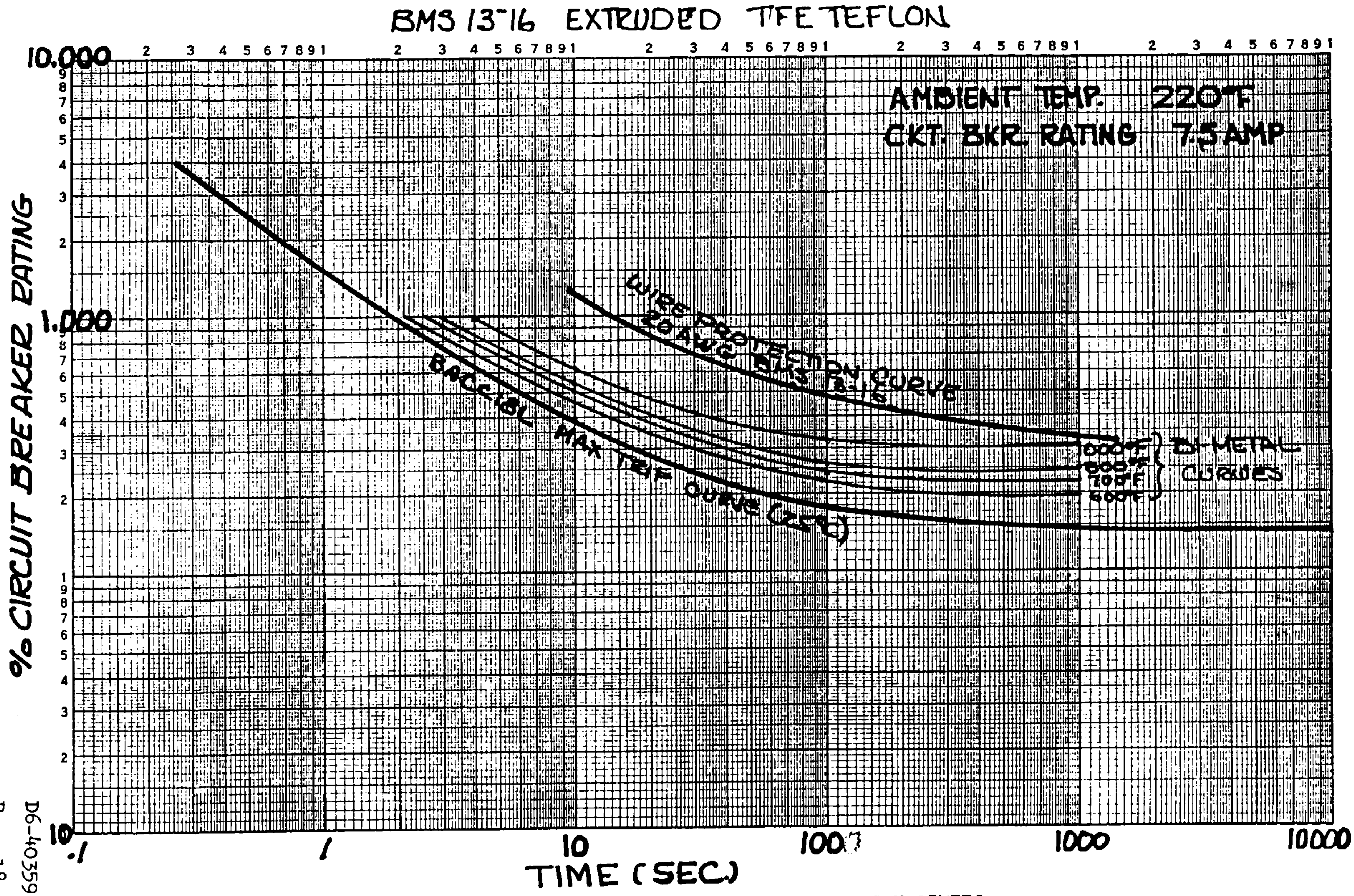
COMPOSITE WIRE AND CIRCUIT BREAKER PROTECTION LIMITS

FIGURE 3



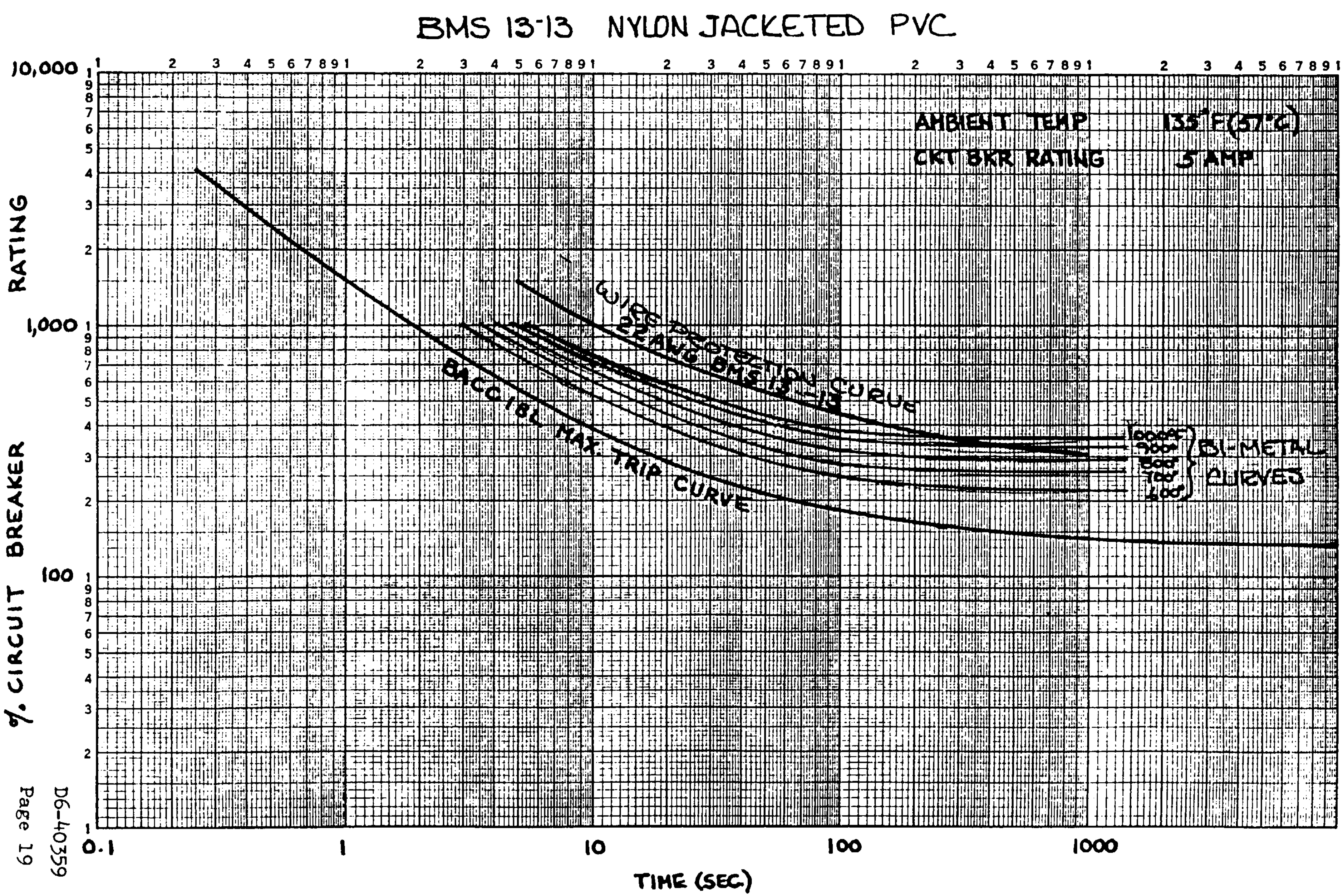
COMPOSITE WIRE AND CIRCUIT BREAKER PROTECTION LIMITS

FIGURE 4



COMPOSITE WIRE AND CIRCUIT BREAKER PROTECTION LIMITS

FIGURE 5



COMPOSITE WIRE AND CIRCUIT BREAKER PROTECTION LIMITS

FIGURE 6

AD 1546D

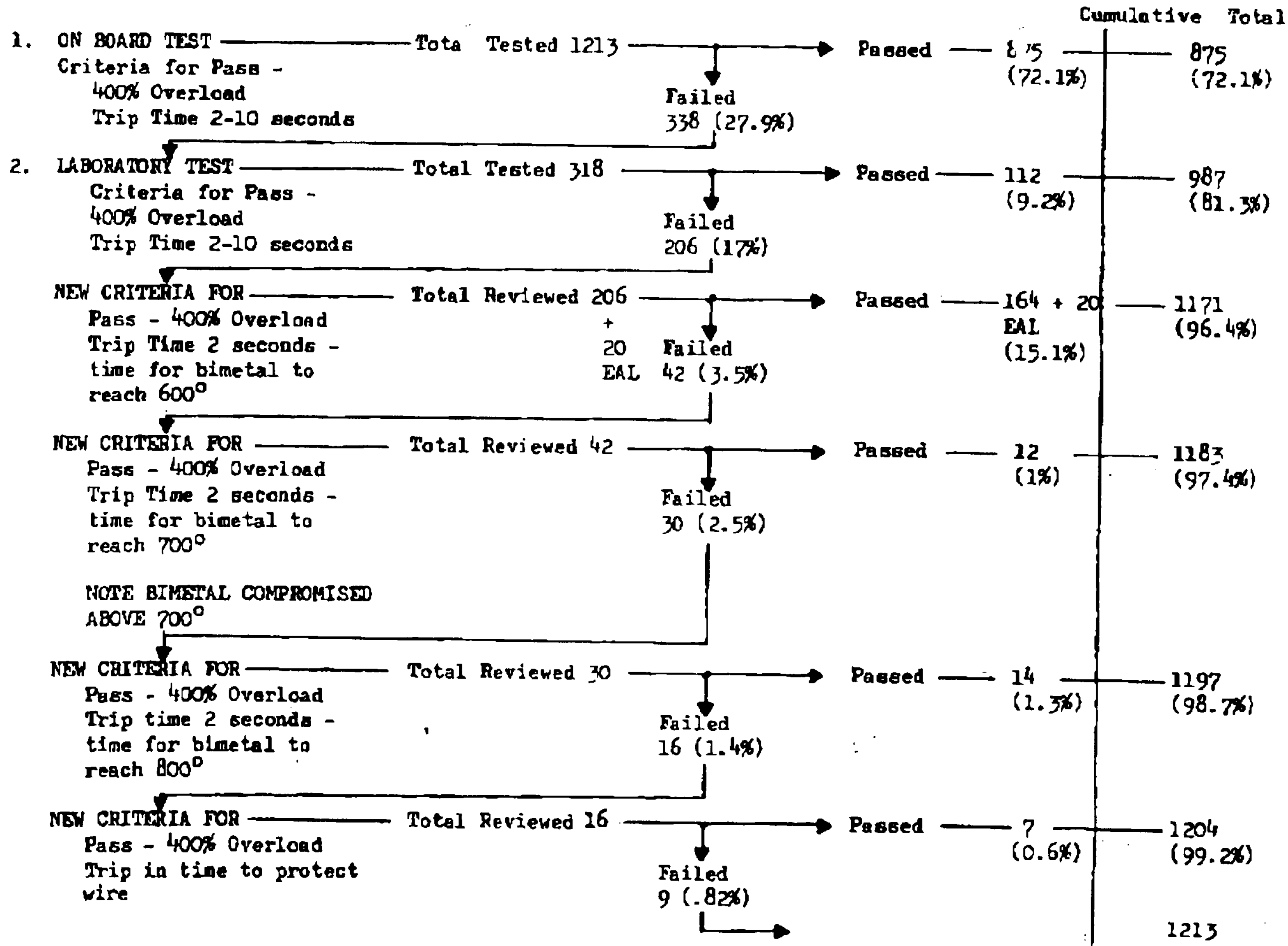
D6760 CIRCUIT BREAKER TEST PROGRAM

Airline	5 Amp	7.5 Amp	10 Amp	15 Amp	20 Amp	25 Amp	50 Amp	TOTAL
American	44	70	20	18	0	10	0	162
Eastern	15	26	8	4	0	4	0	57
Pan American	140	101	8	18	16	26	12	321
TWA	207	188	44	44	7	37	52	579
United	38	33	11	5	0	7	0	94
TOTAL	444	418	91	89	23	84	64	1213

NUMBER OF CIRCUIT BREAKERS TESTED

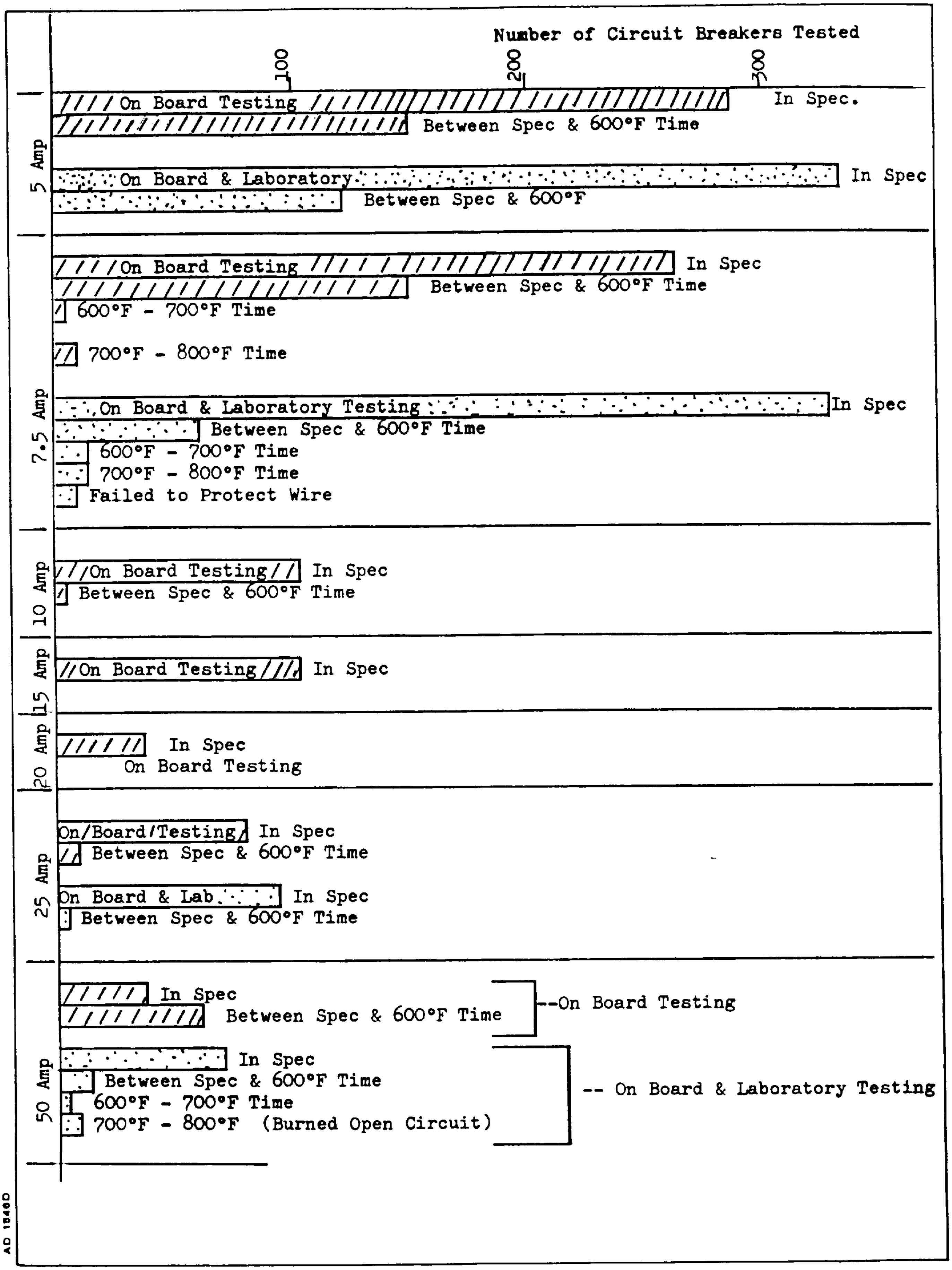
FIGURE 7

AD 1946D



D6760 CIRCUIT BREAKER TEST ANALYSIS

FIGURE 8



CIRCUIT BREAKER TRIP TIME CATEGORIES

FIGURE 9

Douglas Paper No. 1661

ACHIEVING ELECTROMAGNETIC COMPATIBILITY BY CONTROL OF THE WIRING INSTALLATION

By
G. J. King
Communications/Electrical Section
Engineering Department

Presented to
The Ninth Tri-Service Conference on Electromagnetic Compatibility
Chicago, Illinois
October 15-17, 1963

DOUGLAS AIRCRAFT COMPANY, INC. ☐ AIRCRAFT DIVISION ☐ LONG BEACH, CALIFORNIA

ACHIEVING ELECTROMAGNETIC COMPATIBILITY BY CONTROL OF THE WIRING INSTALLATION

G. J. King
AIRCRAFT DIVISION
Douglas Aircraft Company, Inc.
Long Beach, California

Abstract - Control of the wire routing and grouping of the many equipments and systems that are installed in modern aircraft is necessary to assure the electromagnetic compatibility of the ultimate system. Controlled classification of the wiring and the bundles reduces the interaction of equipments caused by the inadvertent coupling resulting from random installation. Wire routing control is mandatory to prevent the interaction of individual systems and may also be required with wiring associated with systems that are susceptible to self-interference. The minimum design concept for adequate wiring isolation is defined in this paper. Definitive grounding of systems and the attendant grounding methods, including the bonding of all equipment installations, is a significant part of the overall compatibility of the electrical/electronic environment. Emphasis is directed towards this area.

I. INTRODUCTION

For many years aircraft have been increasingly burdened with electrical and electronic equipment. These equipments have been evolved from the simple dc systems, of not so many years ago, to the modern integrated complexes operating entirely on an ac power source. As a result, the modern environment is one that is dynamic in nature where the equipments are subjected to an ambient electromagnetic field of complex shape and frequency. It is not strange that some of this ambient energy will appear on the wiring.

Much has been done to reduce interference at the component, equipment and system levels. Little information is available concerning the installation of equipment inter-connecting wiring. Sporadic interest has occurred in wiring compatibility where the various schemes vary from the custom installation (the reference is to "build-it" and "fix-it" methods) to the over-designed brute-force technique. The airframe manufacturer is confronted with the installation problem in which the interconnecting wire coupling effects upon any of the equipments can only be estimated. Few equipment manufacturers are prepared to indicate the necessary installation precautions required for compatibility. The precautions would include requirements for special wiring (other than single conductor), threshold susceptibility values over a specified frequency range, and the characteristics of the conducted and radiated energy over a broad frequency range. The fact remains that special installation requirements of wiring is necessary because most equipments radiate, and almost all equipments are susceptible somewhere in the electromagnetic spectrum.

The method of wiring control to be described classifies all of the interconnecting wiring in accordance with the energy carried by each wire and the probability of that wire becoming either a "transmitter" or a "receiver." A high degree of compatibility is achieved by physical separation of the categories of bundles and by grouping only the wires of similar characteristics and voltage levels.

For example: a wire carrying 28 volts to a lamp would not be susceptible to a wire carrying 115 volts to a motor. However, if the 28 volt wire is connected to a servo amplifier then a degree of susceptibility might exist. Therefore, the first problem is the inductive susceptibility of a wire. The induced voltage is dependent upon the separation distance of the wires and the coupling area or parallel distance. There are many other factors, but if the spacing between the wire is infinite and the parallel length is zero a coupling problem will not exist.

The other factors are modifiers useful to the design engineer to determine the minimum required separation versus the maximum parallel distance before the threshold susceptibility is exceeded.

The other problem of wire coupling is that experienced from electro-static fields (voltage) usually associated with the radio frequency spectrum. Physical isolation will reduce some of the voltage coupling but not as effectively as for magnetic field coupling. Generally, electrostatic coupling is associated with high impedance circuits. Many low impedance circuits can become carriers of electrostatic energy that is conducted directly to a susceptible circuit. Such circuitry is adversely affected by external coupling. Frequently, the reduction of external coupling does not alleviate the problem. Many of these were found to be caused by coupling between the internal wiring. The usual precautions are employed for electrostatic isolation such as shielded wiring and, equally important, the proper grounding of the shield. The grouping of susceptible wires away from "transmitter" wiring frequently reduces the requirements for shielding.

The wire classification methods, described in this paper, have evolved over a number of years. However, it was only a few years ago that the environment reached the degree of complexity where the extensive use of classified wiring was required.

An analysis was conducted on one model of aircraft to determine what could be done to control the interference caused by the interconnecting wiring. All of the empirical and theoretical data colected over the years was evaluated and a logical model of the proposed method was developed. The aircraft was completely remodeled with the new system. After testing the aircraft, it was found necessary to change one wire from a single braid coaxial to a double braid. Filters that had been installed on the original aircraft to reduce interference were found to be unnecessary after implementation of the classification technique. The aircraft was a complex military type that had a history of multiple interferences. Once the wire classification had been implemented, several of the more vexing problems were revealed as being self-induced.

A second model airplane had a similar history of severe and subtle interferences that were subdued by the usual costly rework and loss of time. The entire system was carefully categorized by detailed evaluation of each equipment. After test, one fix was required - the installation of a diode to quiet down the inductive kick of a relay. The subtle interferences were resolved to be self-induced within specific systems.

The latter aircraft has been in current production for one year without any interference problems. Wire classification will make the product like "peas in a pod" as compared to others without wire classification which may exhibit wide variance of interference from unit to unit.

II. DESIGN FOR INTERWIRING COMPATIBILITY

Design Concept - The minimum design concept for adequate wiring isolation is based upon classification according to the energy and power that the wire carries. A second consideration is that of the impedance of the wire that may carry spurious energy. This will indicate whether the interference may be induced by either magnetic or electrostatic fields or both. The third consideration is the division according to the susceptibility of a given wire to either inductive or electrostatic coupling. For example: a wire to the input of an amplifier is more susceptible to spurious energy than a wire connected to a motor.

Category I - Power Wiring - Category I is comprised of the following examples:

1. Three Phase distribution wiring (115/200 volts ac)
2. Single phase distribution wiring (115 volts ac)
3. Other wiring carrying 115 volts ac

There are two sources of coupled energy that can cause interference into numerous systems: the magnetic field and the electrostatic field. Of the two, the magnetic field is the most difficult to handle since shielding is ineffective. The practical method for magnetic field isolation is physical separation where the current-carrying wires are isolated from other wiring that is susceptible to magnetic coupling. Power systems are insensitive to coupled magnetic fields from other power lines. Motors, relays, most power transformers, actuators, and other power devices are inherently insensitive to induced voltages, induced phase shift, transients, etc. Therefore, it is possible to group all distribution power lines into one category. Primary, or feeder wiring, is not grouped with distribution wiring to minimize damage in the case of fault currents.

All of the noted wires may be bundled into groups dependent upon the installed wiring configuration.

Category II - Secondary Power - Secondary power wiring is grouped into Category II. Secondary power wiring is generally classed as wiring carrying watts of power at voltages less than 115 volts (ac/dc). Secondary power wiring can be troublesome in restricted areas such as cockpits, radio racks, conduit runs, and other areas requiring dense wiring runs. Since the magnetic field is directly related to the current, and secondary power lines are found in sensitive equipment wire bundles, it has been necessary to create this category. Secondary power lines are usually associated with interior lighting circuits, synchro circuits, small motors, actuator circuits, etc. Therefore, Category II is comprised of the following examples:

1. Low-voltage power circuits
2. Low-voltage lighting circuits
3. Synchro and servo circuits not in Category IV
4. Includes wiring from an equipment power supply to other equipments within the same system for dc voltages up to 5000 volts.

Category III - Control Wiring - Reference was made in Category I on the coupling effects of the magnetic and electrostatic fields. In Category III, the wiring is grouped according to the transient fields that exhibit both characteristics. Line transients occasioned by operating characteristics of the equipment can produce transient magnetic fields associated with a fast rise time of the current. High voltage transients, caused by the familiar "inductive kick-back" can produce broadband RF voltages. Therefore, Category III is similar to Category II except that it also carries transient energy. Category III is comprised of the following examples:

1. All wiring that involves the operation of relays (solenoid), stepper switches, automatic homing switches, intermittent pulsing energy, etc.
2. Any other wire that can produce pulse energy caused by operating characteristics of the system or equipment such as wiring to flashing incandescent or fluorescent exterior lights.

Note: Category III can be converted to a Category II by reducing or eliminating transient energy. Category III could be eliminated entirely by use of transient suppressors at each relay or inductive device. Other wiring could be placed in Category II by determining the frequency of occurrence of transient energy that could affect other equipmentl If the transient does not affect a critical circuit or an equipment listed under safety of flight, then it may be changed to Category II. Eventually, by consideration of these elements in the design stage, the need for this category may not be required.

Category IV - Sensitive Wiring - Sensitive wiring is somewhat of a misnomer since sensitiveness is directly related to susceptibility in this case. There are many wires within a system or complex that would appear under this category. Most of the wiring in this category is susceptible to electrostatic types of energy because of high impedance circuits. Low impedance circuits are susceptible to magnetic fields. However, a low impedance circuit can act as a carrier of electrostatic energy that will conduct spurious energy directly into a sensitive circuit such as a microphone input to an amplifier. Dual protection is usually required for these circuits.

Category IV is comprised of the following examples:

1. All microphone circuits. These invariably require twisted/shielded leads to reduce coupled magnetic fields and prevent the conduction of electrostatic RF fields.
2. All audio output and video output circuits.
3. All sensitivity control circuits and volume/gain controls.
4. All cathode and grid circuits.
5. Signal wiring requiring a "shield out" shield.
6. All metering and bridge input circuits.
7. All circuits associated with signal inputs to a computer.
8. All signal circuits associated with a demodulator.

A high percentage of the above wires are required by the designer to be shielded. To avoid ground circuit problems it is necessary to emphasize that all shielded wire shall be insulated with an external non-conductive jacket.

Category V - Susceptible Wiring - Experience has shown that certain wiring is extremely susceptible to most all levels of electrical energy. Such wiring shall be routed free of all other wiring and must not be grouped into a bundle unless associated with a single system. Antenna cables may be grouped provided that the shielding integrity of the entire system is good. High power antenna cables and pulse cables shall be run separately.

Category V is comprised of the following examples:

1. All radio antenna coaxial cables.
2. All wiring to electro-explosive devices.
3. Fire Warning shielded wires.
4. Fuel Quantity coaxial cables.
5. Liquid Oxygen indicator coaxial cables.
6. Other wiring pertaining to safety of flight items such as anti-skid systems, spoiler actuator circuits, etc.

Category VI - System Wiring - Category VI is a compromise designed for convenience of installation. To minimize extensive separation of system wiring bundles and to reduce the resulting wiring complexity, certain system bundles may contain wiring that otherwise would appear in Categories II, III, and IV. The category does not contain wiring that is classed as Category I or V. System groups may be installed only after careful analysis has indicated that the system is free of self-induced interference. An example would be the Automatic Flight Control System (AFCS) that is inherently susceptible. The AFCS usually has many interconnecting wires between multiple black boxes grouped in close proximity. These runs, and the long runs from the immediate area to the control center, are classed as Category VI. There may be more than one system within the complex that has been classified as a Category VI. It is suggested that each system bundle be identified and routed separately. It is not recommended that bundles of Category VI be grouped together.

Design Limits for Separation - Minimum coupling between wires of the various categories can only be controlled by specifying the minimum distances to be maintained throughout the cable run. Table I gives the minimum design data for physical isolation. Modifications to the rather rigid requirements are described in subsequent paragraphs. It must be emphasized that the design parameters noted in (Table I) are to be used as the minimum, and that the compromises suggested be used only where necessary. Compromises are the responsibility of the Electromagnetic Compatibility engineer and are useful only when the threshold susceptibility of a given wire is known.

Classifying the categories as "transmitters" and "receivers" will help in understanding why the groups are spaced and will assist in the selection of compromises where required. It will be noticed that Categories I, II, and III may be classed as transmitters and that Categories IV, and V as good broadband receivers. Category VI is in the position of proving that it will not interfere with itself since it contains potential transmitters and receivers. Another way of classification is to consider that Categories I and II carry relatively intense magnetic fields, Category III carries magnetic fields of similar intensity and transient RF fields of relatively high energy with a broadband distribution. Categories IV and V are then susceptible to these fields. The third consideration is that the groups carry similar types of energy: Category I, power line voltages (115/200 volts ac); Categories II and III carry low voltage power (28 volts ac-dc), and Categories IV and V carry signal voltages and frequencies. The method of classifying is based upon the minimum voltage gradients between wires within any given category.

Installation Consideration - The possibility of maintaining the minimum separation distance for all categories throughout the aircraft is remote. Structural areas and design prohibit such luxuries. Requirements for the three common areas of minimum isolation are noted in the following:

Lightening Holes - Wire bundles shall maintain the minimum spacing until they immediately enter the lightening hole and shall break away at the first opportunity. Lightening hole parallel runs are added to compute the overall parallel run. Normally, there is no restriction on the category of bundles. It is preferred, however, to route Categories IV, V, and VI through adjacent holes wherever possible. The category to be routed through adjacent holes depends upon the physical size of the bundle, see Figure 1.

Common Plugs - Common equipment plugs and bulkhead plugs are treated the same as for lightening holes. Common plug wiring should break into categories as soon as possible, see Figures 2 and 3.

Conduit - Grouping of bundles in conduit will be similar to the grouping used for marriage clamping. Non-metallic conduit is preferred. Metallic conduit may be used to increase the isolation when conduits are closely nested and to take advantage of the shielding effects. Aluminum conduit should be used for electrostatic shielding and special purpose steels for magnetic "shielding." Unrestricted use of metallic conduit should be discouraged since the reflected inner fields could increase coupling between wires within the conduit, see Figure 4.

Compromises - Practical considerations for the installation of bundles require some modification of the basic rules. It must be emphasized that modification of the basic rules must be held to an absolute minimum. There will be areas where the minimum spacing of the bundles cannot always be maintained. Other areas may require that the wires originating at an equipment plug must be bundled together for a specified distance. The installation designer must control the wiring to ensure that the compromised areas do not result in an unbalance towards the interference end of the scales. What is lost on one end of the scales must be regained on the other.

Category VI - Category VI is a compromise as noted under the categories.

Marriage Clamping - The minimum design spacing may be relaxed in close areas such as cockpits, control centers, and other dense areas. This is based upon achieving separation in the rest of the aircraft that results in coupling far below threshold sensitivity. The following categories may be marriage clamped:

Category

1. II with III
2. IV with V
3. VI with either II, III or IV

It is recommended that Category I not be marriage clamped with any other category or group. Maximum distance should be maintained between Category I and Categories IV and V.

Special Wiring - Special wiring includes all types of wiring configurations other than the single-conductor-insulated wire. Special wires are always used for the control of interference and, in the wire categorization plan, they are used for isolation purposes where the minimum physical isolation distances must be reduced for practical reasons. Therefore, the special wiring would replace the single conductor wire under certain installation conditions.

There are two types of special wire: twisted wires (two or more) and shielded conductors (one or more). Twisted wires are used for control of radiated or induced magnetic fields, and the shielded wire is used for the containment or exclusion of electrostatic fields. Combinations of both are used where the circuitry may be susceptible to magnetic and electrostatic fields. Configurations recommended for use include the following: twisted pairs, shielded twisted pairs, shielded single conductor, and the various configurations of coaxial cable.

Special wiring is used only when and where necessary if not called out in the system design. Use of special wiring is an admission that the system is susceptible or radiates over some specified portion of the electromagnetic spectrum (just like a gasket is an admission that a perfect mechanical joint cannot be obtained). Requirements for extensive use of special wiring may be reduced by considering the environmental effects preliminary to the design of the electrical/electronics portion of the system. Wire categorization does not require, per se, additional requirements for the use of special wire. The necessity for the use of special wire can be reduced in many cases. Unrestricted use of shielded wire can produce more problems than it cures, and the unrestricted use of twisted wiring is frowned upon because of the increased cross sectional area. Special wiring installed for the prevention of coupling can be eliminated for the most part. Under the categorization rules, special wiring is used only in areas where the design separation distances cannot be achieved.

Special Wiring and Pigtails - Electronic and electrical equipment racks are frequently so highly congested that wire separation to the design limits is an impossibility. The problem can be resolved by considering all of the wires emanating from a single equipment plug as a pigtail to where the wires can break out into categories at a distribution center or a terminal board. Pigtail length can vary from two to ten feet. Lengths in excess of ten feet should be considered for classification into categories. Since space isolation is not possible in a pigtail, the only recourse is to specify the use of special wiring, refer to Figure 5. Power wiring should be twisted with the ground return for wires grouped under Categories I and II. Single conductor signal wiring should be shielded (Categories IV and V). Two conductor signal wirings (Categories IV and V), such as microphone circuits, should be twisted and shielded. Category II, other than power wiring, and Category III do not require special wiring. In general, the requirement for special wiring to achieve isolation in a pigtail grouping does not exist after the wiring has entered the proper categories. Figure 6 is a description of an equipment rack utilizing pigtails from the equipment plugs to the terminal junction and then to the categorized ship's wiring.

In referring to Figure 5, it will be noticed that the categorized wiring has been labeled in a definite order. When using parallel runs (where all of the categories are in the same plane) it is desirable to locate the bundles for minimum coupling. The suggested order would be: 1, 2, 3, 6, 4, and 5 where Category I is always the farthest distance from any terminal board wiring and/or Categories IV and V.

Ground Wires - Ground wires shall always take the category of the mating "hot" wire. Twisting of pairs of wires always refers to the hot wire and the (ground) return. Twisted pairs of wires may be used on circuits of either transmission (Categories

I, II, and III) or circuits of reception (Categories IV and V). The former reduces the magnetic field coincident with current flow and the latter inhibits induced magnetic fields. Twisted wires may also be used to reduce the loop aperture where a tight twist results in minimum loop area.

Ground Studs - All ground studs will take on the category of the attaching wire. This immediately states that only one category can be connected to a given ground stud.

III. INSTALLATION CONTROL

Engineering Control - Engineering control of the wiring installation is a corollary to the wire classification plan. Previously, engineering furnished the wiring schematics and pertinent data. Actual installation of the aircraft wiring was accomplished without specific engineering requirements for a specific installation design. Wiring installations were then frequently modified by the electromagnetic compatibility group to reduce interwiring interference. If the wiring installations could not be modified for diverse reasons, efforts for interference reduction were then directed at the affected equipment. Occasionally, this resulted in equipment redesign to operate satisfactorily in an interference environment. More often, external filters were required. The desired engineering control is accomplished by carefully designing the installation on the development aircraft in accordance with the data contained in this paper. From this effort, engineering control of the actual wire runs and locations is established. Engineering documents define the classification of each bundle where each wire in the bundle is identified. Application of the engineering control made it mandatory that subsequent aircraft would be wired identical to the development aircraft.

IV. CONCLUSIONS

Application of a classification plan to all of the wiring in the aircraft will result in a considerable reduction of system interferences caused by inadvertent wire coupling. Many of the knotty problems associated with the equipment or auxiliary hardware can then be defined as having been caused by wire coupling. The reverse may also be true. Interferences, mistakenly laid to wire coupling, may be resolved as system deficiencies. Wire classification is a distinct aid in the solution and tracking down of many electromagnetic compatibility problems. The classification plan does not conflict with circuit or interconnecting wiring design. It is merely a specific installation procedure. The preparation of drawings that apply a part number to the wiring are not affected by wire classification requirements. Removals or additions of equipment to an existing aircraft present no major problems. Economically, the costs of engineering design are more than offset because of the minimum rework for a given production design. Rework of the final installation design for two military types of aircraft has been negligible. Wire classification eliminates the wide variance in compatibility found on aircraft that contain a random wiring installation.

ACKNOWLEDGMENT

The material presented herein is based upon work conducted by the Aircraft Division of Douglas in the performance of contracts for the Bureau of Naval Weapons.

THE BOEING COMPANY

COMMERCIAL AIRPLANE DIVISION

RENTON, WASHINGTON

THIS DOCUMENT HAS BEEN MICROFILMED DATE

DOCUMENT NO. D6-42974

TITLE: INVESTIGATION OF WIRE ON WIRE ABRASION TESTING

MODEL

ISSUE NO. TO: (DATE)

ORIGINAL

PREPARED BY	R. Fischer	5/14/76
SUPERVISED BY	J. A. York	5/14/76
APPROVED BY	A. M. Taylor	5/17/76
APPROVED BY		
		(DATE)

AD 1:

REV SYM

1.0 INTRODUCTION

The thin wall insulated electric wires used on the early models of the wide body jets were selected, qualified and installed in accordance with procedures and techniques which had been standard in the commercial aircraft manufacturing industry for years. However, incidents of failure of the wire insulation after periods between five and ten thousand flight hours gave rise to speculation that techniques and practices which were formerly satisfactory may not be sufficient to ensure the integrity of aircraft wire. Analysis of failed (and purportedly failed) wire shows the failure to be the result of abrasion of the wire insulation. This abrasion could have been caused by wire rubbing on wire or wire rubbing on metal and other materials. Techniques, practices and designs for installation of the wire have been revised and put into effect quickly in order to reduce the exposure of the wire to vibration and shock induced environments which cause the abrasion. However, the fact remains that when the wires in question were subject to qualification testing prior to selection for aircraft usage, they passed the tests which are designed to identify and categorize the abrasion resistant qualities of the insulation. The fact that the wearout pattern evidenced from in service failures is different from that obtained by either scrape or tape abrasion testing raises the questions - Are the present scrape abrasion and tape abrasion tests meaningful? Should these tests be augmented by another test? If so, what should comprise that test?

In an attempt to provide answers to some of these questions, a wire abrasion evaluation program was established in mid-1974. This report documents the work accomplished to date in the area of wire-on- wire abrasion testing.

3.0 DEVELOPMENT OF THE TEST

The initial task was to examine the wires which had been returned from service to determine the nature of the failure. In all cases, it was evident that the failure was occurring as a result of abrasion of the insulation. Figures 1 and 2 show examples of wear of the insulation. As can be seen, the wear patterns are different. The wear shown in Figure 1 is postulated to have resulted from wire rubbing on wire tangentially i.e., wire beating on wire; hence the small area over which the abrasion damage is spread. The wear shown in Figure 2 is postulated to have occurred when wires are in intimate contact with one another and at the same time moving longitudinally with respect to one another. It was further postulated that while installation details such as clamps, ties, etc., can minimize many of the wire abrasion problems, it will be impossible to eliminate all movement of wire with respect to other wires either in bundles or at breakouts. Accordingly, it was decided that a test which consisted of wire rubbing on wire would be meaningful. Wire bundles are no longer "combed" during manufacture. Therefore, it is possible that wires within bundles can be twisted with respect to one another and that breakouts can become crossover point. It was decided that a practical simulation of in-flight abrasion could be realized by causing movement of one wire relative to another wire about which the first wire is twisted as shown in Figure 3. In the initial test, the frequency of motion, the distance of motion and the force between the wires (controlled by the tension applied to the stationary wire) should be realistic with respect to the airplane environment but, should be sufficiently low to minimize the introduction of friction induced heating.

3.1 Vibration Laboratory Test Equipment

A test fixture representing the test set up shown in Figure 4 was constructed in the Vibration Laboratory in the 9-101 Building, Developmental Center. The test fixture is shown in Figure 5 and 6.

The fixture can accommodate up to 11 pairs of crossed wire samples at any given time. This feature was incorporated for the following specific reason.

1. It allows for comparison of eleven paired-samples of the same wire under identical environmental conditions, in order to derive more data for statistical analysis.

2. It allows for comparison of up to eleven different types of wire pairs under the same environmental conditions.

Each wire is connected to a system which monitors the number of cycles to which it has been exposed and automatically shuts down the equipment when the insulation between two wires is totally abraded and a conductor to conductor short occurs.

To minimize the effects of friction temperature on the wire insulation in the crossover area, the following test parameters were controlled:

3.3 Test Program (Continued)

TABLE I

WIRE TYPES VERSUS FIXTURE POSITION
(Vibration Lab., 0.6 lbs.Tension)

POSITION	WIRE TYPE	AWG.	DESCRIPTION	MARK ON MARK*
1	BMS 13-13	20	PVC Nylon	No
2	BMS 13-13	20	PVC Nylon	Yes
3	BMS 13-31	20	MF Teflon	No
4	BMS 13-31	20	MF Teflon	Yes
5	BMS 13-42B	20	Poly X	No
6	BMS 13-42B	20	Poly X	Yes
7	BMS 13-42C	20	Poly A	No
8	BMS 13-42C	20	Poly A	Yes
9	BMS 13-48	20	Tefzel	No
10	BMS 13-48	20	Tefzel	Yes
11	BMS 13-38	20	Polyalkene	No
5**	MIL-W-81381/12	20	Kapton	No
6**	MIL-W-81381/12	20	Kapton	No

* Mark-on Mark wires were coded using the hot stamp process and the resultant marks were used as the points of wire-to-wire contact. The purpose of this was to determine if the serations caused by the hot stamp process had any effect on the abrasion characteristics.

** Replaced Poly X after approximately 5 x 10^6 cycles.

The wear pattern of these wires was observed on a day to day basis. The first wire to fail was BMS 13-42B. This failure occurred after approximately 5 million cycles. Positions 5 and 6 were then loaded with MIL-W-81381/12 Kapton wire and the test continued until 25 million cycles had been applied to surviving wires. Table 2 shows the condition of each wire after 25 million cycles and/or the number of cycles to failure for each wire type.

There was no discernible difference in the failure rate or wear rate of wires which were rubbing mark on mark and of unmarked wires.

Figures A1 through A48 show the wires after the test had been completed. Sections of the wire are also shown so that the amount of wear can be assessed for samples which did not fail.

TABLE 2

TEST RESULTS - WIRE-ON-WIRE ABRASION
(Vibration Lab., 0.6 lbs.Tension)

WIRE TYPE	CYCLES-TO-FAILURE	REMARKS (1)	APPLICABLE FIGURES
BMS 13-13	Did not fail	Slight evidence of abrasion of Nylon @ 25×10^6	A1 through A8
BMS 13-31	20.8×10^6	Average of four samples	A9 through A16
BMS 13-42B	5×10^6	Average of four samples	A17 through A24
BMS 13-42C	Did not fail	Abrasion through outer extrusion at 25×10^6	A25 through A32
BMS 13-48	25×10^6	Badly abraded, two of four samples showed exposed conductor (2)	A33 A33 through A40
BMS 13-38	22×10^6	Average of two samples	A41 through A44
MIL-W-81381/ 12(3)	Did not fail	Slight wear of outer coat @ 20×10^6	A45 through A48

(1) One pair of wires constitute two samples.
(2) One wire of each pair had exposed conductor.
(3) MIL-W-81381/12 wire was used to replace BMS 13-42B after 5×10^6 cycles.

The Vibration Laboratory fixture was then reloaded with selected wire types for tests at 5 pounds tension and 10 pounds tension. The results are contained in Tables 3 and 4.

D1 4100 7740 ORIG.3/71

TABLE 3

TEST RESULTS - WIRE-ON-WIRE ABRASION
(Vibration Lab., 5 lbs. tension)

WIRE TYPE	AVERAGE CYCLES TO FAILURE	REMARKS	APPLICABLE FIGURE
BMS 13-13	Did not fail	Abrasion of Nylon apparent but not worn through @ 22×10^6	None
BMS 13-31	2.8×10^6	1 of 2 samples badly worn, failed	A49
BMS 13-42B	1.4×10^6	All samples badly worn and failed	A50
BMS 13-42C	2.8×10^6	All samples failed	A51
BMS 13-48	1.3×10^6	All samples failed	A52
MIL-W-81381/12	22.2×10^6	One layer of Kapton & FEP worn. One sample failed.	A60

TABLE 4

TEST RESULTS - WIRE-ON-WIRE ABRASION
(Vibration Lab., 10 lbs. tension)

WIRE TYPE	AVERAGE CYCLES TO FAILURE	REMARKS	APPLICABLE FIGURE
BMS 13-42B	5.5×10^5	All samples badly worn and failed	A53
BMS 13-42C	1.5×10^6	"	None
BMS 13-31	1×10^6	"	None
BMS 13-48	5×10^5	"	None

3.3 Test Program (Continued)

The Electrical Laboratory fixture was similarly loaded with various wire types and similar tests conducted except that a tension of 1.5 pounds was used in this test. A second difference between the Vibration Laboratory Test and the Electrical Laboratory Test was that whereas the vibration laboratory tests were conducted for eight hours a day, the electrical laboratory was run on a continuous 24 hour basis.

The results of the test conducted in the Electrical Laboratory are shown on Table 5.

TABLE 5

TEST RESULTS - WIRE ON WIRE ABRASION
(Electrical Lab., 1.5 lbs. Tension)

WIRE TYPE	AVERAGE: CYCLES TO FAILURE	REMARKS	APPLICABLE FIGURE
BMS 13-13	Did not fail	No Failure @ 30 x 10^6	None
BMS 13-31	9.8 x 10^6	Failed	A54
BMS 13-42B	1.5 x 10^6	Failed	A55
BMS 13-42C	5 x 10^6	Failed	A56
BMS 13-38	14 x 10^6	Failed	A57
BMS 13-48	4 x 10^6	Failed	A58
MIL-W-81381	Did not fail	Abrasion of Liquid H outer coat @ 65 x 10^6	A59

3.4 Evaluation of Test Results

The data from the tests show the following:

1. The wire-on-wire abrasion tests produced wear patterns similar to some of those which have been observed on wires taken from service aircraft. See Figures 10 and 11.

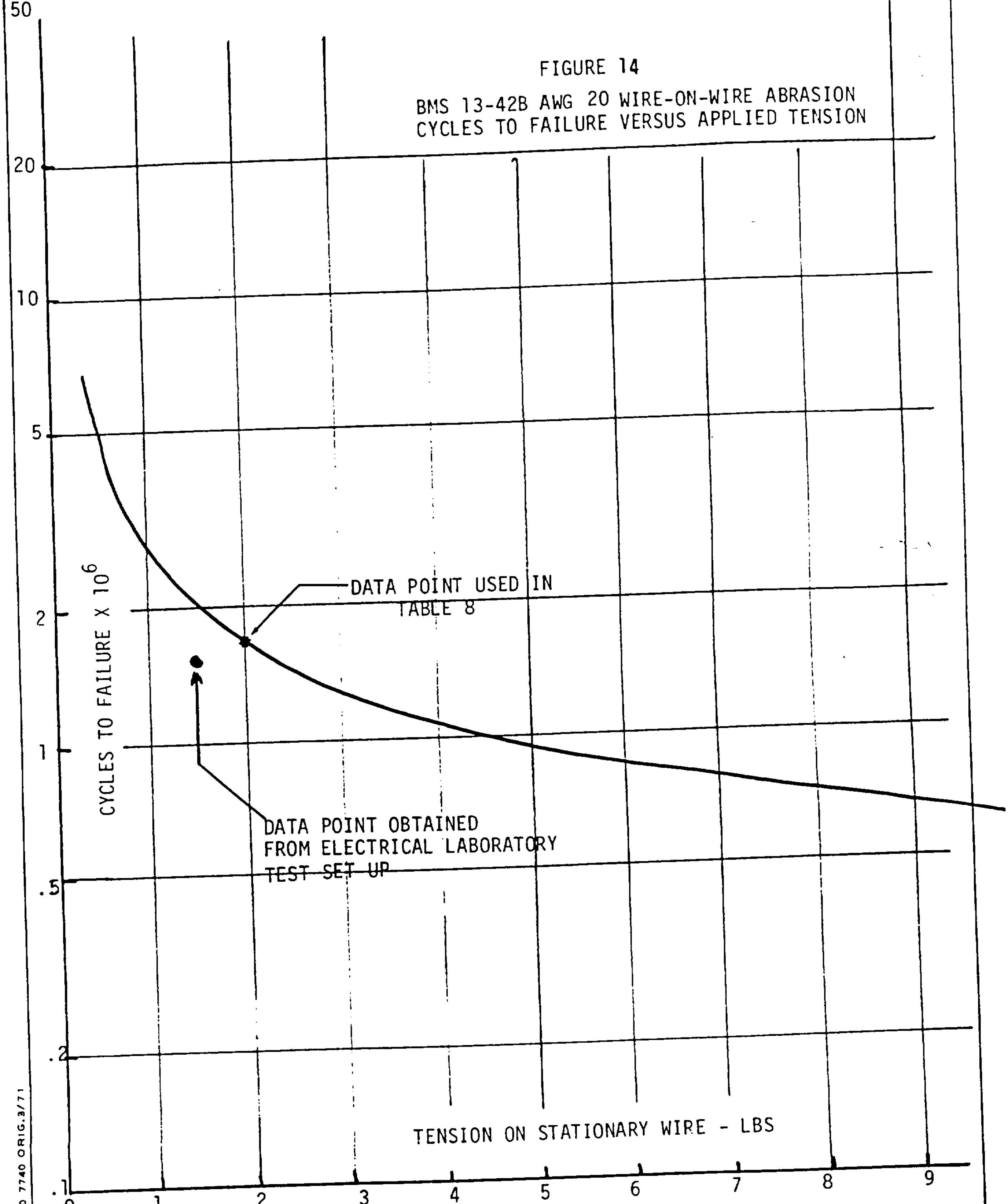
2. The wear pattern of wires tested on the Vibration Laboratory Test fixture and the wear pattern of wires tested on the Electrical Laboratory test fixture were practically identical. See Fig.12 & 13.

3. A plot of cycles to failure versus tension derived by a computer curve fitting of the data obtained from the Vibration Laboratory test fixture shows good correlation with the test data points.

   Overlaying the data obtained from the Electrical Laboratory test fixture shows fairly good correlation. See Figures 14 through 17. The results are consistent enough to warrent confidence in the

FIGURE 14

BMS 13-42B AWG 20 WIRE-ON-WIRE ABRASION CYCLES TO FAILURE VERSUS APPLIED TENSION



3.4 Evaluation of Test Results (Continued)

Electrical Laboratory test fixture and to warrant further development to refine this fixture. It is interesting to note that in three out of four of these plots, the Electrical Laboratory Test Set-up data point indicates fewer cycles to failure. Further, investigation is necessary to determine whether this anomoly is introduced by the slight dimensional differences between the two set ups. See Figures 3 and 7 to identify other factors which can account for the difference.

NOTE: Failure Rate versus Tension on Stationary Wire data for BMS 13-13 (PVC Nylon) and MIL-W-81381/12 (Kapton) are not shown in graphical form. No failure of the BMS 13-13 wires was recorded. The single failure of MIL-W081381/12 wire does not provide sufficient data points from which to plot a curve.

4. The time taken to create failure at the lower tension makes it impractical to consider tensions of less than 1 pound for evaluation testing or qualification testing. However, the spread in data obtained at higher tensions also presents a problem which requires a larger number of tests to be conducted to obtain creditable results, (see Table 6 in Paragraph 4).

3.5 CONCLUSIONS

1. Based on the amount of test data accumulated thus far, it appears that the method and equipment used for the test will produce controlled, repeatable abrasion patterns which can be used to estimate the expected performance of the wire installed on aircraft.

2. The rate of abrasion of the insulation is a function of the tension on the fixed wire (or wire contact force).

3. The Electrical Laboratory test fixture is expected to be capable of performing this test in the future. However, further examination is necessary to explain why the data obtained from this fixture is slightly lower (lower cycles to failure) than the Vibration Laboratory fixture.

4. The rate of wear of each wire in a pair was not the same. In all cases, one wire of each pair was abraded more than the others.

5. The amount of insulation worn away on some samples indicate that a failure should have been recorded by the test equipment earlier than actually occurred.

3.6 Recommendations

1. The Electrical Laboratory test fixture should be refined. Design details, calibration and certification details should be completely established and final documentation of the fixture completed.

2. A wire-on-wire abrasion requirement and test should be included in future evaluation of candidate wires for BCAC usage.

3. Further study should be made to determine the reason for uneven wear of the two wires in each paired sample.

4. A review of the failure detector and indicator system should be undertaken to determine (a) if the indication should be based on failure of a single conductor, (b) what sensitivity is required and (c) what type of hardware will be required to implement (a) or (b)?

4.0 COMPARISON OF ABRASION RATE OF THE VARIOUS TYPES OF WIRE AND WIRE INSULATING MATERIALS

Having established that the test method and the test equipment discussed in paragraph 3 are viable approaches to measure the resistance of wire to abrasion, the data gathered as part of the verification can also be used to compare the wire-on-wire abrasion resistance of various types of wire currently being installed in commercial aircraft.

4.1 Materials and Wires Being Compared

Figure 18 tabulates the wires which were tested and illustrates the individual construction details associated with each type.

4.2 Test Results

The results of the tests have already been presented in Tables 2, 3, 4 and 5. As explained in paragraph 3.4.3, the results where failure occurred were used as data points to obtain the computer derived curves of cycles to failure versus tension applied to the wire shown in Figures 14, 15, 16 and 17 and shown as a compositein Figure 19.

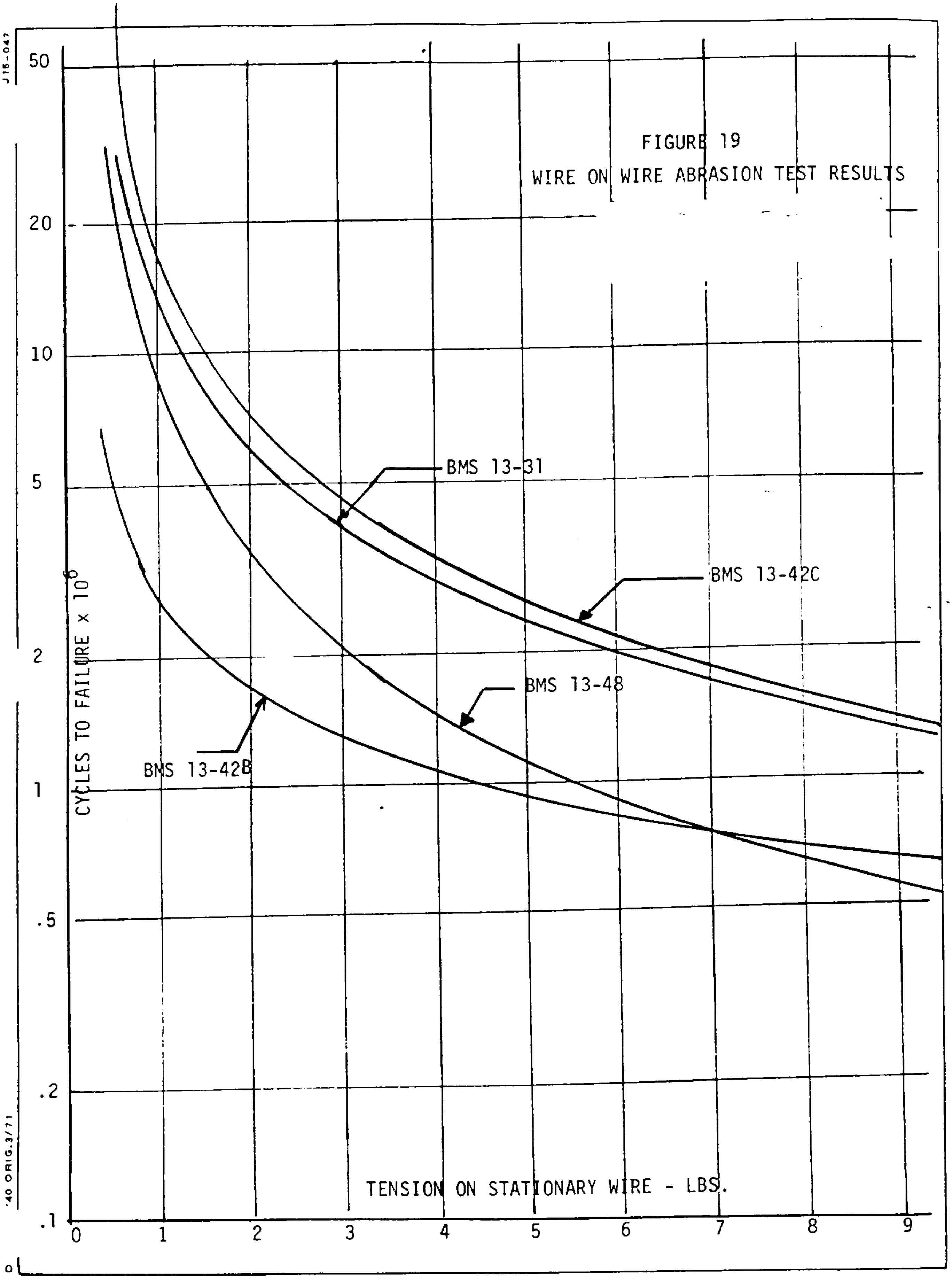
No failures occurred for PVC Nylon (BMS 13-13) and only one occurred for the Kapton (MIL-W-81381/12) during the cycles and tension loads to which they were subjected. Therefore, they are not included on Figure 19.

It was observed during the testing of BMS 13-42C wires at the higher tensile forces that the spread in cycles-to-failure for different samples of the same wire from the same spool was greater than expected. This spread is as shown in Table 6 and Table 7. Table 6 data was obtained from the Vibration Laboratory Test Set-up and Table 7 data was obtained from the Electrical Laboratory Test Set-up. The Teflon based wires (BMS 13-31 and BMS 13-48), did not exhibit this tendency, the spread in test data being very close. This wide spread in data is of interest and the samples of the BMS 13-42 wire have been saved for further analysis to determine if there is any difference in the chemical or physical composition of the insulation which could explain the wide variation in readings.

NOTE: The performance of BMS 13-42C (Stilan) is being given more scrutiny in this test than otherwise would be given because it is the general purpose wire to which Boeing is presently most heavily committed.

FIGURE 19

WIRE ON WIRE ABRASION TEST RESULTS



4.3 Analysis and Comment on Test Results

[redacted]

The testing of Kapton insulated wire illustrates another problem which faces the airline maintenance mechanic - after very few cycles (200,000) the outer liquid H coating wears off exposing the Kapton and gives the impression that bare copper wire is being exposed (see Figures A45 through A48 and A59).

The testing of BMS 13-38B wire was not pursued to any great length because of the fact that it most likely would not be considered for new design.

[redacted]

4.4 Conclusions

1. The test method is a viable approach to testing wires in order to rate their resistance to wire-on-wire abrasion.

2. Based on this test, Kapton (MIL-W-81381/12 and PVC Nylon are superior to the other wires in terms of resistance to abrasion induced by wire-on-wire rubbing. BMS 13-42B is least resistive to this type of abrasion.

3. The test method categorizes the wires in an order of resistance to wire-on-wire abrasion more or less as previous experience would dictate.

4. Futher testing must be undertaken to establish and explain the reasons for the wide spread in the BMS 13-42C test data. The variation due to the wire itself and the variation due to the test method, if any, must be established.

5. The sensitivity and repeatability of the failure detector must be reliable and dependable if this test method is to be used as aprt of any qualification or selection criteria.

4.5 Recommendations

1. Immediate attention should be focused on the problem of spread in the BMS 13-42C data.

2. Immediate attention should be focused on the accuracy and sensitivity of the failure detection system.

3. This method should be considered in the future as one of the tools to rate the resistance of a wire insulation to wire-on-wire abrasion.

5.1 The Scrape Abrasion Test (Continued)

TABLE 8

COMPARISON OF WIRE ABRASION RESISTANCE RATING:
SCRAPE VERSUS WIRE-ON-WIRE

WIRE TYPE	SCRAPE ABRASION TESTING			WIRE-ON-WIRE ABRASION TESTING		
	SCRAPES TO FAILURE	ABRASION RESISTANCE FACTOR	ABRASION RESISTANCE RATING	CYCLES TO FAILURE	ABRASION RESISTANCE FACTOR	ABRASION RESISTANCE RATING
BMS 13-13	142	5.75	2	Greater Than* 22.2×10^6	Greater Than 13.1	1
BMS 13-31	565	22.9	1	5.8×10^6	3.4	4
BMS 13-42B	39.2	1.6	4	1.7×10^6	1	6
BMS 13-42C	70.7	2.86	3	6.2×10^6	3.65	3
BMS 13-48	24.7	1	6	3.5×10^6	2.1	5
MIL-W-81381/12	48.2	1.95	5	Greater Than* 22.2×10^6	Greater Than 13.1	1

* No data from curves. Use Table 3 data - 5 lbs. tension.

Table 8 has been constructed using the following: Abrasion Resistance Factor is the ratio of the actual number of scrapes-to-failure for that particular wire to the number of scrapes-to-failure for the wire requiring the least number of scrapes-to-failure. For the wire-to-wire test, the factor is derived by using a value at 2 lbs. tension derived from cycles-to failure from Figures 14, 15, 16 and 17.

Since there were no failures of BMS 13-13 and only one of MIL-W-81381, curves of cycles to failure vs tension could not be derived. Hence, the number of test cycles to which these wires were tested without failure at 5 lbs. tension have been used in Table 8 as a conservative approach for purposes of comparison.

As can be seen from the Table 8, the major difference between these two tests is the behavior of MIL-W-81381/12 Kapton.

Further research is necessary to explain why the Kapton shows so well in the wire-on-wire test and so poorly in the scrape abrasion test.

The other wires show up to be in general agreement, with BMS 13-42B and BMS 13-48 showing in both tests to rank lower in abrasion resistance than BMS 13-13, BMS 13-31, and BMS 13-42C. The high value for BMS 13-31 is sometimes attributed to the fact that the blade becomes teflon coated thus becoming insulated and circumventing the failure detecting mechanism.

5.2 The Tape Abrasion Test

This system abrades the wire insulation by drawing an abrasive tape in one direction along the longitudinal axis of the wire. The wire is clamped in position and weight is applied to the wire for pressure contact with the abrasive tape. The equipment and its use is described in MIL-T-5438. For pictoral description of the test set-up, see Figure 21.

This method is used industry wide, but paradoxically, the results are always treated with some reserve because of the number of variables which can affect the result, e.g., temperature, humidity, the wire construction, etc., etc.

Table 9 was constructed in a manner similar to Table 8. Table 9 compares the results obtained by the tape abrasion method with results obtained by wire-on-wire abrasion and compares the rating of wire based on both methods. As in the scrape abrasion test comparison, the values for BMS 13-13 and MIL-W-81381 are estimates.

TABLE 9

COMPARISON OF WIRE ABRASION RESISTANCE RATING:

TAPE VERSUS WIRE-ON-WIRE

WIRE TYPE	TAPE ABRASION TESTING			WIRE-ON-WIRE ABRASION TESTING		
	INCHES TO FAILURE	ABRASION RESISTANCE FACTOR	ABRASION RESISTANCE RATING	CYCLES TO FAILURE	ABRASION RESISTANCE FACTOR	ABRASION RESISTANCE RATING
BMS 13-13	84.5	3.86	2	Greater Than 22.2×10^6*	Greater Than 13.1	1
BMS 13-31	100	4.57	1	5.8×10^6	3.4	4
BMS 13-42B	35.2	1.6	4	1.7×10^6	1	6
BMS 13-42C	46.0	2.1	3	6.2×10^6	3.65	3
BMS 13-48	34.4	1.57	5	3.5×10^6	2.1	5
MIL-W-81381/12	21.9	1.0	6	Greater Than 22.2×10^6*	Greater Than 13.1	1

* No data from curves. Use Table 3, 5 lbs. Tension.

As can be seen from Table 9, the major difference between the two tests is in the performance of the Kapton. Again, further research is necessary to explain the difference. Apart from the above and the fact that BMS 13-31 falls from 1st rating in the tape test to #4 in the wire-on-wire test, the results from both tests are fairly comparable.

J18-047

5.5 Recommendations

It is recommended that the study of wire-on-wire abrasion testing be continued to develop a more thorough knowledge of this test method. A broad data base should be developed from which requirements can be established for a practical application of wire-on-wire abrasion testing.

The relationships between the scrape and tape abrasion tests and the wire-on-wire abrasion tests hould be explored in greater depth to establish the optimum application of each.

D1 4100 7740 ORIG.3/71

6.0 PROGRAM CONCLUSIONS

A conclusion drawn from this program is that the wire-on-wire abrasion test provides a potential new tool to be used for the evaluation of airplane wire. The wire-on-wire abrasion test reveals wear characteristics that are not obtained by existing test methods.

It is concluded that the wire-on-wire abrasion test is especially suited to predict the wear characteristics of thin wall insulations. While equally adaptable to all wall thicknesses tested, the most dramatic differences were noted in the materials used in thin wall wire insulations.

Another conclusion is that the vibration laboratory test is both costly and time consuming. The electrical laboratory test can be run continuously, thus, reducing the test time. Additionally, the electrical laboratory test equipment is more economical than the vibration laboratory test equipment.

Finally, it is concluded that the wire-on-wire abrasion test is suitable for a qualification test but should not be considered for receiving testing at this time.

7.0 RECOMMENDATIONS

It is recommended that the wire-on-wire abrasion study be continued in order to develop a thorough understanding of this type of failure mode. From the data provided, a specification requirement will be derived for inclusion in BMS wire specifications.

Although the benefits of a thorough study are not yet available, it is strongly recommended that all new wire constructions and all new wire insulating materials considered for use on Boeing airplanes, be subjected to a wire-on-wire abrasion test. The results of the wire-on-wire abrasion test should be included as one of the factors used to determine the acceptability of any new wire considered for use.

Nominal Inner Diameter (inch)	Wall Thickness	
	Target (inch)	Tolerance (inch)
5/8	0.035	± 0.008
3/4		
7/8		
1		

O. Tie Materials

NOTE: For each manufacturer, identify the color.

TABLE XX
TIE MATERIALS

Grade	Class	Part Number	Supplier	Description
A	-	None Available	-	Use Grade B
B	1	18DZ-A	Gudebrod	BMS 13-54 Type I; Finish C, Dacron with self-extinguishing finish; flat braid; 0.014 inch ±0.003 inch thick, 0.085 inch ±0.009 inch wide
		50DOF17FR	Western Filament	
C	1	218Z	Gudebrod	BMS 13-54, Type IB; Finish C, Dacron with self-extinguishing finish; flat braid; 0.014 inch ±0.003 inch thick, 0.085 inch ±0.009 inch wide
		80DKF17-4RFR	Western Filament	
D	1	190LOF21R	Western Filament	BMS 13-54, Type II; Finish D/C, Fiberglass; flat braid; 0.016 inch ±0.003 inch thick, 0.125 inch ±0.013 inch wide
		1045M	Gudebrod	BMS 13-54, Type III; Finish C, Nomex; flat braid; 0.014 ±0.003 inch thick, 0.110 inch ±0.011 inch wide
		70HOF25R	Western Filament	
		1074M	Gudebrod	BMS 13-54, Type III; Finish C, Nomex; flat braid; 0.012 inch ±0.003 inch thick, 0.075 inch ±0.008 inch wide
		40HOF17R	Western Filament	

Make sure that the loop clamp is the smallest possible size that:

- Holds the wire harness tight
- Does not allow any movement that is abrasive to the wires in the wire harness
- Does not crush or pinch the wires.

CAUTION: TO PREVENT DAMAGE TO ANY OF THE WIRES OR THE CABLES, OR BOTH, DO NOT INSTALL A LOOP CLAMP SO THAT THE WIRES OR CABLES GO ACROSS EACH OTHER IN THE CLAMP. THIS CONDITION DOES NOT APPLY TO MULTIPLE CONDUCTOR, TWISTED CABLES.

B. Loop Clamp Part Numbers

TABLE I
LOOP CLAMP PART NUMBERS

Boeing Standard	Supplier
287T0011-()	Boeing
BACC10DK()	Boeing
BACC10GE()	Boeing
BACC10GU()	Boeing
BACC10KL()	Boeing

TABLE II
BACC10DK LOOP CLAMPS

Boeing Standard	Color	Inner Diameter (inch)
BACC10DK2	Brown	0.125
BACC10DK3	Orange	0.187
BACC10DK4	Pink	0.250
BACC10DK5	Natural	0.312
BACC10DK6	Gray	0.375
BACC10DK7	Blue	0.437
BACC10DK8A	Yellow	0.500
BACC10DK9A	Brown	0.562
BACC10DK10	Orange	0.625
BACC10DK11	Pink	0.687
BACC10DK12	Natural	0.750
BACC10DK13	Gray	0.812
BACC10DK14	Blue	0.875

When the selection of the smallest possible size of loop clamp does not meet the necessary conditions given in Paragraph 1.A., it is necessary to increase the diameter of the wire harness so that the clamp holds the wires or cables correctly.

To increase the diameter of the wire harness, any of these materials can be installed:

- BACP20BA filler plugs or filler rods; refer to Figure 3 and Figure 4
- An applicable length of RT-876 heat shrinkable sleeve or an equivalent sleeve (do not shrink the sleeve)
- The sufficient number of layers of Scotch 70 tape or an equivalent insulation tape; refer to Figure 5
- The sufficient quantity of E125-2 film or equivalent film strip; refer to Figure 5.

CAUTION: DO NOT USE THE 287T0011-() CLAMPS IN THE FUEL CELLS. IF THE PLASTIC TIES, THE LACING TAPE, OR ANY FILLER RODS COME FREE, THE FUEL FILTERS CAN BECOME CLOGGED.

The clamp is closed:

- With the ends a plastic tie strap or a length of lacing tape that are attached through the holes of the clamp bar
- Correctly, if the distance between the ears of the clamp is 1/8 inch minimum.

If it is necessary to use a filler rod, make sure that:

- The rod is on the same side of the clamp as the ears of the clamp
- The ends of the rod are 1/2 inch to to 3/4 inch beyond both sides of the clamp.

CAUTION: DO NOT USE FILLER RODS TO INCREASE THE DIAMETER OF WIRE HARNESSES THAT HAVE COAX CABLES.

E. BACC10GE Loop Clamps

For the BACC10GE() part numbers, refer to Table IV.

The BACC10GE loop clamp is a general purpose clamp that is used in the pressurized areas of the airplane where these conditions occur:

- The wire harness is 1.25 inches or greater in diameter
- The temperature of the area is 275 degrees F or greater.

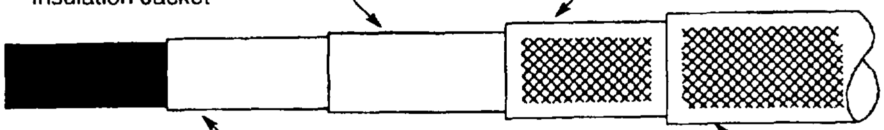
The BACC10GE loop clamp is also used to support:

- A power feeder wire harness where a BACC10KL clamp cannot be used
- A wire harness that goes across a hinge point
- A coax cable in a high vibration area
- A wire harness that is routed on an electronic shelf
- A wire harness that is inside the panel of electrical equipment.

NOTE: The BACC10GE clamp is an acceptable alternative to the BACC10DK clamp, except in the fuel cells.

When the selection of the smallest possible size of loop clamp does not meet the necessary conditions given in Paragraph 1.A., it is necessary to increase the diameter of the wire harness so that the clamp holds the wires or cables correctly.

REPAIR OF ELECTRICAL WIRE AND COAX CABLE



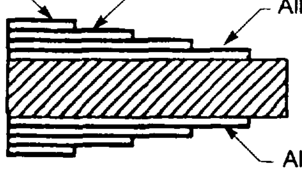
CONFIGURATION OF BMS 13-40 WIRE
Figure 4

E. BMS 13-42B Wire

BMS 13-42B has a POLY-X insulation. Refer to Figure 5.

Repair is:

- Necessary if the outer jacket is damaged
- Not necessary if the damage does not go through the color coat or the ML coat or both
- Necessary if the damage goes through the color coat and the ML coat, and into the layer of alkane-imide.



CONFIGURATION OF BMS 13-42B WIRE
Figure 5

F. BMS 13-42C and BMS 13-42D Wire

BMS 13-42C and BMS 13-42C wire have a polyarylene insulation. Refer to Figure 6.

Make sure that the solder sleeves are not overheated or damaged. A sleeve that is overheated or damaged shows any of these conditions:

- The insulation of the sleeve not clear
- The sleeve is punctured
- The insulation of the sleeve is very dark.

(10) If the solder sleeve is not installed correctly:

(a) Remove the solder sleeve. Refer to Paragraph 3.B.

(b) Do the installation procedure again from Step (2).

4. Repair of a Wire or a Cable with a Splice

A. Conditions for Repair with a Splice

NOTE: The replacement of a wire is recommended over the repair of that wire with a splice.

NOTE: The maximum number of splices that a wire can have is 3. This maximum does not include the splices that are identified by the wiring diagram.

A engine wire harness wire that is repaired with a splice:

- Is an acceptable, temporary repair
- Must be replaced when the next maintenance of the power plant is done.

All splices must be moisture resistant splices.

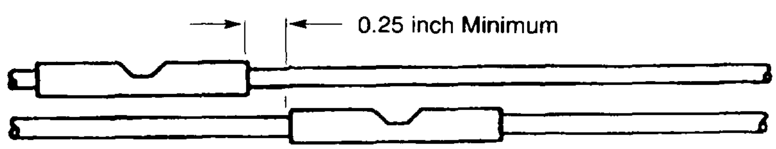
A splice must not be assembled or installed:

- Under a clamp or other support
- Inside a connector backshell or adapter
- Inside a conduit
- On the wire harness where the wire harness is frequently bent, such as an instrument panel or a hinged door
- On a wire in the fuel tank.

When the repair of more than one wire in a wire harness is necessary, the splices must be installed:

- Apart from each other so that the diameter of the wire harness is increased symmetrically, slowly, and continuously
- So that the opposite ends of two splices on adjacent wires do not make an overlap
- So that the minimum distance from the end of a splice on one wire to the opposite end of the splice on the other wire is 0.25 inch.

Refer to Figure 15.



RECOMMENDED SEPARATION OF SPLICES
Figure 15

WIRE TYPE CODES

Wire Part Number or Specification	Notes	WTC	#	Model: 7( )7 2	3	4	5	6	7	R WTC
VE 3042, Vermillion Enterprises	Coax, Shielded	WN	02	-	-	4	-	-	-	-
VE 3043, Vermillion Enterprises	Shielded	WP	03	-	-	4	-	-	-	-
VE 556, Vermillion Enterprises	Shielded	WM	02	-	-	4	-	-	-	-
VSC-A1-10-17	Fiber Optic Cable	F1	-	-	-	4	-	-	-	-
Varglas Type H0 or HP, Varflex	Sleeve	SL	-	-	-	4	-	6	7	-
Varglas Type H0 or HP, Varflex	Sleeve, Silver Or Gray	SX	-	-	-	4	-	6	7	-
Varglas, Varflex	Sleeve, Full Length	SY	-	-	-	4	-	6	7	-
Varglas, Varflex	Sleeve, Green	S5	-	2	3	-	5	-	-	-
Varglas, Varflex	Sleeve, Tan	S6	-	-	-	-	5	-	-	-
WW500, Warren, MIL-W-7139B	Shielded, High Temperature	49	01	2	3	-	-	-	-	EE
ZTZ-0550-SHN-15B, Zippertubing Company	Shield	Z3	-	-	-	4	-	-	-	-
ZTZ-0625-SHN-15B, Zippertubing Company	Shield	Z8	-	-	-	4	-	-	-	-
ZTZ-0875-SHN-15B, Zippertubing Company	Shield	Z2	-	-	-	4	-	-	-	-
ZTZ-1000-SHN-15B, Zippertubing Company	Shield	Z5	-	-	-	4	-	-	-	-
ZTZ-1125-SHN-15B, Zippertubing Company	Shield	Z7	-	-	-	4	-	-	-	-

C. Cross Reference of the Specified Wire to the Alternative Wire

NOTE: Boeing Customer Service Engineering can supply more data if there are any questions about the alternative wires.

TABLE III
ALTERNATIVE WIRES

Specified Wire	Alternative Wire	Special Conditions
0024A0014, Raychem	831-4245270, Pirelli	Ships Bundles Only
0024A0014, Raychem	831-4245379, Pirelli	Shelf, Panel, and Modules Only
1/0766/9D032E-6, Tensolite	30-05899, Champlain	-
10-60233-1	10-60233-7	-
10-60233-10	10-60233-4	-
10-60233-3	10-60233-9	-

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
10-60233-4	10-60233-10	-
10-60233-7	10-60233-1	-
10-60233-9	10-60233-3	-
10-60816-1	BMS 13-55 Type IV	-
10-60816-11	10-60816-43	-
10-60816-13	BMS 13-55 Type II	-
10-60816-13	BMS 13-60 Type 10	-
10-60816-15	10-60816-45	-
10-60816-16	10-60816-46	-
10-60816-17	BMS 13-55 Type V	-
10-60816-19	10-60816-47	-
10-60816-2	10-60816-36	-
10-60816-21	10-60816-49	-
10-60816-22	10-60816-50	-
10-60816-23	BMS 13-55 Type II	-
10-60816-26	10-60816-52	-
10-60816-27	10-60816-53	-
10-60816-31	BMS 13-60 Type 10	-
10-60816-36	10-60816-2	-
10-60816-38	10-60816-4	-
10-60816-39	10-60816-7	-
10-60816-4	10-60816-38	-
10-60816-40	10-60816-8	-
10-60816-43	10-60816-11	-
10-60816-45	10-60816-15	-
10-60816-46	10-60816-16	-
10-60816-47	10-60816-19	-
10-60816-49	10-60816-21	-
10-60816-50	10-60816-22	-
10-60816-52	10-60816-26	-
10-60816-53	10-60816-27	-
10-60816-56	BMS 13-60 Type 10	-
10-60816-62	DM-F-2MF, Matsushita	-
10-60816-7	10-60816-39	-
10-60816-8	10-60816-40	-
10-61299-1	10-61299-4	-

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
10-61299-2	10-61299-5	-
10-61299-4	10-61299-1	-
10-61299-5	10-61299-2	-
10-61299-5	10-61299-6	-
10-61299-6	10-61299-5	-
10-61299-6	20531/9E039LL-4(TL), Tensolite	-
12621, Teledyne	BWC-890014-2-18, Barcel	-
14750, Thermatics	1W014, Northrop Spec	E3/E6 Models Only
170291, Thermax	BMS 13-58 Type V	-
1W014, Northrop Spec	14750, Thermatics	E3/E6 Models Only
1W014, Northrop Spec	W-1195-98, Witmore	E3/E6 Models Only
204-15578-1	707-1195, Thermax	-
204-17468-1, Twinax	51-04570, Champlain	-
20531/9E039LL-4(TL), Tensolite	10-61299-6	-
24-00033, Champlain	BMS 13-55 Type II Class 1	AWG 18
24-00033, Champlain	BMS 13-55 Type V	-
24-00034, Champlain	BMS 13-55 Type II Class 1	AWG 16
24-00034, Champlain	BMS 13-55 Type V	-
24-00115, Champlain	BMS 13-55 Type V	-
252-94102, Al-Ch, Galite	852-4991980, Al-Ch, Specialty	-
254-100338, Cu-Cn, Revere	852-4236774, Cu-Cn, Pirelli	-
262-62737, Al-Ch, Revere	852-4991972, Al-Ch, Specialty	-
30-04373, Cu-Cn, Champlain	853-4221073, Cu-Cn, Pirelli	-
30-04373, Cu-Cn, Champlain	853-4310074, Cu-Cn, Pirelli	-
30-04680, Champlain	975-295, Thermax	-
30-04749, Champlain	975-295, Thermax	-
30-05899, Champlain	1/0766/9D032E-6, Tensolite	-
4/0591/31886PT-1, Tensolite	BMS 13-28 Type I Class 1	E3/E6 Models Only, AWG 4/0
4/0591/31886PT-1, Tensolite	M22759/11-()-9	E3/E6 Models Only, AWG 4/0
4/0591/31886PT-1, Tensolite	M22759/8-()-9	E3/E6 Models Only, AWG 4/0
411-63221, Cu-Cn, Revere	853-4125928, Cu-Cn, Pirelli	-
412-67587, Cu-Cn, Revere	853-4221073, Cu-Cn, Pirelli	-
421-166, Amphenol	7524D5011-(), Raychem	-
421-176, Amphenol	MIL-C-17/60, RG-142	-

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
44A7620-(), Al-Ch, Raychem	CTC-0039-()-9/5-9, Al-Ch, Raychem	-
5012F1339(), Raychem	MIL-C-17/163, RG-213	-
5012F1339(), Raychem	MIL-C-17/163, RG-213	-
5012F1339(), Raychem	MIL-C-17/163, RG-8	-
5012H3012, Raychem	BA20048, Surprenant	-
5020G3442, Raychem	AA-1500, Times Wire Company	-
5020G3442, Raychem	BA-14349, ITT Surprenant	-
5020G3442, Raychem	BA14349, Surprenant	-
5020G3442, Raychem	MI-5406, Times Wire Company	-
5021E1331(), Raychem	BA5903A, Surprenant	-
5021K1011, Raychem	BA20049, Surprenant	-
5026A1314-9, Raychem	5026D1018, Raychem	-
5026D1018, Raychem	5026A1314-9, Raychem	-
51-04569, Champlain	976-295, Thermax	-
51-04570, Champlain	204-17468-1, Twinax	-
51-04570, Champlain	986-495, Thermax	-
51-04763, Champlain	831-4245379, Pirelli	-
51-04859, Champlain	977-295, Thermax	-
550-292, Thermax	61-02651, Champlain	-
551-292, Thermax	61-02783, Champlain	-
55A1211-10-9-9, Raychem	BMS 13-48 Type 12 Class 1	AWG 10
55A1211-10-9-9, Raychem	C4201358, Judd	-
61-02651, Champlain	550-292, Thermax	-
61-02783, Champlain	551-292, Thermax	-
63546, Filotex	BMS 13-08 Type III Class A	-
63832, Filotex	BMS 13-55 Type IV	-
65B47866-5	72016, Thermax	-
65B47866-5	SS72016, Thermax	-
691-295, Thermax	AA6343, Times Wire Company	-
707-1195, Thermax	204-15578-1	-
7120D0011(), Raychem	BA6848, Surprenant	-
72016, Thermax	65B47866-5	-
7524D5011-(), Raychem	421-166, Amphenol	-
7524D5011-(), Raychem	BA6416A, Surprenant	-
81993, Filotex	BMS 13-55 Type II Class 1	AWG 18

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
8220D0011(), Raychem	BA6580, Surprenant	-
831-4245270, Pirelli	0024A0014, Raychem	Ships Bundles Only
831-4245270, Specialty	977-295, Thermax	-
831-4245379, Pirelli	0024A0014, Raychem	Shelf, Panel, and Modules Only
831-4245379, Pirelli	51-04763, Champlain	-
852-4000303, Al-Ch, Pirelli	852-4991980, Al-Ch, Specialty	-
852-4104717, Al-Ch, Pirelli	852-4991972, Al-Ch, Specialty	-
852-4207072, Al-Ch, Pirelli	852-4985321, Al-Ch, Specialty	-
852-4236774, Cu-Cn, Pirelli	254-100338, Cu-Cn, Revere	-
852-4236774, Cu-Cn, Pirelli	LWC-160, Cu-Cn, Lewis	-
852-4985321, Al-Ch, Specialty	852-4207072, Al-Ch, Pirelli	-
852-4991972, Al-Ch, Specialty	262-62737, Al-Ch, Revere	-
852-4991972, Al-Ch, Specialty	852-4104717, Al-Ch, Pirelli	-
852-4991972, Al-Ch, Specialty	LWAC-99, Al-Ch, Lewis	-
852-4991972, Al-Ch, Specialty	WC-62737, Al-Ch, Revere	-
852-4991980, Al-Ch, Specialty	252-94102, Al-Ch, Galite	-
852-4991980, Al-Ch, Specialty	852-4000303, Al-Ch, Pirelli	-
853-4125928, Cu-Cn, Pirelli	411-63221, Cu-Cn, Revere	-
853-4125928, Cu-Cn, Pirelli	WW-63221, Cu-Cn, Revere	-
853-4218376, Al-Ch, Pirelli	WC101767, Al-Ch, Pirelli	-
853-4221073, Cu-Cn, Pirelli	30-04373, Cu-Cn, Champlain	-
853-4221073, Cu-Cn, Pirelli	412-67587, Cu-Cn, Revere	-
853-4221073, Cu-Cn, Pirelli	853-4310074, Cu-Cn, Pirelli	-
853-4221073, Cu-Cn, Pirelli	WW67587, Cu-Cn, Revere	-
853-4221172, Al-Ch, Pirelli	WC-101763, Al-Ch, Revere	-
853-4310074, Cu-Cn, Pirelli	30-04373, Cu-Cn, Champlain	-
853-4310074, Cu-Cn, Pirelli	853-4221073, Cu-Cn, Pirelli	-
85842, Filotex	BMS 13-55 Type II Class 1	AWG 16
975-295, Thermax	30-04680, Champlain	-
975-295, Thermax	30-04749, Champlain	-
976-295, Thermax	51-04569, Champlain	-
977-295, Thermax	51-04859, Champlain	-
977-295, Thermax	831-4245270, Specialty	-
986-495, Thermax	51-04570, Champlain	-
986-495, Thermax	BL 782, Times Wire Company	-

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
AA-1500, Times Wire Company	5020G3442, Raychem	-
AA6343, Times Wire Company	691-295, Thermax	-
BA-14349, ITT Surprenant	5020G3442, Raychem	-
BA14349, Surprenant	5020G3442, Raychem	-
BA20048, Surprenant	5012H3012, Raychem	-
BA20049, Surprenant	5021K1011, Raychem	-
BA5903A, Surprenant	5021E1331(), Raychem	-
BA6416A, Surprenant	7524D5011-(), Raychem	-
BA6580, Surprenant	8220D0011(), Raychem	-
BA6848, Surprenant	7120D0011(), Raychem	-
BA6903A, Surprenant	MIL-C-17/75, RG-214	E3/E6 Models Only
BL 782, Times Wire Company	986-495, Thermax	-
BMS 13-08 Type I Class A	BMS 13-55 Type II Class 1	-
BMS 13-08 Type II Class A	BMS 13-08 Type III Class A	-
BMS 13-08 Type III Class A	63546, Filotex	-
BMS 13-08 Type III Class A	BMS 13-08 Type II Class A	-
BMS 13-10 Type I	BMS 13-60 Type 1	-
BMS 13-10 Type III	BMS 13-60 Type 2	-
BMS 13-11 Type I	BMS 13-60 Type 1	-
BMS 13-11 Type V	BMS 13-60 Type 2	-
BMS 13-13 Type I	BMS 13-60 Type 1	-
BMS 13-13 Type III	BMS 13-60 Type 2	-
BMS 13-13 Type IV	BMS 13-60 Type 3	-
BMS 13-16 Type I	BMS 13-60 Type 1	-
BMS 13-16 Type I Class 1	BMS 13-51 Type XIV Class 1	E3/E6 Models Only, Same AWG
BMS 13-16 Type I Class 1	BMS 13-51 Type XVII Class 1	E3/E6 Models Only, AWG 24
BMS 13-16 Type I Class 1	M81381/21-()-9	E3/E6 Models Only, Same AWG
BMS 13-16 Type I Class 1	M81381/9-24-9	E3/E6 Models Only, AWG 24
BMS 13-16 Type I, Solid Color	BMS 13-48 Type 8, White with Stripe	Same Class, and AWG
BMS 13-16 Type III	BMS 13-60 Type 2	-
BMS 13-18 Type I	BMS 13-60 Type 7	-
BMS 13-18 Type III	BMS 13-60 Type 8	-
BMS 13-18 Type IV	BMS 13-60 Type 9	-
BMS 13-28	BMS 13-31	Same Type, Class, AWG, and Color, AWG 22 through AWG 8

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
BMS 13-28	BMS 13-58	Same Type, Class, AWG, and Color
BMS 13-28 Type I Class 1	4/0591/31886PT-1, Tensolite	E3/E6 Models Only, AWG 4/0
BMS 13-28 Type I Class 1	M22759/3-()-9	E3/E6 Models Only, Same AWG
BMS 13-28 Type I Class 1	M22759/6-()-9	E3/E6 Models Only, Same AWG
BMS 13-29 Type I	BMS 13-60 Type 7	-
BMS 13-30 Type I	BMS 13-60 Type 4	-
BMS 13-30 Type III	BMS 13-60 Type 5	-
BMS 13-31	BMS 13-28	Same Type, Class, AWG, and Color, AWG 22 through AWG 8
BMS 13-31	BMS 13-58	Same Type, Class, AWG, and Color
BMS 13-31 Type I	BMS 13-60 Type 7	Same Class, AWG, and Color
BMS 13-31 Type I Class 1	M22759/8-()-9	E3/E6 Models Only, Same AWG
BMS 13-31 Type III	BMS 13-60 Type 8	Same Class, AWG, and Color
BMS 13-31 Type IV	BMS 13-60 Type 9	Same Class, AWG, and Color
BMS 13-31 Type V	BMS 13-60 Type 10	Same Class, AWG, and Color
BMS 13-31 Type VII	BMS 13-60 Type 11	Same Class, AWG, and Color
BMS 13-31 Type VIII	BMS 13-60 Type 12	Same Class, AWG, and Color
BMS 13-38 Type I	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-38 Type V	BMS 13-48 Type 9	Same Class, AWG, and Color
BMS 13-39 Type I	BMS 13-48 Type 10	Same Class, AWG, and Color
BMS 13-39 Type III	BMS 13-48 Type 12	Same Class, AWG, and Color
BMS 13-39 Type VI	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-40 Type I	BMS 13-35 Type I	Same Class, and AWG
BMS 13-42 Type I	BMS 13-48 Type 10	Same Class, AWG, and Color
BMS 13-42 Type I	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-42 Type VIII	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-42 Type IX	BMS 13-48 Type 9	Same Class, AWG, and Color
BMS 13-42 Type XII	BMS 13-48 Type 12	Same Class, AWG, and Color
BMS 13-42 Type XIII	BMS 13-48 Type 13	Same Class, AWG, and Color
BMS 13-48 Type 1	BMS 13-48 Type 10	Same Class, AWG, and Color
BMS 13-48 Type 1	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-48 Type 1	BMS 13-60 Type 1	Same Class, AWG, and Color
BMS 13-48 Type 10	BMS 13-39 Type I	Same Class, AWG, and Color
BMS 13-48 Type 10	BMS 13-42 Type I	Same Class, AWG, and Color
BMS 13-48 Type 10	BMS 13-48 Type 8	Same Class and Color, AWG 22 Only

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
BMS 13-48 Type 10	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-48 Type 10	BMS 13-51 Type VIII	Same Class, AWG, and Color
BMS 13-48 Type 10	BMS 13-51 Type XIV	Same Class, AWG, and Color
BMS 13-48 Type 10	BMS 13-51 Type XXVI	Same Class, AWG, and Color
BMS 13-48 Type 10	BMS 13-60 Type 1	Same Class, AWG, and Color
BMS 13-48 Type 11	BMS 13-48 Type 9	Same Class and Color, AWG 24 Only
BMS 13-48 Type 11	BMS 13-48 Type 9	Same Class, AWG, and Color
BMS 13-48 Type 11	BMS 13-51 Type XI	Same Class, AWG, and Color
BMS 13-48 Type 11	BMS 13-51 Type XVII	Same Class, AWG, and Color
BMS 13-48 Type 11	BMS 13-60 Type 4	Same Class, AWG, and Color, Not Solderable
BMS 13-48 Type 12	BMS 13-39 Type III	Same Class, AWG, and Color
BMS 13-48 Type 12	BMS 13-42 Type XII	Same Class, AWG, and Color
BMS 13-48 Type 12	BMS 13-48 Type 25	Same Class, AWG, and Color
BMS 13-48 Type 12	BMS 13-48 Type 3	Same Class and Color, AWG 22 Only
BMS 13-48 Type 12	BMS 13-60 Type 2	Same Class, AWG, and Color
BMS 13-48 Type 12 Class 1	55A1211-10-9-9, Raychem	AWG 10
BMS 13-48 Type 13	BMS 13-42 Type XIII	Same Class, AWG, and Color
BMS 13-48 Type 13	BMS 13-48 Type 6	Same Class and Color, AWG 24 Only
BMS 13-48 Type 13	BMS 13-60 Type 5	Same Class, AWG, and Color, Not Solderable
BMS 13-48 Type 22	BMS 13-60 Type 10	Same Class, AWG, and Color
BMS 13-48 Type 24	BMS 13-60 Type 5	Same Class, AWG, and Color
BMS 13-48 Type 25	BMS 13-48 Type 12	Same Class, AWG, and Color
BMS 13-48 Type 25	BMS 13-48 Type 3	Same Class, AWG, and Color
BMS 13-48 Type 25	BMS 13-60 Type 13	Same Class, AWG, and Color
BMS 13-48 Type 26	BMS 13-48 Type 6	Same Class, AWG, and Color
BMS 13-48 Type 26	BMS 13-60 Type 15	Same Class, AWG, and Color
BMS 13-48 Type 3	BMS 13-48 Type 12	Same Class and Color, AWG 22 Only
BMS 13-48 Type 3	BMS 13-48 Type 12	Same Class, AWG, and Color
BMS 13-48 Type 3	BMS 13-48 Type 25	Same Class, AWG, and Color
BMS 13-48 Type 3	BMS 13-51 Type XV	Same Class, AWG, and Color
BMS 13-48 Type 3	BMS 13-60 Type 13	Same Class, AWG, and Color

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
BMS 13-48 Type 6	BMS 13-48 Type 13	Same Class and Color, AWG 24 Only
BMS 13-48 Type 6	BMS 13-48 Type 13	Same Class, AWG, and Color
BMS 13-48 Type 6	BMS 13-48 Type 26	Same Class, AWG, and Color
BMS 13-48 Type 6	BMS 13-51 Type XII	Same Class, AWG, and Color
BMS 13-48 Type 6	BMS 13-51 Type XVIII	Same Class, AWG, and Color
BMS 13-48 Type 6	BMS 13-60 Type 15	Same Class, AWG, and Color, Not Solderable
BMS 13-48 Type 8	BMS 13-38 Type I	Same Class, AWG, and Color
BMS 13-48 Type 8	BMS 13-39 Type VI	Same Class, AWG, and Color
BMS 13-48 Type 8	BMS 13-42 Type I	Same Class, AWG, and Color
BMS 13-48 Type 8	BMS 13-42 Type VIII	Same Class, AWG, and Color
BMS 13-48 Type 8	BMS 13-48 Type 10	Same Class and Color, AWG 22 Only
BMS 13-48 Type 8	BMS 13-49 Type VIII	Same Class, AWG, and Color
BMS 13-48 Type 8	BMS 13-60 Type 1	Same Class, AWG, and Color
BMS 13-48 Type 9	BMS 13-38 Type V	Same Class, AWG, and Color
BMS 13-48 Type 9	BMS 13-42 Type IX	Same Class, AWG, and Color
BMS 13-48 Type 9	BMS 13-48 Type 11	Same Class and Color, AWG 24 Only
BMS 13-48 Type 9	BMS 13-60 Type 4	Same Class, AWG, and Col[illegible] Not Solderable
BMS 13-49 Type VIII	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-51 Type I	BMS 13-60 Type 1	Same Class, AWG, and Color
BMS 13-51 Type III	BMS 13-60 Type 2	Same Class, AWG, and Color
BMS 13-51 Type VI	BMS 13-60 Type 5	Same Class, AWG, and Color
BMS 13-51 Type VIII	BMS 13-48 Type 10	Same Class, AWG, and Color
BMS 13-51 Type VIII	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-51 Type VIII	BMS 13-60 Type 1	Same Class, AWG, and Color
BMS 13-51 Type IX	BMS 13-60 Type 2	Same Class, AWG, and Color
BMS 13-51 Type X	BMS 13-60 Type 3	Same Class, AWG, and Color
BMS 13-51 Type XI	BMS 13-48 Type 11	Same Class, AWG, and Color
BMS 13-51 Type XI	BMS 13-48 Type 9	Same Class, AWG, and Color
BMS 13-51 Type XI	BMS 13-60 Type 4	Same Class, AWG, and Color, Not Solderable
BMS 13-51 Type XII	BMS 13-48 Type 6	Same Class, AWG, and Color
BMS 13-51 Type XII	BMS 13-60 Type 5	Same Class, AWG, and Color, Not Solderable

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
BMS 13-51 Type XIV	BMS 13-48 Type 10	Same Class, AWG, and Color
BMS 13-51 Type XIV	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-51 Type XIV	BMS 13-60 Type 1	Same Class, AWG, and Color
BMS 13-51 Type XIV Class 1	BMS 13-16 Type I Class 1	E3/E6 Models Only, Same AWG
BMS 13-51 Type XIV Class 1	M81381/12-()-2	E3/E6 Models Only, Same AWG
BMS 13-51 Type XIV Class 1	M81381/12-()-9	E3/E6 Models Only, Same AWG
BMS 13-51 Type XIV Class 1	M81381/21-()-2	E3/E6 Models Only, Same AWG
BMS 13-51 Type XIV Class 1	M81381/21-()-9	E3/E6 Models Only, Same AWG
BMS 13-51 Type XV	BMS 13-48 Type 12	Same Class, AWG, and Color
BMS 13-51 Type XV	BMS 13-48 Type 3	Same Class, AWG, and Color
BMS 13-51 Type XV	BMS 13-60 Type 13	Same Class, AWG, and Color
BMS 13-51 Type XV	M27500-()MY()T12	E3/E6 Models Only, Same Class and AWG
BMS 13-51 Type XV	M27500-()NK()T12	E3/E6 Models Only, Same Class and AWG
BMS 13-51 Type XVI	BMS 13-60 Type 3	Same Class, AWG, and Color
BMS 13-51 Type XVII	BMS 13-48 Type 11	Same Class, AWG, and Color
BMS 13-51 Type XVII	BMS 13-48 Type 9	Same Class, AWG, and Color
BMS 13-51 Type XVII	BMS 13-60 Type 4	Same Class, AWG, and Color, Not Solderable
BMS 13-51 Type XVII Class 1	BMS 13-16 Type I Class 1	E3/E6 Models Only, AWG 24
BMS 13-51 Type XVII Class 1	M81381/13-24-9	E3/E6 Models Only, AWG 24
BMS 13-51 Type XVII Class 1	M81381/9-24-9	E3/E6 Models Only, AWG 24
BMS 13-51 Type XVIII	BMS 13-48 Type 13	Same Class, AWG, and Color
BMS 13-51 Type XVIII	BMS 13-48 Type 6	Same Class, AWG, and Color
BMS 13-51 Type XVIII	BMS 13-60 Type 15	Same Class, AWG, and Color, Not Solderable
BMS 13-51 Type XVIII	M27500-24MT()T12	E3/E6 Models Only, Same Class, AWG 24
BMS 13-51 Type XVIII	M27500-24NA()T12	E3/E6 Models Only, Same Class, AWG 24
BMS 13-51 Type XXVI	BMS 13-48 Type 10	Same Class, AWG, and Color
BMS 13-51 Type XXVI	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-51 Type XXVI	BMS 13-60 Type 1	Same Class, AWG, and Color
BMS 13-51 Type XXVII	BMS 13-60 Type 2	Same Class, AWG, and Color
BMS 13-51 Type XXIX	BMS 13-60 Type 4	Same Class, AWG, and Color
BMS 13-51 Type XXX	BMS 13-60 Type 5	Same Class, AWG, and Color

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
BMS 13-55 Type I	BMS 13-55 Type II	Same Class, AWG, and Color
BMS 13-55 Type I Class 1	H22-4000, Rockbestos	AWG 18
BMS 13-55 Type II	10-60816-13	-
BMS 13-55 Type II	10-60816-23	-
BMS 13-55 Type II	BMS 13-55 Type V	-
BMS 13-55 Type II Class 1	81993, Filotex	AWG 18
BMS 13-55 Type II Class 1	85842, Filotex	AWG 16
BMS 13-55 Type IV	10-60816-1	-
BMS 13-55 Type IV	63832, Filotex	-
BMS 13-55 Type V	10-60816-17	-
BMS 13-55 Type V	BMS 13-55 Type II	-
BMS 13-58 Type I	BMS 13-60 Type 7	747/767 Only (except AWACS), Same Class, AWG, and Color
BMS 13-58 Type I	Type 2100-1-(), Filotex	-
BMS 13-58 Type III	BMS 13-60 Type 8	747/767 Only, Same Class, AWG, and Color
BMS 13-58 Type V	170291, Thermax	-
BMS 13-58 Type V	BMS 13-60 Type 10	747/767 Only, Same Class, AWG, and Color
BMS 13-58 Type VII	BMS 13-60 Type 11	747/767 Only, Same Class, AWG, and Color
BMS 13-60 Type 1	BMS 13-10 Type I	-
BMS 13-60 Type 1	BMS 13-11 Type I	-
BMS 13-60 Type 1	BMS 13-13 Type I	-
BMS 13-60 Type 1	BMS 13-16 Type I	-
BMS 13-60 Type 1	BMS 13-48 Type 10	Same Class, AWG, and Color
BMS 13-60 Type 1	BMS 13-48 Type 8	Same Class, AWG, and Color
BMS 13-60 Type 1	BMS 13-51 Type I	Same Class, AWG, and Color
BMS 13-60 Type 1	BMS 13-51 Type VIII	Same Class, AWG, and Color
BMS 13-60 Type 1	BMS 13-51 Type XIV	Same Class, AWG, and Color
BMS 13-60 Type 1	BMS 13-51 Type XXVI	Same Class, AWG, and Color
BMS 13-60 Type 1	BMS 13-60 Type 7	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 10	10-60816-13	-
BMS 13-60 Type 10	10-60816-31	-
BMS 13-60 Type 10	10-60816-56	-

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
BMS 13-60 Type 10	BMS 13-31 Type V	Same Class, AWG, and Color
BMS 13-60 Type 10	BMS 13-58 Type V	747/767 Only, Same Class, AWG, and Color
BMS 13-60 Type 11	BMS 13-31 Type VII	Same Class, AWG, and Color
BMS 13-60 Type 11	BMS 13-58 Type VII	747/767 Only, Same Class, AWG, and Color
BMS 13-60 Type 12	BMS 13-31 Type VIII	Same Class, AWG, and Color
BMS 13-60 Type 13	BMS 13-48 Type 25	Same Class, AWG, and Color
BMS 13-60 Type 13	BMS 13-48 Type 3	Same Class, AWG, and Color
BMS 13-60 Type 13	BMS 13-51 Type XV	Same Class, AWG, and Color
BMS 13-60 Type 13	BMS 13-60 Type 2	Same Class, AWG, and Color
BMS 13-60 Type 15	BMS 13-48 Type 26	Same Class, AWG, and Color
BMS 13-60 Type 15	BMS 13-48 Type 6	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 15	BMS 13-51 Type XVIII	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 19	BMS 13-60 Type 4	AWG 14 through AWG 4/0
BMS 13-60 Type 2	BMS 13-10 Type III	-
BMS 13-60 Type 2	BMS 13-11 Type V	-
BMS 13-60 Type 2	BMS 13-13 Type III	-
BMS 13-60 Type 2	BMS 13-16 Type III	-
BMS 13-60 Type 2	BMS 13-48 Type 12	Same Class, AWG, and Color
BMS 13-60 Type 2	BMS 13-51 Type III	Same Class, AWG, and Color
BMS 13-60 Type 2	BMS 13-51 Type IX	Same Class, AWG, and Color
BMS 13-60 Type 2	BMS 13-51 Type XXVII	Same Class, AWG, and Color
BMS 13-60 Type 22	TLA-150-(), Tensolite	Same AWG
BMS 13-60 Type 3	BMS 13-13 Type IV	-
BMS 13-60 Type 3	BMS 13-51 Type X	Same Class, AWG, and Color
BMS 13-60 Type 3	BMS 13-51 Type XVI	Same Class, AWG, and Color
BMS 13-60 Type 4	BMS 13-30 Type I	-
BMS 13-60 Type 4	BMS 13-48 Type 11	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 4	BMS 13-48 Type 9	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 4	BMS 13-51 Type XI	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 4	BMS 13-51 Type XVII	Same Class, AWG, and Color, Not Solderable

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
BMS 13-60 Type 4	BMS 13-51 Type XXIX	Same Class, AWG, and Color
BMS 13-60 Type 4	BMS 13-60 Type 10	Same Class, AWG, and Color
BMS 13-60 Type 4	BMS 13-60 Type 19	AWG 14 through AWG 4/0
BMS 13-60 Type 5	BMS 13-30 Type III	-
BMS 13-60 Type 5	BMS 13-48 Type 13	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 5	BMS 13-48 Type 24	Same Class, AWG, and Color
BMS 13-60 Type 5	BMS 13-51 Type VI	Same Class, AWG, and Color
BMS 13-60 Type 5	BMS 13-51 Type XII	Same Class, AWG, and Color, Not Solderable
BMS 13-60 Type 5	BMS 13-51 Type XXX	Same Class, AWG, and Color
BMS 13-60 Type 5	BMS 13-60 Type 11	Same Class, AWG, and Color
BMS 13-60 Type 7	BMS 13-18 Type I	-
BMS 13-60 Type 7	BMS 13-29 Type I	-
BMS 13-60 Type 7	BMS 13-31 Type I	Same Class, AWG, and Color
BMS 13-60 Type 7	BMS 13-58 Type I	747/767 Only (except AWACS), Same Class, AWG, and Color
BMS 13-60 Type 8	BMS 13-18 Type III	-
BMS 13-60 Type 8	BMS 13-31 Type III	Same Class, AWG, and Color
BMS 13-60 Type 8	BMS 13-58 Type III	747/767 Only, Same Class, AWG, and Color
BMS 13-60 Type 8	BMS 13-60 Type 11	Same Class, AWG, and Color
BMS 13-60 Type 8	MIL-W-7139, MIL-W-7078	-
BMS 13-60 Type 8	RSS-5-191, MIL-W-7139	-
BMS 13-60 Type 8	WARREN WW500, MIL-W-7139	-
BMS 13-60 Type 9	BMS 13-18 Type IV	-
BMS 13-60 Type 9	BMS 13-31 Type IV	Same Class, AWG, and Color
BMS 13-65 Type 0E	S280W503-1	-
BMS 13-65 Type 0F	S280W503-2	-
BMS 13-65 Type 0G	S280W503-3	-
BMS 13-65 Type 0H	S280W503-4	-
BMS 13-65 Type 0J	S280W503-5	-
BWC-890014-2-18, Barcel	12621, Teledyne	-
C4201358, Judd	55A1211-10-9-9, Raychem	-
CTC-0039-()-9/5-9, Al-Ch, Raychem	44A7620-(), Al-Ch, Raychem	-

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
DM-F-2MF, Matsushita	10-60816-62	-
H22-4000, Rockbestos	BMS 13-55 Type I Class 1	AWG 18
H22-4000, Rockbestos	BMS 13-55 Type II Class 1	AWG 18
JW1177/9-(XXX), Magnet Wire	M1177/9-(XXX)	-
JW1177/9-(XXX), Magnet Wire	NYLAC-(XXX), Anaconda	-
JW1177/9-(XXX), Magnet Wire	NYLEZE-(XXX), Phelps Dodge	-
LWAC-99, Al-Ch, Lewis	852-4991972, Al-Ch, Specialty	-
LWC-160, Cu-Cn, Lewis	852-4236774, Cu-Cn, Pirelli	-
M1177/9-(XXX)	JW1177/9-(XXX), Magnet Wire	-
M22759/11-()-9	4/0591/31886PT-1, Tensolite	E3/E6 Models Only, AWG 4/0
M22759/11-()-9	M22759/3-()-9	E3/E6 Models Only, AWG 22 through AWG 2/0
M22759/3-()-9	BMS 13-28 Type I Class 1	E3/E6 Models Only, Same AWG
M22759/3-()-9	M22759/11-()-9	E3/E6 Models Only, AWG 22 through AWG 2/0
M22759/3-()-9	M22759/8-()-9	E3/E6 Models Only, AWG 22 through AWG 2/0
M22759/6-()-9	BMS 13-28 Type I Class 1	E3/E6 Models Only, Same AWG
M22759/6-()-9	M27500-24MT1T12	E3/E6 Models Only, AWG 24
M22759/8-()-9	4/0591/31886PT-1, Tensolite	E3/E6 Models Only, AWG 4/0
M22759/8-()-9	BMS 13-31 Type I Class 1	E3/E6 Models Only, Same AWG
M22759/8-()-9	M22759/3-()-9	E3/E6 Models Only, AWG 22 through AWG 2/0
M27500-()BA()T13	M27500-()ML()T08	E3/E6 Models Only, Same Class and AWG
M27500-()BA()T13	M27500-()MY()T12	E3/E6 Models Only, Same Class and AWG
M27500-()BA()U00	M27500-()ML()U00	E3/E6 Models Only, Same Class and AWG
M27500-()BA()U00	M27500-()MY()U00	E3/E6 Models Only, Same Class and AWG
M27500-()BF()T18	M27500-()MY()T12	E3/E6 Models Only, Same Class and AWG
M27500-()BF()T19	M27500-()ML()T08	E3/E6 Models Only, Same Class and AWG
M27500-()BF()T19	M27500-()MY()T12	E3/E6 Models Only, Same Class and AWG
M27500-()BF()U00	M27500-()ML()U00	E3/E6 Models Only, Same Class and AWG

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
M27500-()BF()U00	M27500-()MY()U00	E3/E6 Models Only, Same Class and AWG
M27500-()ML()T08	M27500-()BA()T13	E3/E6 Models Only, Same Class and AWG
M27500-()ML()T08	M27500-()BF()T19	E3/E6 Models Only, Same Class and AWG
M27500-()ML()T08	M27500-()ML()T09	E3/E6 Models Only, Same Class and AWG
M27500-()ML()T09	M27500-()ML()T08	E3/E6 Models Only, Same Class and AWG
M27500-()ML()U00	M27500-()BA()U00	E3/E6 Models Only, Same Class and AWG
M27500-()ML()U00	M27500-()BF()U00	E3/E6 Models Only, Same Class and AWG
M27500-()MY()T12	BMS 13-51 Type XV	E3/E6 Models Only, Same Class and AWG
M27500-()MY()T12	M27500-()BA()T13	E3/E6 Models Only, Same Class and AWG
M27500-()MY()T12	M27500-()BF()T18	E3/E6 Models Only, Same Class and AWG
M27500-()MY()T12	M27500-()BF()T19	E3/E6 Models Only, Same Class and AWG
M27500-()MY()T12	M27500-()NK()T12	E3/E6 Models Only, Same Class and AWG
M27500-()MY()U00	M27500-()BA()U00	E3/E6 Models Only, Same Class and AWG
M27500-()MY()U00	M27500-()BF()U00	E3/E6 Models Only, Same Class and AWG
M27500-()MY()U00	M27500-()NK()U00	E3/E6 Models Only, Same Class and AWG
M27500-()NK()T12	BMS 13-51 Type XV	E3/E6 Models Only, Same Class and AWG
M27500-()NK()T12	M27500-()MY()T12	E3/E6 Models Only, Same Class and AWG
M27500-()NK()U00	M27500-()MY()U00	E3/E6 Models Only, Same Class and AWG
M27500-()RA()N06	M27500-()TA()N06	E3/E6 Models Only, Same Class and AWG
M27500-()TA()N06	M27500-()RA()N06	E3/E6 Models Only, Same Class and AWG

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
M27500-24BB()T13	M27500-24MM()T08	E3/E6 Models Only, Same Class
M27500-24BB()T13	M27500-24NA()T12	E3/E6 Models Only, Same Class
M27500-24BB()U00	M27500-24MM()U00	E3/E6 Models Only, Same Class
M27500-24BB()U00	M27500-24NA()U00	E3/E6 Models Only, Same Class
M27500-24BH()T19	M27500-24MM()T08	E3/E6 Models Only, Same Class
M27500-24BH()T19	M27500-24NA()T12	E3/E6 Models Only, Same Class
M27500-24BH()U00	M27500-24MM()U00	E3/E6 Models Only, Same Class
M27500-24BH()U00	M27500-24NA()U00	E3/E6 Models Only, Same Class
M27500-24MM()T08	M27500-24BB()T13	E3/E6 Models Only, Same Class
M27500-24MM()T08	M27500-24BH()T19	E3/E6 Models Only, Same Class
M27500-24MM()U00	M27500-24BB()U00	E3/E6 Models Only, Same Class
M27500-24MM()U00	M27500-24BH()U00	E3/E6 Models Only, Same Class
M27500-24MT()T12	BMS 13-51 Type XVIII	E3/E6 Models Only, Same Class, AWG 24
M27500-24MT()T12	M27500-24NA()T12	E3/E6 Models Only, Same Class
M27500-24MT()U00	M27500-24NA()U00	E3/E6 Models Only, Same Class
M27500-24MT1T12	M22759/6-()-9	E3/E6 Models Only, AWG 24
M27500-24NA()T12	BMS 13-51 Type XVIII	E3/E6 Models Only, Same Class, AWG 24
M27500-24NA()T12	M27500-24BB()T13	E3/E6 Models Only, Same Class
M27500-24NA()T12	M27500-24BH()T19	E3/E6 Models Only, Same Class
M27500-24NA()T12	M27500-24MT()T12	E3/E6 Models Only, Same Class
M27500-24NA()U00	M27500-24BB()U00	E3/E6 Models Only, Same Class

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
M27500-24NA()U00	M27500-24BH()U00	E3/E6 Models Only, Same Class
M27500-24NA()U00	M27500-24MT()U00	E3/E6 Models Only, Same Class
M81044/12-()-0	M81044/9-()-0	E3/E6 Models Only, Same AWG
M81044/12-()-9	M81044/16-()-9	E3/E6 Models Only, Same AWG
M81044/12-()-9	M81044/20-()-9	E3/E6 Models Only, Same AWG
M81044/12-()-9	M81381/21-()-9	E3/E6 Models Only, Same AWG
M81044/13-24-9	M81044/17-24-9	E3/E6 Models Only
M81044/13-24-9	M81044/22-24-9	E3/E6 Models Only
M81044/16-()-2	M81381/12-()-2	E3/E6 Models Only, Same AWG
M81044/16-()-9	M81044/12-()-9	E3/E6 Models Only, Same AWG
M81044/16-()-9	M81381/12-()-9	E3/E6 Models Only, Same AWG
M81044/17-24-9	M81044/13-24-9	E3/E6 Models Only
M81044/17-24-9	M81381/13-24-9	E3/E6 Models Only
M81044/20-()-2	M81381/12-()-2	E3/E6 Models Only, Same AWG
M81044/20-()-9	M81044/12-()-9	E3/E6 Models Only, Same AWG
M81044/20-()-9	M81381/12-()-9	E3/E6 Models Only, Same AWG
M81044/22-24-9	M81044/13-24-9	E3/E6 Models Only
M81044/22-24-9	M81381/13-24-9	E3/E6 Models Only
M81044/9-()-0	M81044/12-()-0	E3/E6 Models Only, Same AWG
M81381/12-()-2	BMS 13-51 Type XIV Class 1	E3/E6 Models Only, Same AWG
M81381/12-()-2	M81044/16-()-2	E3/E6 Models Only, Same AWG
M81381/12-()-2	M81044/20-()-2	E3/E6 Models Only, Same AWG
M81381/12-()-9	BMS 13-51 Type XIV Class 1	E3/E6 Models Only, Same AWG
M81381/12-()-9	M81044/16-()-9	E3/E6 Models Only, Same AWG
M81381/12-()-9	M81044/20-()-9	E3/E6 Models Only, Same AWG
M81381/12-()-9	M81381/12-()-N	E3/E6 Models Only, Same AWG
M81381/12-()-9	M81381/21-()-9	E3/E6 Models Only, Same AWG
M81381/12-()-N	M81381/12-()-9	E3/E6 Models Only, Same AWG
M81381/13-24-9	BMS 13-51 Type XVII Class 1	E3/E6 Models Only, AWG 24
M81381/13-24-9	M81044/17-24-9	E3/E6 Models Only
M81381/13-24-9	M81044/22-24-9	E3/E6 Models Only
M81381/13-24-9	M81381/13-24-N	E3/E6 Models Only
M81381/13-24-9	M81381/9-24-9	E3/E6 Models Only
M81381/13-24-N	M81381/13-24-9	E3/E6 Models Only
M81381/21-()-2	BMS 13-51 Type XIV Class 1	E3/E6 Models Only, Same AWG

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
M81381/21-()-9	BMS 13-16 Type I Class 1	E3/E6 Models Only, Same AWG
M81381/21-()-9	BMS 13-51 Type XIV Class 1	E3/E6 Models Only, Same AWG
M81381/21-()-9	M81044/12-()-9	E3/E6 Models Only, Same AWG
M81381/21-()-9	M81381/12-()-9	E3/E6 Models Only, Same AWG
M81381/9-24-9	BMS 13-16 Type I Class 1	E3/E6 Models Only, AWG 24
M81381/9-24-9	BMS 13-51 Type XVII Class 1	E3/E6 Models Only, AWG 24
M81381/9-24-9	M81381/13-24-9	E3/E6 Models Only
MI-5406, Times Wire Company	5020G3442, Raychem	-
MIL-C-17/113, RG-188	MIL-C-17/113, RG-316	-
MIL-C-17/113, RG-316	MIL-C-17/113, RG-188	-
MIL-C-17/127, RG-393	MIL-C-17/174-00001	-
MIL-C-17/155, RG-58	BA5903A, Surprenant	-
MIL-C-17/163, RG-213	5012F1339(), Raychem	-
MIL-C-17/163, RG-213	5012F1339(), Raychem	-
MIL-C-17/163, RG-8	5012F1339(), Raychem	-
MIL-C-17/164, RG-214	BA6903A, Surprenant	-
MIL-C-17/174-00001	MIL-C-17/127, RG-393	-
MIL-C-17/60, RG-142	421-176, Amphenol	-
MIL-C-17/75, RG-214	BA6903A, Surprenant	E3/E6 Models Only
MIL-C-17/95, RG-180	MIL-C-17/95, RG-195	-
MIL-C-17/95, RG-195	MIL-C-17/95, RG-180	-
MIL-W-22759/2-()1-9	BMS 13-60 Type 7 Class 1	Same AWG
MIL-W-7139, MIL-W-7078	BMS 13-60 Type 8	-
NYLAC-(XXX), Anaconda	JW1177/9-(XXX), Magnet Wire	-
NYLEZE-(XXX), Phelps Dodge	JW1177/9-(XXX), Magnet Wire	-
P606671, Axon	RSS-5-148B-16, Rockbestos	-
P606672, Axon	RSS-5-148B-18, Rockbestos	-
RSS-5-148B-16, Rockbestos	P606671, Axon	-
RSS-5-148B-18, Rockbestos	P606672, Axon	-
RSS-5-191, MIL-W-7139	BMS 13-60 Type 8	-
S280T001-1	S280T001-3	-
S280T006-2, Spoiler Cable	BMS 13-60 Type 24	Shield is not Solderable
S280W503-1	BMS 13-65 Type OE	-
S280W503-2	BMS 13-65 Type OF	-
S280W503-3	BMS 13-65 Type OG	-
S280W503-4	BMS 13-65 Type OH	-

WIRE TYPE CODES

Specified Wire	Alternative Wire	Special Conditions
S280W503-5	BMS 13-65 Type OJ	-
SS72016, Thermax	65B47866-5	-
TLA-150-(), Tensolite	BMS 13-60 Type 22	Same AWG
Type 2100-1-(), Filotex	BMS 13-58 Type I	-
W-1195-98, Witmore	1W014, Northrop Spec	E3/E6 Models Only
WARREN WW500, MIL-W-7139	BMS 13-60 Type 8	-
WC-101763, Al-Ch, Revere	853-4221172, Al-Ch, Pirelli	-
WC-62737, Al-Ch, Revere	852-4991972, Al-Ch, Specialty	-
WC101767, Al-Ch, Pirelli	853-4218376, Al-Ch, Pirelli	-
WW-63221, Cu-Cn, Revere	853-4125928, Cu-Cn, Pirelli	-
WW67587, Cu-Cn, Revere	853-4221073, Cu-Cn, Pirelli	-
BMS 13-51 Type XXIX Class 1	BWC-880079-1-(), Barcel	-
BMS 13-51 Type XXIX Class 1	18734/41225KA-1, Tensolite	-
BWC-880079-1-(), Barcel	BMS 13-51 Type XXIX Class 1	-
18734/41225KA-1, Tensolite	BMS 13-51 Type XXIX Class 1	-
BWC-880079-2-(), Barcel	BMS 13-51 Type XXIX Class 2	-
BMS 13-51 Type XXIX Class 2	BWC-880079-2-(), Barcel	-
BWC-880079-3-18, Barcel	BMS 13-51 Type XXIX Class 3	-
BMS 13-51 Type XXIX Class 3	BWC-880079-3-18, Barcel	-
BWC-880080-4-20, Barcel	BMS 13-51 Type XXIX Class 4	-
BMS 13-51 Type XXIX Class 4	BWC-880080-4-20, Barcel	-
BMS 13-51 Type XXX Class 1	12628 Type XXX Class 1	-
12628 Type XXX Class 1	BMS 13-51 Type XXX Class 1	-
BMS 13-51 Type XXX Class 2	12621/1 Type XXX Class 2	-
12621/1 Type XXX Class 2	BMS 13-51 Type XXX Class 2	-
BMS 13-51 Type XXX Class 3	13054 Type XXX Class 3	-
13054 Type XXX Class 3	BMS 13-51 Type XXX Class 3	-
BMS 13-51 Type XXX Class 1	12628 Type XXX Class 1	-
12628 Type XXX Class 1	BMS 13-51 Type XXX Class 1	-
BMS 13-51 Type XXX Class 1	12628 Type XXX Class 1	-
12628 Type XXX Class 1	BMS 13-51 Type XXX Class 1	-
24-00522, Champlain	24-00115, Champlain	-
24-00115, Champlain	24-00522, Champlain	-
24-00523, Champlain	24-00034, Champlain	-
24-00034, Champlain	24-00523, Champlain	-

INTERCHANGEABILITY OF WIRE AND CABLE

1. Interchangeable Wires and Cables

A. General Data

Table I, Table II, Table III, and Table IV:

- Give the interchangeability of the BMS 13-31, BMS 13-48, BMS 13-51 and BMS 13-60 wire and cable
- Contain only the equivalent wire Type or cable Type.

NOTE: The number of conductors, the size of conductor, and the color of the equivalent wire must be the same as the wire that is to be replaced.

B. BMS 13-48 and BMS 13-60

TABLE I
INTERCHANGEABILITY OF BMS 13-48 AND BMS 13-60

BMS 13-48	BMS 13-60
Type I	Type 1
Type III	Type 2
	Type 13
Type IV	Type 14
	Type 3
Type VI	Type 5
Type VIII	Type 1
Type X	Type 1
Type XII	Type 2
Type XIII	Type 5
Type XIV	Type 3
Type XV	Type 2
Type XXIV	Type 5
Type XXV	Type 2
	Type 13

INTERCHANGEABILITY OF WIRE AND CABLE

BMS 13-48	BMS 13-60
Type XXVI	Type 5
	Type 15

C. BMS 13-31 and BMS 13-60

TABLE II
INTERCHANGEABILITY OF BMS 13-31 AND BMS 13-60

BMS 13-31	BMS 13-60
Type I	Type 7
Type III	Type 8
Type IV	Type 9
Type V	Type 10
Type VII	Type 11

D. BMS 13-51 and BMS 13-60

TABLE III
INTERCHANGEABILITY OF BMS 13-51 AND BMS 13-60

BMS 13-51	BMS 13-60
Type I	Type 4
Type VI	Type 5
Type VII	Type 6
Type VIII	Type 1
Type IX	Type 2
Type X	Type 3
Type XI	Type 4
Type XII	Type 5
Type XIV	Type 1
Type XV	Type 2
Type XVI	Type 3
Type XVII	Type 4
Type XVIII	Type 5
Type XXVI	Type 4
Type XXVII	Type 5
Type XXIX	Type 4

INTERCHANGEABILITY OF WIRE AND CABLE

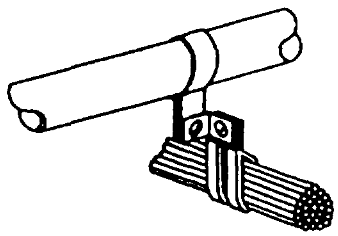
BMS 13-51	BMS 13-60
Type XXX	Type 5

E. BMS 13-51 and BMS 13-48

TABLE IV
INTERCHANGEABILITY OF BMS 13-51 AND BMS 13-48

BMS 13-51	BMS 13-48
Type VIII	Type X
Type IX	Type XII
Type X	Type XIV
Type XI	Type XI
Type XII	Type XIII
Type XIV	Type X
Type XV	Type XII
Type XVI	Type XIV
Type XVII	Type XI
Type XVIII	Type XIII
Type XXVI	Type XXXI
Type XXVII	Type XXXII
Type XXIX	Type XXXI
Type XXX	Type XXXII

NOTE: This minimum clearance can be reduced when a positive separation is made sure by mechanical support. Refer to Figure 1.



POSITIVE SEPARATION
Figure 1

(3) Maintain a 1/2 inch minimum clearance for lines that carry water and Pitot static lines.

NOTE: This minimum clearance can be reduced when a positive separation is made sure by mechanical support. Refer to Figure 1.

(4) For bleed air ducts:

(a) Maintain a 2 inch minimum from the top of the ducts

(b) Maintain a 1 inch minimum from the sides and bottom of the ducts.

B. General Wire Harness Requirements

(1) In all areas except the engine areas, the length of the wire harnesses between clamps can touch smooth flat surfaces and smooth, 1/8 inch minimum radii of either metal or plastic.

(2) Do not use 66-3539-() insulated retainer rings where the electrical wire harnesses are routed through any insulation blankets.

(3) For unshielded AWG 22 or smaller wire, use either of these methods:

- Put 3 or more wires into a harness
- Clamp the wire or wires to the structure at intervals of 6 inches or less.

(4) Put production copper to aluminum wire power feeder splices in such a position so that the splices are outboard of the power feeder separation device in the leading edge of the wing.

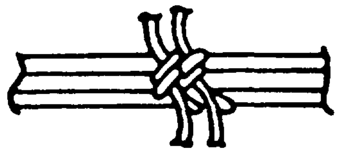
(5) Several wire harnesses can be routed in the same raceway or in one clamp.

CAUTION: MAKE SURE ALL CHANNEL SEPARATION REQUIREMENTS ARE MET.

(6) Do not tie wire harnesses together unless support for small wire harnesses is required.

(7) Use BACS38K() plastic straps as an alternative to BMS 13-54 lacing tape in pressurized areas.

NOTE: BACS38K() plastic straps have been used on wire harnesses in the unpressurized areas. This installation is acceptable.



TWO TIES IN THE SAME LOCATION
Figure 2

C. Assembly of Ties

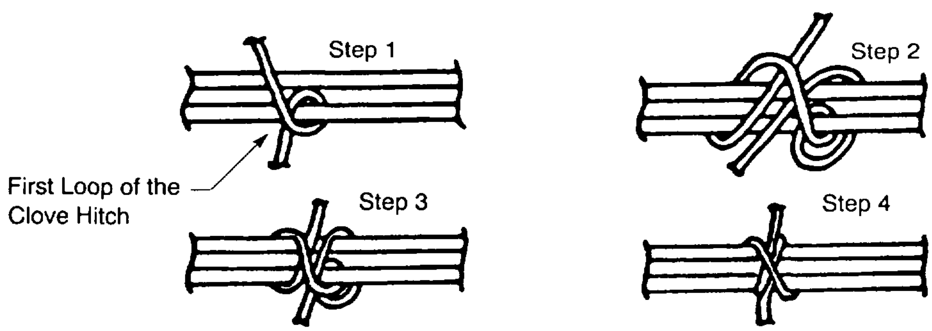
(1) Make the first loop of the clove hitch on the harness. Refer to Figure 3.

<u>CAUTION</u>: DO NOT MAKE THE FIRST LOOP ON:

- A THERMOCOUPLE CABLE (YELLOW JACKET)
- A THERMOCOUPLE WIRE (RED OR YELLOW INSULATION).

(2) Complete the clove hitch on the harness. Refer to Figure 3 and Figure 4.

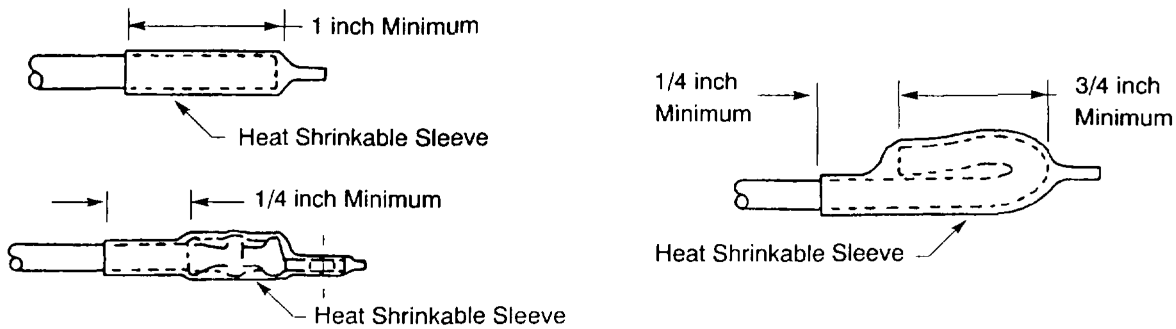
Make sure that the knot is tight.



STEPS TO MAKE A CLOVE HITCH KNOT
Figure 3

(3) Assemble a tie to hold the sleeve. Refer to Figure 4.

C. Installation of a Heat Shrinkable Sleeve



HEAT SHRINKABLE SLEEVES
Figure 5

(1) Make a selection of a heat shrinkable sleeve. Refer to Subject 20-00-11.

(2) Put the sleeve on the wire so that the terminal or the end of the wire is contained in the sleeve. Refer to Figure 5.

Make sure that the wire insulation is not removed from the free end of the wire.

(3) Shrink the sleeve into position. Refer to Subject 20-00-14.

D. Installation of a Crimp Type End Cap

TABLE XXIV
END CAP CRIMP TOOLS

End Cap	Crimp Tool	
	Basic Unit	Color
324484	46063	-
324485	46063	-
324486	46063	-
324487	46063	-
324854	69272-1 WA27XE-EP	Green
328855	69272-1 WA27XE-EP	Green
328856	69272-1 WA27XE-EP	Green

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

17 June 1998
B-B600-16433-ASI

Mr. R. Swaim, AS-40
National Transportation Safety Board
490 L'Enfant Plaza East, S.W.
Washington D.C. 20594-2000

BOEING

Subject: Recovered Wiring, TWA 747-100 N93119 Accident off Long Island, NY - 17 July 1996

Reference: Your email to Dennis Rodrigues, dated 28 May 1998

Dear Mr. Swaim:

In your reference message you requested assistance in trying to estimate the amount of wiring recovered from the accident airplane.

The enclosed report provides details of the wiring recovered and identified, by wire bundle. If you have any questions, please do not hesitate to call.

Very truly yours,

for John W. Purvis
Director, Air Safety Investigation
Org. B-B600, M/S 67-PR
Telex 32-9430, STA DIR PURVIS
Phone (425) 237-8525
Fax (425) 237-8188

Enclosures: As noted, 4 pages

cc: Mr. A. Dickinson, IIC

3112

Subject: Quantify Percentage of Wiring Recovered during February 13, 1998, Systems Group Activities, Calverton, NY.

Group: Post Production Engineering, B-E214.

Reference: NTSB field notes, "Systems Sub-group for Wiring", dated February 13, 1998.

Summary:

In this report we have calculated the approximate percentages of wire and wire bundles recovered from the Boeing 747-131, N93119, used on Trans World Airlines Flight 800. The data used for these calculations was compiled from the NTSB field notes, "Systems Sub-group for Wiring", dated February 13, 1998.

We have calculated the percent of recovered and missing wires as follows; Approximately 91% of the W480 wire bundle, used in the center tank fuel quantity and ground refueling systems, has been recovered (Per the reference field notes, all but eight feet of the bundle was recovered and identified). In examining the primary Fuel Quantity Indication Bundles W480, W332, and W864, we found that approximately 30% of the wiring from these bundles combined were recovered. The Fuel Quantity Indication bundles begin at the Flight Engineers panel and end at the left and right Wing/Body disconnects for the Main Fuel Tanks, and the rear spar connector for the Center Fuel Tank.

In addition to the primary FQIS wire bundles, a calculation was made of the total number of wire bundles identified in the referenced field notes. Approximately 21% of the wire segments of all the identified wire bundles were recovered. This is based on the last known configuration of these bundles to Boeing, and the length in feet of recovered wiring from these bundles out of the total length (in feet) that should be present in each bundle. Since individual wire segments in each bundle have not been consistently accounted for, the percentages given are likely high. The number of bundles examined and identified in the field notes, represent less than 3.5% of the wire bundles installed on the 747-131 (Flight 800) at the time of delivery.

How calculations were made:

Because all FQIS and related wire bundles identified in the field notes, were not identified by wire segment, approximations were made in calculating the total lengths and percentages of wire recovered. When a range of lengths was given for recovered segments of a wire bundle, the average length was used to calculate the percentage. The number of wires recovered and associated with a particular wire bundle were multiplied by the average length, unless a length was given for all segments recovered. This number was then divided by the total length of all the wires identified in Boeing records (our last known) for that particular bundle configuration. In a few cases the number of wire segments found exceeded the number of wires in the last known (to Boeing) design of the particular bundle. In these cases the maximum number of wires fitting the characteristics of the wire bundle, per our records, was multiplied by the average length. For wire bundle W480 the reference field notes specified that all but eight feet was recovered, we subtracted this length from each of the wire segments in the bundle, totaled these numbers, and divided this sum by the lengths of all segments of wire recorded in our documentation the wire bundle.

4/12

Details based on wiring recovered and identified in the referenced field notes:

BUNDLE	# OF WIRES	LENGTH(feet)	% RECOVERED	NOTES
W480	9	N/A	91.4%	all but 8 ft recovered
W292	0.0	0.0	0.0%	
W294	4	24, 10, 4.5	35.3%	
W1036	4	14, 19.5	37.85%	
W1520	18	6.5	18.0%	
W330	30,24	9,18	35.1%	
W332	11	5, 10.8, 20, 25	40.4%	
W366	13, 3, 11, 9	5, 11.25, 7.5, 18.3	11.36%	
W370	6, 3, 14	12.92, 26.25, 17.5	23.35%	
W844	2	3.3	.90%	wires; C802 & C1625
W275	10	11.67	24.6%	
W384	13	18.3	20.37%	data had more wires than records show for this bundle
W418	37	28.3	49.0%	
W528	0.0	0.0	0.0%	
W632	14	14.2	13.96%	
W634	13	16.25	13.12%	
W684	10	10, 12.1	26.12%	1 wire in 1st segment was 26.7 ft
W772	9,13,13,10	4.58, 16.67, 15.4, 18.3	44.0%	according to our records the twisted pair and triplets identified are not part of bundle W772
W796	7, 10	10.8,29.2	42.4%	
W792	0.0	0.0	0.0%	
W795	0.0	0.0	0.0%	
W798	0.0	0.0	0.0%	
W846	5, 6, 5	20.8, 7.2, 15	34.1%	according to our records the twisted wire identified is not part of bundle W846
W848	17	24.75	22.3%	
W932	0.0	0.0	0.0%	
W934	0.0	0.0	0.0%	
W994	8, 6	26.25, 15.8	20.7%	
W1186	5, 9, 4	5.4, 10.8, 23.75	20.7%	5.4 ft of wires: Q66, Q67,Q68,W75,W442
W1192	6, 3, 3	8.33, 21.67, 11.67	17.6%	
W1362	13, 12, 12, 12	23, 7.9, 18.75, 9.2	44.76%	

5/12

BUNDLE	# OF WIRES	LENGTH(feet)	% RECOVERED	NOTES
W1478	0.0	0.0	0.0%	
W1648	7, 5	10, 15	42.6%	
W1560	22	22.08	50.5%	
W186	1, 1(Q383), 1(Q325), 9	.83, .5, 2, 4.56	1.2%	9 wires:N1070, Q621, Q623, Q326, Q622, Q325, Q383, Q619, Q20
W985	0.0	0.0	0.0%	
W066	18	5	14.95%	wires: Q1211, Q1219, Q1213, Q229, Q1215, Q228, Q227, Q1218, Q1214, Q632, Q622, Q642, Q612, Q607, Q227, Q527, Q1212, H113
W326	12	23	23.23%	
W342	0.0	0.0	0.0%	
W350	13, 13, 27	26.67, 24.58, 25	58.7%	wires: Q228, Q227, Q617, Q637, Q632, Q622, Q607, Q384, Q612, Q242, 1E76, 1Z1; 1E1, 1E3-6, 1E87, 1E46, 1E42, 1E12, Q1003
W378	0.0	0.0	0.0%	
W517	0.0	0.0	0.0%	
W531	0.0	0.0	0.0%	
W810	0.0	0.0	0.0%	
W1360	16, 22	25, 5	41.0%	wires: 4E1, 4E3-6, 4E8, 4E42, 4E12, 4E221, 4E69, 4E46, 4E75, Q1006, 4J67, 4Z1, 4D98; connector D1410J wires
W580	20	27.5	17.4%	
W1378	0.0	0.0	0.0%	
W304	0.0	0.0	0.0%	
W404	0.0	0.0	0.0%	
W748	3, 11	5, 20.8	19.0%	
W750	17	15.42	9.8%	
W740	0.0	0.0	0.0%	

6/12

BUNDLE	# OF WIRES	LENGTH(feet)	% RECOVERED	NOTES
W144	44	full length	40.0%	used full wire lengths for reported connectors: DN051M, DN052M, DN053M, DN054M, DN055M, D2804J
W365	1	1.17	.23%	wire N36

General Notes:

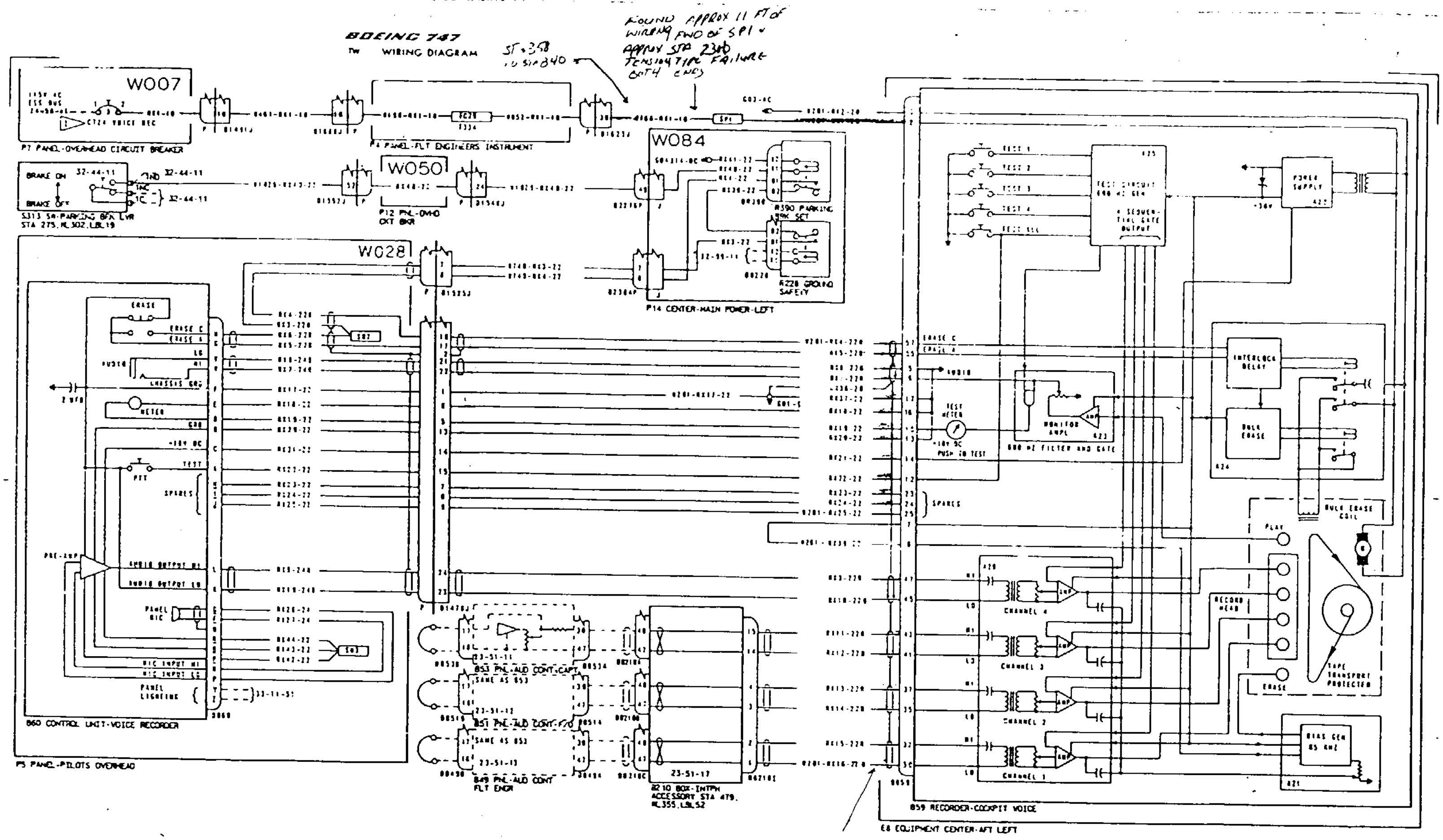
- Out of more than 1023 bundles present on Boeing 747-131 (Flight 800) at delivery, 36 were recovered and identified in the referenced field notes, accounting for less than 3.52 % of the total number of wire bundles on the accident aircraft. The number of total wire bundles does not include Vendor built bundles controlled by Specification Drawings, or bundles purchased from Vendors. In addition, the numbers are not reflective of bundles that are multiple issue - usually payload systems related - such as window reveals or passenger service units.
- The total sum of wire lengths found and identified in the field notes was calculated to be 13,025.65 feet out of a total 61,772.5 feet listed in our records (last known configuration to Boeing) for these bundles, accounting for approximately 21.09% of the wiring in the bundles examined.

Prepared by: Leah N. Burk
Leah N. Burk
747 Post Production Engineering
System Installation Design & Processes

Concurrence by:
L. W. Williams II
Principal Technical Designer
747 Post Production Engineering
System Installation Design & Processes

Approved by:
C. A. Mitchell
Supervisor
747 Post Production Engineering
System Installation Design & Processes

7/12



NOTES:

1 5 AMP FOR 107-999 (RA107-RA199)

DRAFTED BY

CHECKED BY

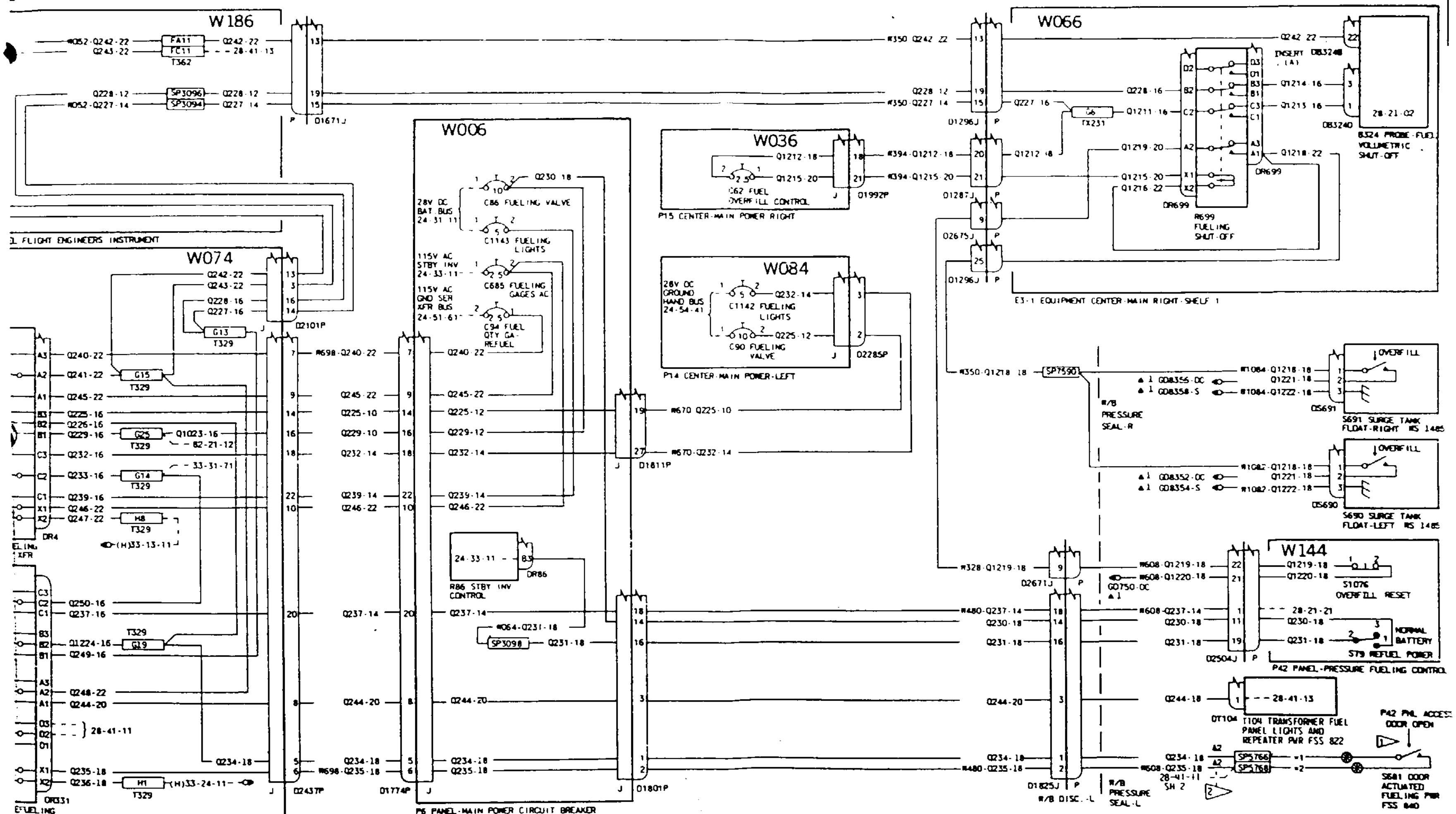
DRAWING NO 61074102

PAGE DATE: SEP 10/73

ECN R CHANGE

TWA	DWG NO.	SHT	VOICE RECORDER
		1	EFFECTIVITY: ALL

23-71-11
PAGE 1



‡ MAGNET ACTUATED REED PROXIMITY SWITCH

EQUIPMENT LIST CHANGES:
AFTER INC OF SB 32-2141R1 REPLACE PART NUMBERS FOR D2285J (P/N BACC45FN14-4S) WITH P/N BACC45FN18-8S & D2285P (P/N BACC45FT14-4P) WITH P/N BACC45FT18-8P.

2 119 (RA164) AFTER INC. OF SB 28-2069 (R1).

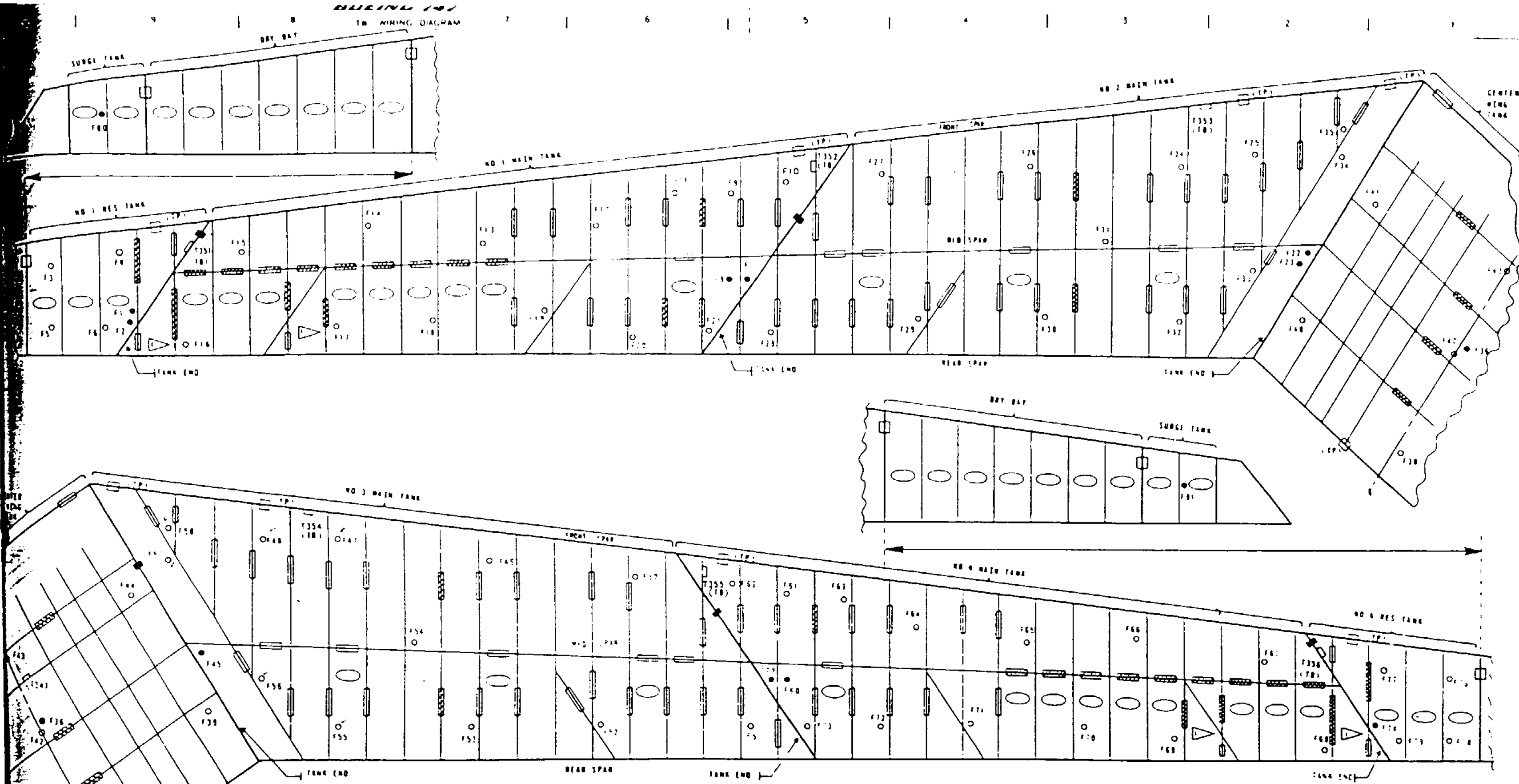
INCORPORATES:
MO 88134 (SB 33-2031) 118-119 (RA163-RA164)
SB 32-2141R1
SB 28-2069 (R1) FOR 119 (RA164)

M.O. 88134	FUEL QUANTITY- AC AND DC POWER
TWA — DWG NO 1-84253, SHT 3, CHG	EFFECTIVITY 118-119
RA163 - RA164	747-131

61874702 MAR 1/81

DCN V CHANGE.

28-21-11
PAGE 3



NOTES

1. PROBES F16 F17 F68 F69 LOCATED JUST OUTBOARD OF ADJACENT RIBS ON SOME AIRPLANES
2. WIRING DIAGRAM FOR LEFT WING AND CENTER TANK SEE 28-41-21 FOR RIGHT WING SEE 28-41-22

- ACCESS DOOR
- ACCESS HOLE
- CABLE CONNECTOR ASSEMBLY
- ○ FUEL QUANTITY TANK UNIT
- ● FUEL QUANTITY COMPENSATOR
- UNDERWING ACCESS
- SEAL LOCATIONS
- TP TEST POINT
- TB TERMINAL BOARD

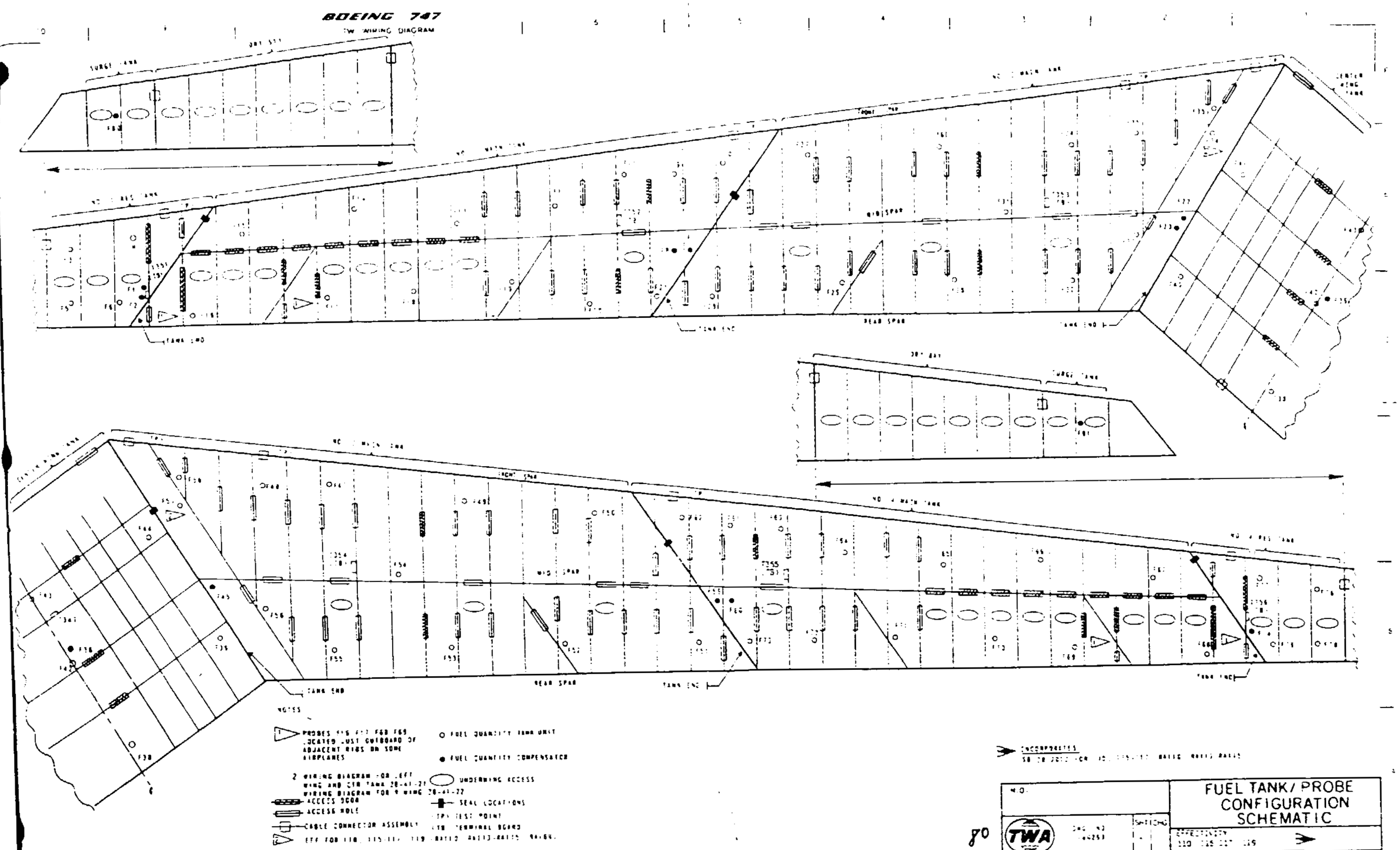
INCORPORATES SB 28-2012 FOR 186-189

M.O	FUEL TANK / PROBE CONFIGURATION SCHEMATIC
TWA — DWG NO 1-84263 — SH 1 — CHG	EFFECTIVITY 186 189

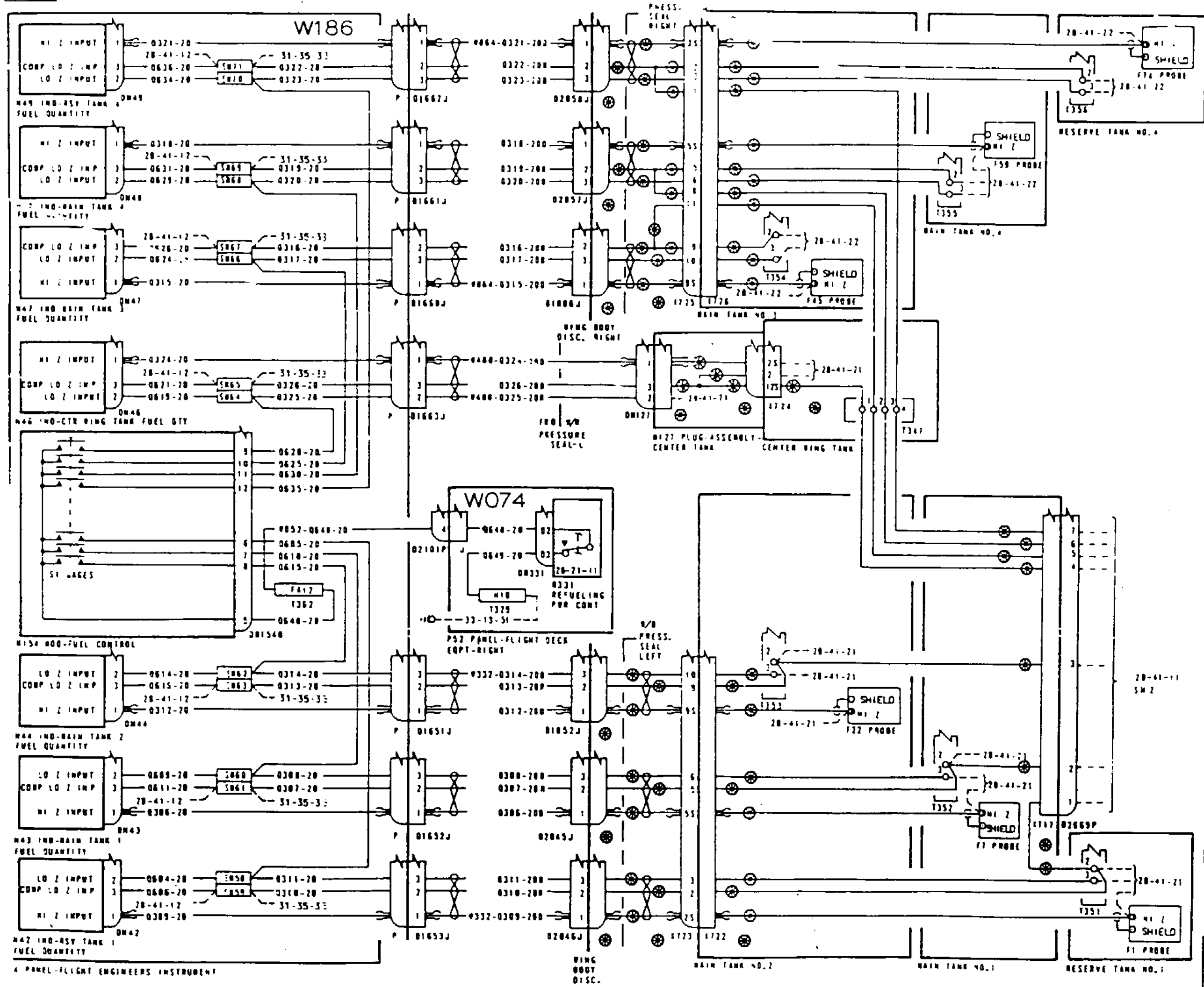
79

OCN 0
CHANGE ADCN 6049

28-41-01
PAGE 101



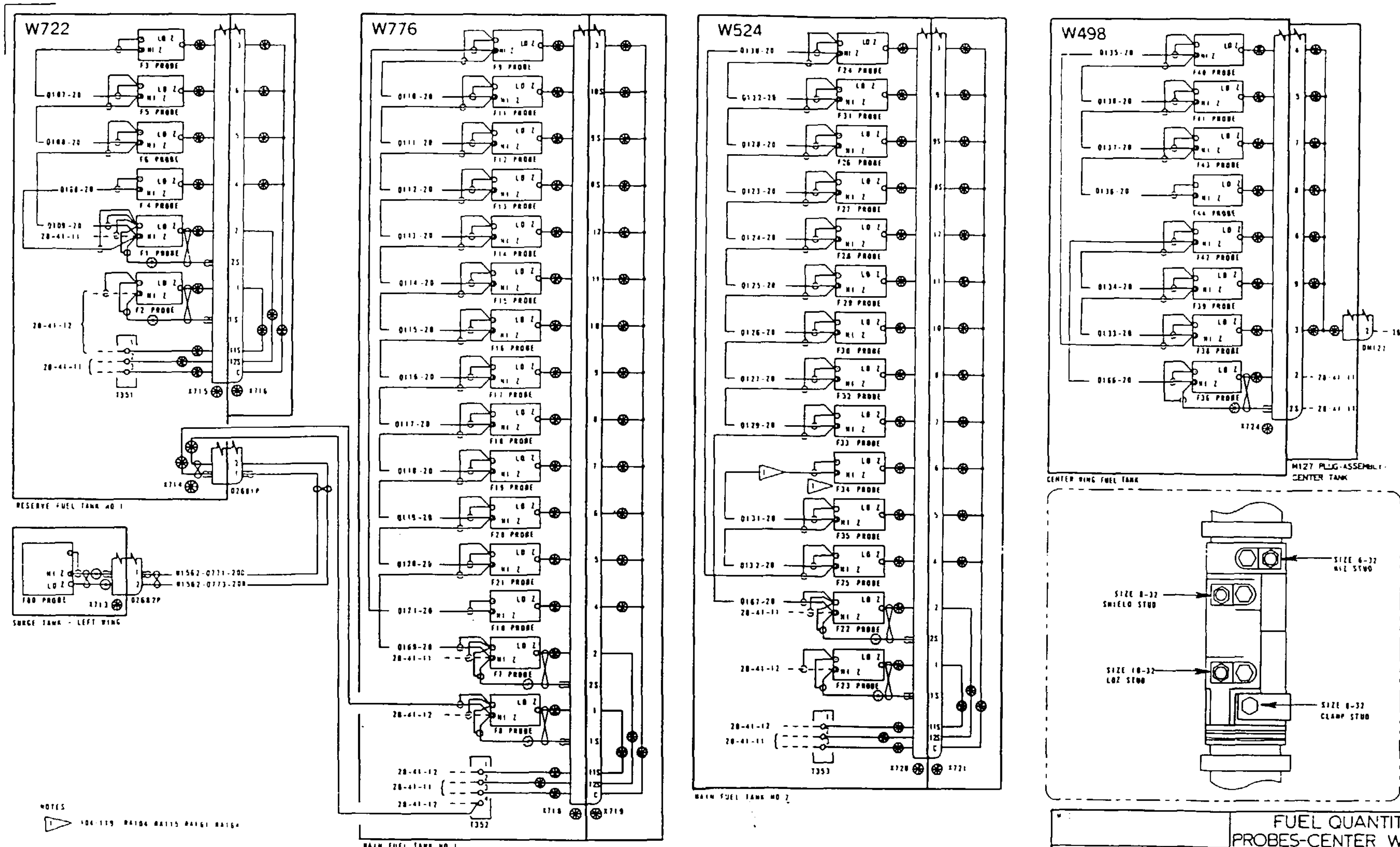
28-41-01
PAGE 102



INCORPORATES

M.O.	FUEL QUANTITY GAGES-SIGNAL 1		
DRAWING NO. 1-8426A	SHT	CHG	EFFECTIVITY

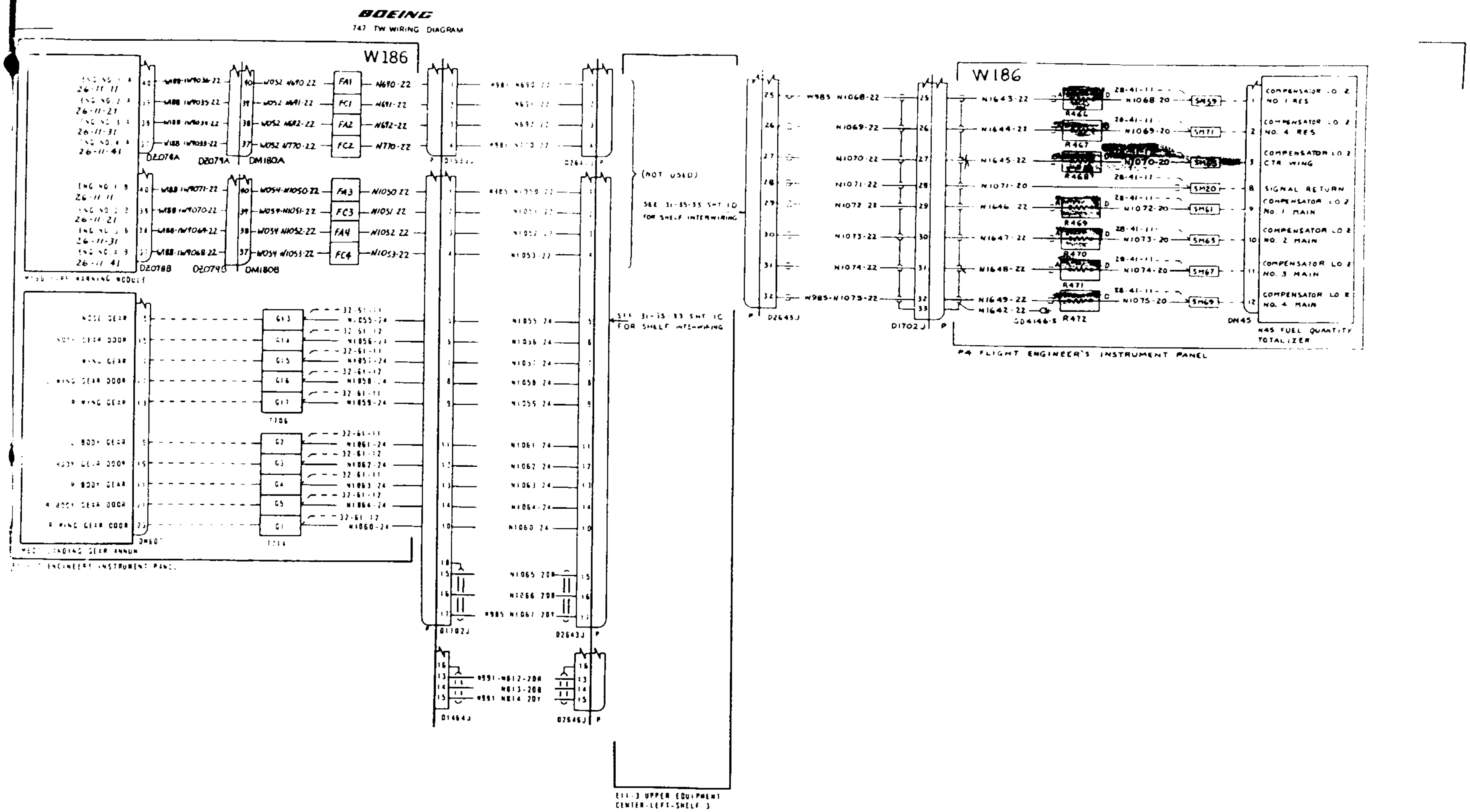
28-41-11
SH1 PAGE 4



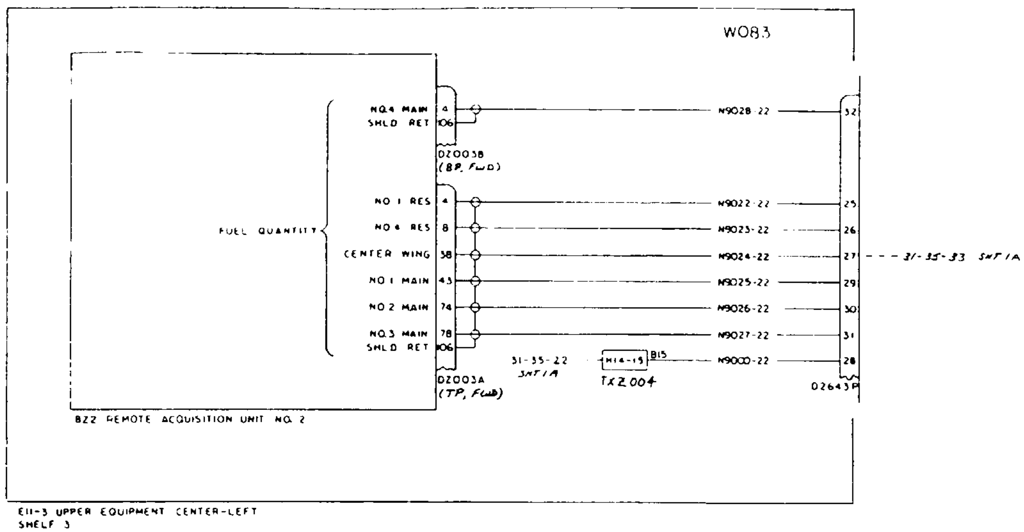
FUEL QUANTITY
PROBES-CENTER WING
AND LEFT WING

TWA

28-41-21
PAGE 2



AIDS-PARAMETERS - INS NO.2	
TWA	SHT 1A, CHG D
EFFECTIVITY	101 - 199



1-84308

31-35-33
PAGE 1 SHT 5

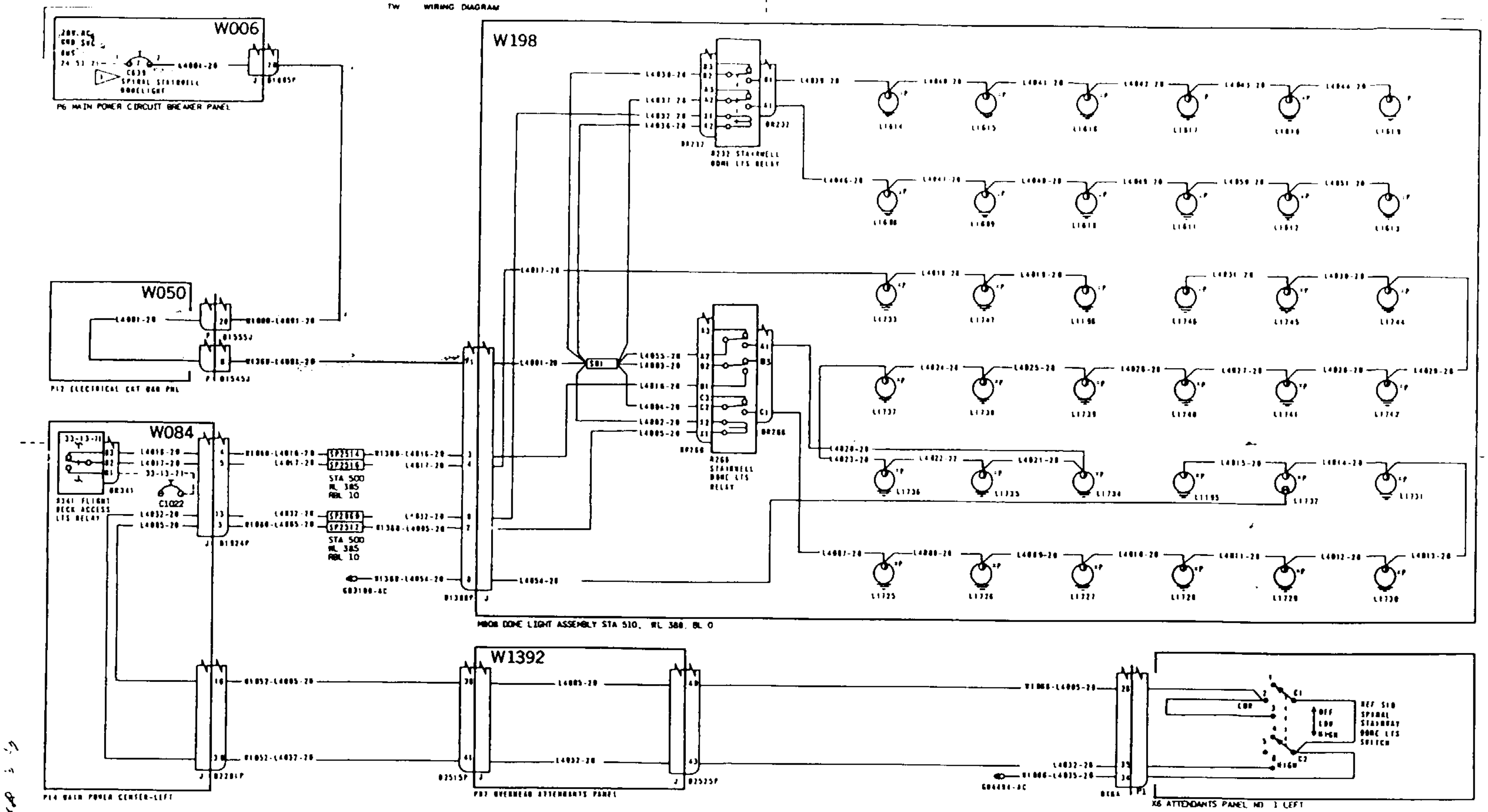
MODEL	747-131	101-199
STRUCTURES		
PROJ. ENG.	W. D. GREEN	
CHECKED		1/9/70
DRAWN	L. L. Corlew	12/4/69

NAME OF PART	AIDS-PARAMETERS INS NO 1
SCALE	E.O. 84872
	1-84309
CHG.	A
	SHT 1D

31-35-33
PAGE 1 SHT 5

4-303

BOEING 747
TW WIRING DIAGRAM



NOTES

(RA107-RA199) USE 7.5 AMP C/B

DRAFTED BY
CHECKED BY

TWA			DOME LIGHTS – SPIRAL STAIRWELL
			EFFECTIVITY ALL

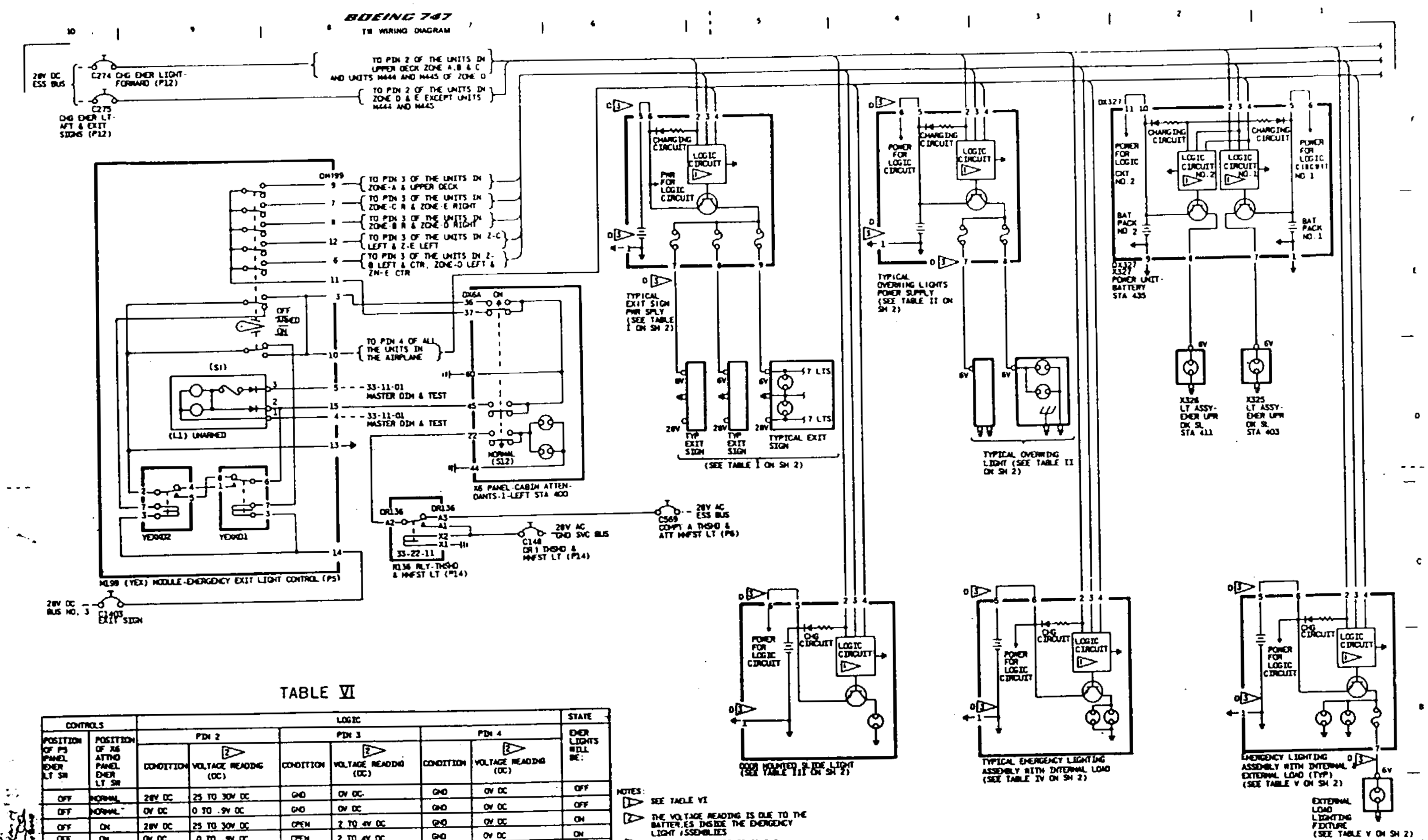


TABLE VI

CONTROLS		LOGIC						STATE
		PIN 2		PIN 3		PIN 4		
POSITION OF P5 PANEL EMER LT SW	POSITION OF X6 ATTND PANEL EMER LT SW	CONDITION	VOLTAGE READING (DC) [2]	CONDITION	VOLTAGE READING (DC) [2]	CONDITION	VOLTAGE READING (DC) [2]	EMER LIGHTS WILL BE:
OFF	NORMAL	28V DC	25 TO 30V DC	GND	0V DC	GND	0V DC	OFF
OFF	NORMAL	0V DC	0 TO .9V DC	GND	0V DC	GND	0V DC	OFF
OFF	ON	28V DC	25 TO 30V DC	OPEN	2 TO 4V DC	GND	0V DC	ON
OFF	ON	0V DC	0 TO .9V DC	OPEN	2 TO 4V DC	GND	0V DC	ON
ARM	NORMAL	28V DC	25 TO 30V DC	OPEN	2.5 TO 5.5V DC	OPEN	2.5 TO 5.5V DC	OFF
ARM	NORMAL	0V DC	0 TO 1V DC	OPEN	2.5 TO 5.5V DC	OPEN	2.5 TO 5.5V DC	ON
ARM	ON	28V DC	25 TO 30V DC	OPEN	2 TO 4V DC	GND	0V DC	ON
ON	NORMAL	28V DC	25 TO 30V DC	OPEN	2 TO 4V DC	GND	0V DC	ON
ON	NORMAL	0V DC	0 TO .9V DC	OPEN	2 TO 4V DC	GND	0V DC	ON

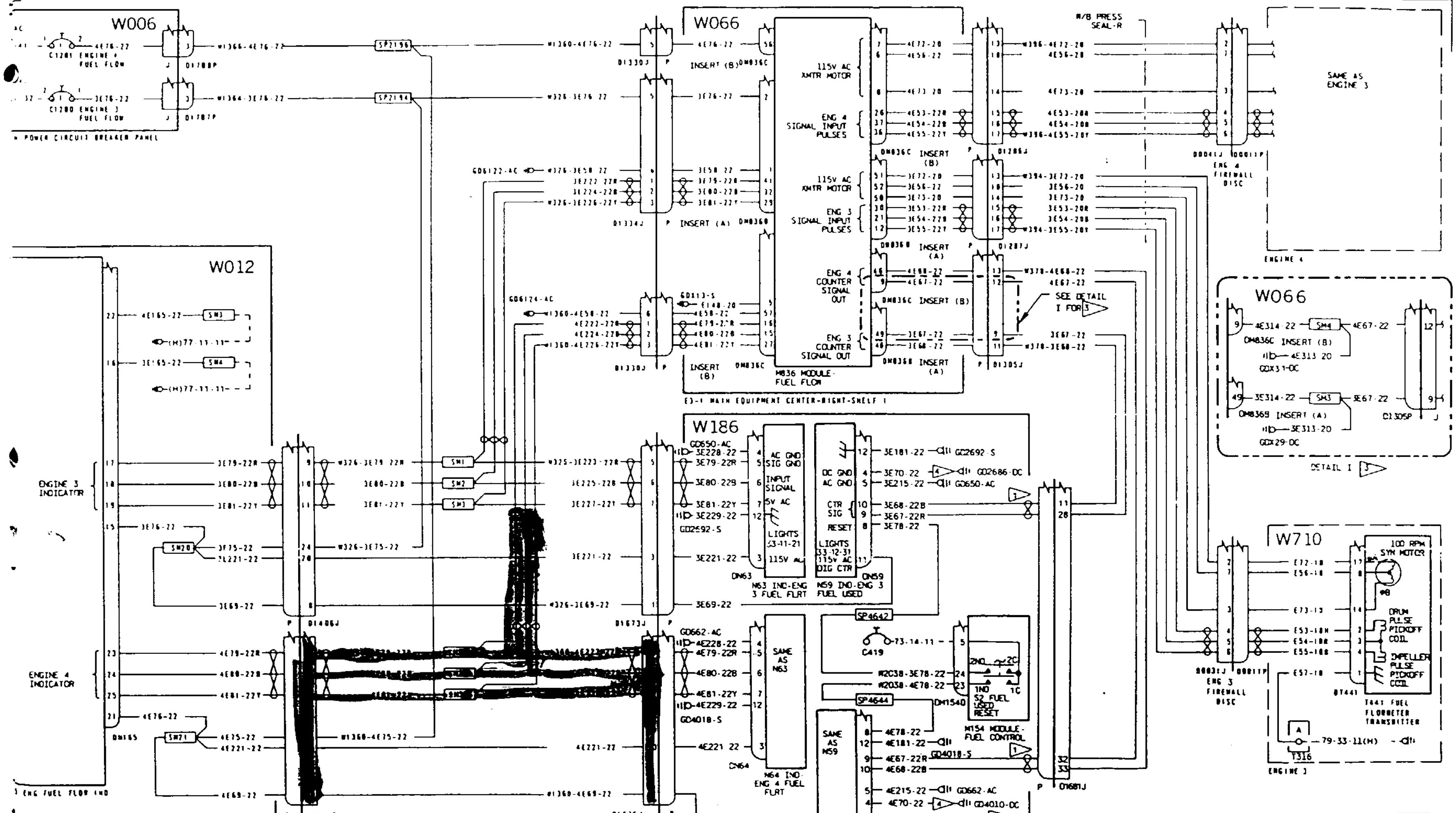
NOTES:
[1] SEE TABLE VI
[2] THE VOLTAGE READING IS DUE TO THE BATTERIES INSIDE THE EMERGENCY LIGHT ASSEMBLIES
[3] SUFFIX ITEM NO. OF EQUIPMENT

DRAWN:
CHECKED:
SYS APVD:
DRAWING NO: 61B74702
PAGE DATE: SEP 23/77
DCN: 8
CHANGE:

M.O.

EMERGENCY LIGHTS SCHEMATIC

TWA
DWG NO 1-64617 SH 3A CHG
EFFECTIVITY 111, 119

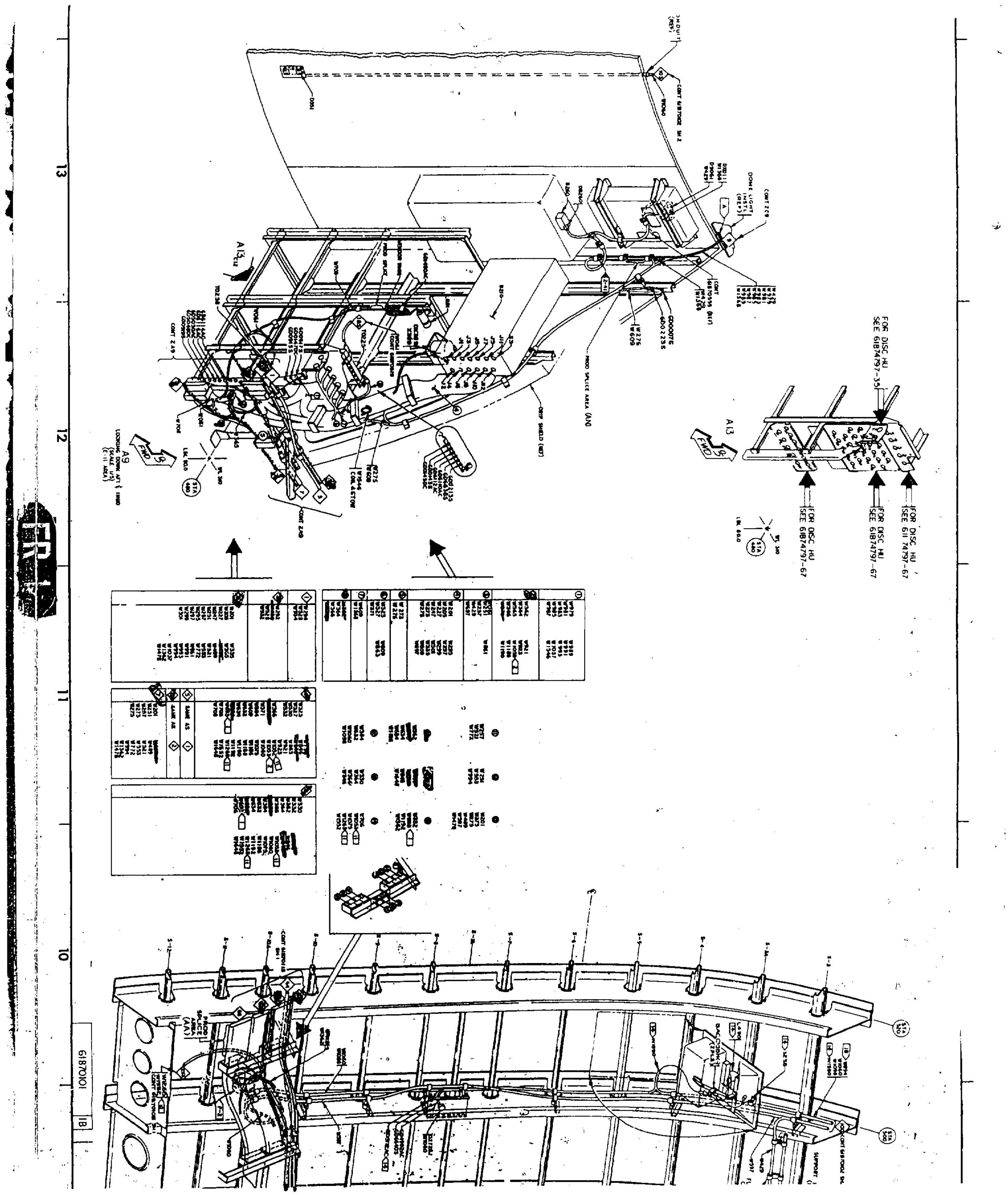


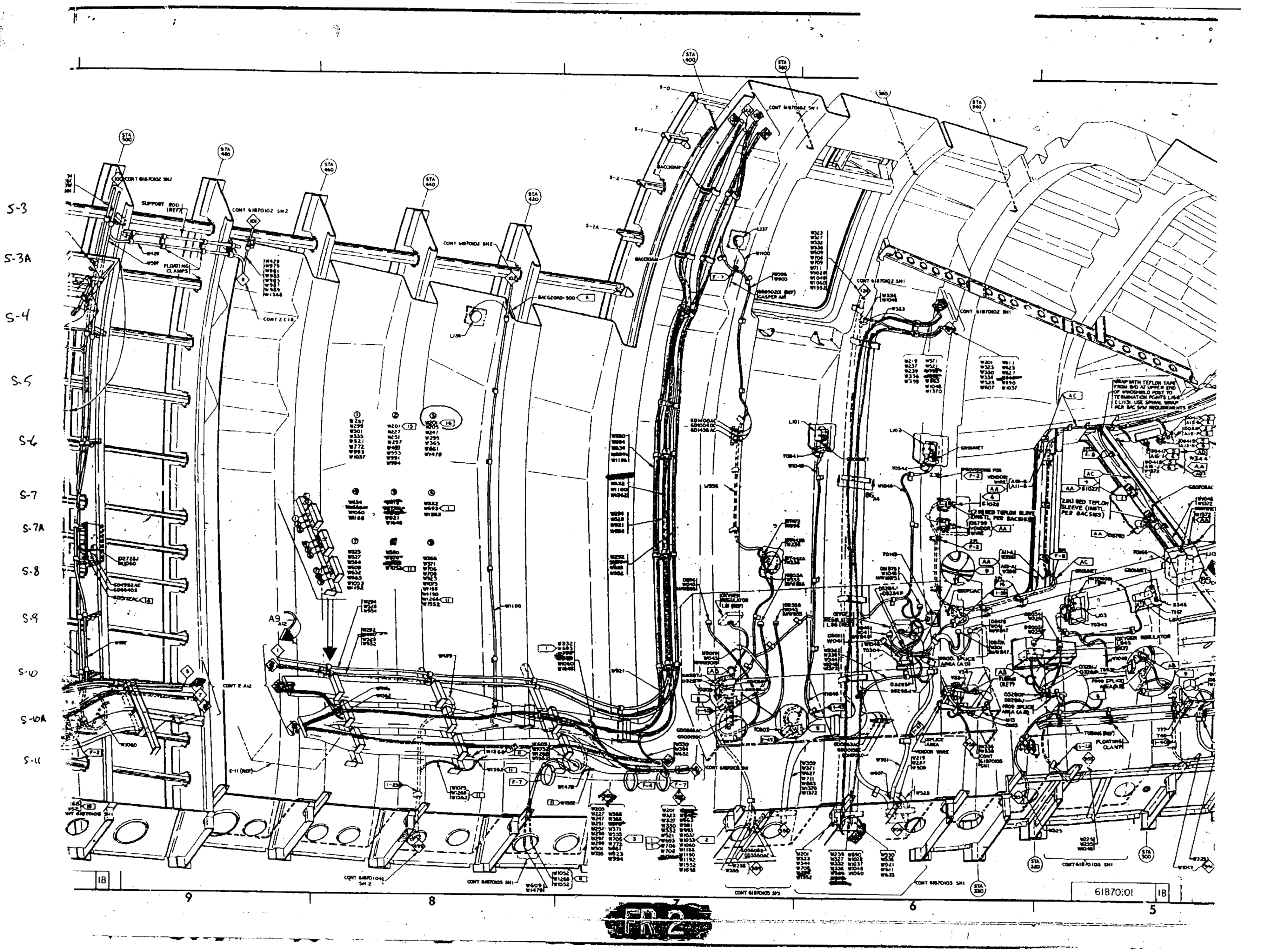
EL-PILOTS CENTER INSTRUMENT

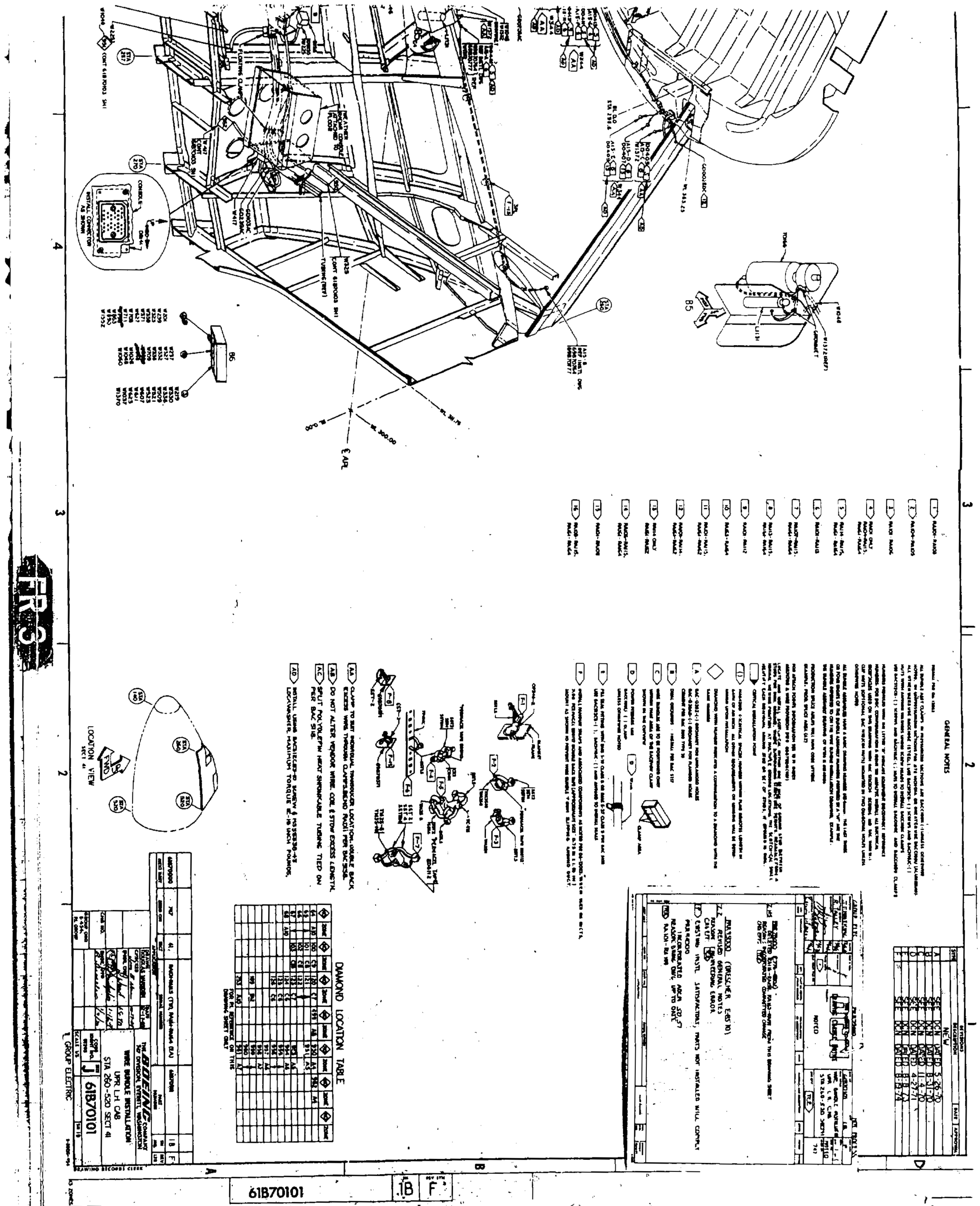
1. TWISTED PAIR FOR 115, 118-999 (RA113-RA113, RA116-RA159, RA163-RA199)
2. GD4172-DC FOR 115, 118-119 (RA113-RA113, RA163-RA164)
3. ALL EXCEPT 101-119 (EFF FOR RA116-RA159, RA165-RA199)
4. 101-119 (RA101-RA115, RA161-RA164)

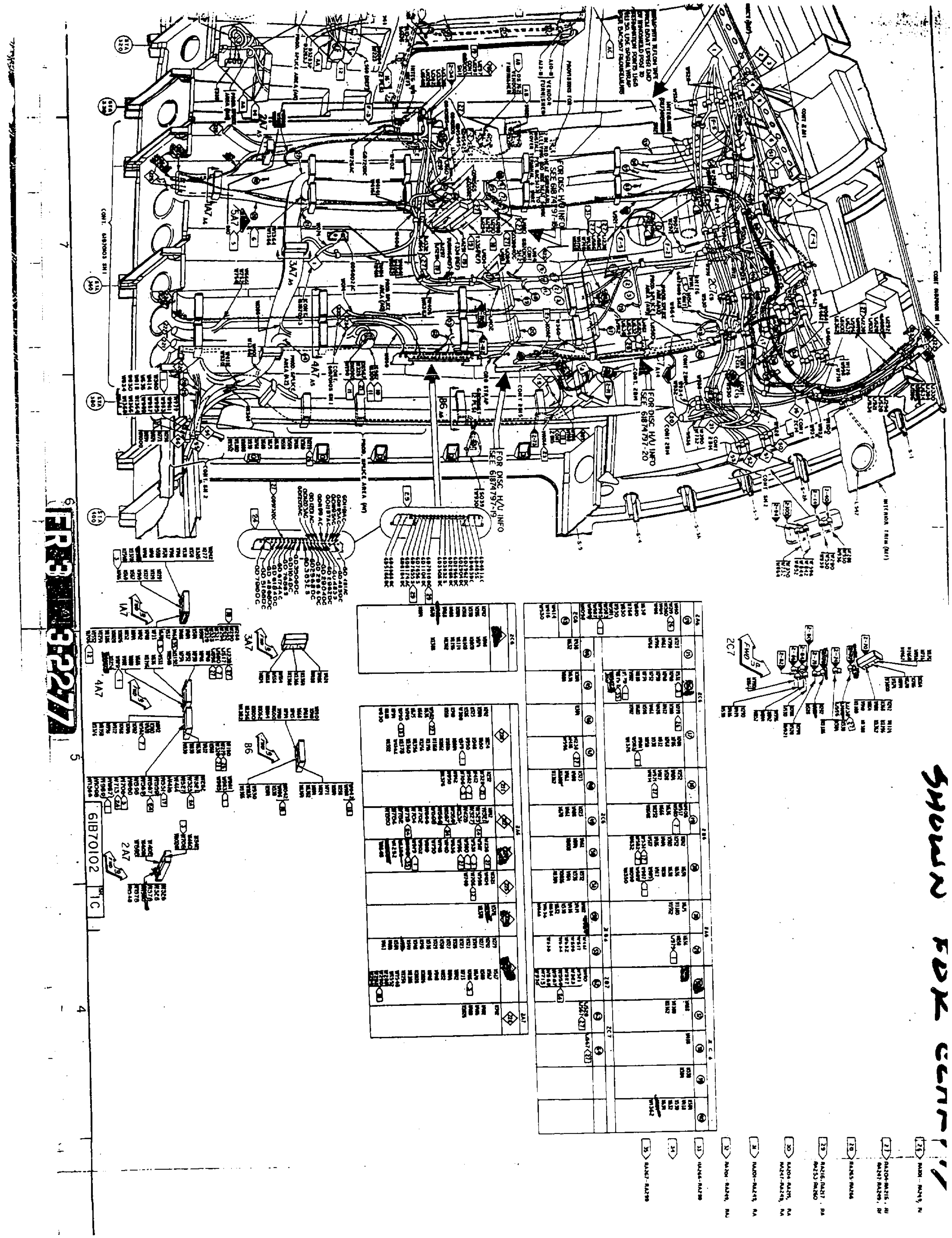
61874782 OCT 9/72 — DCN N CHANGE

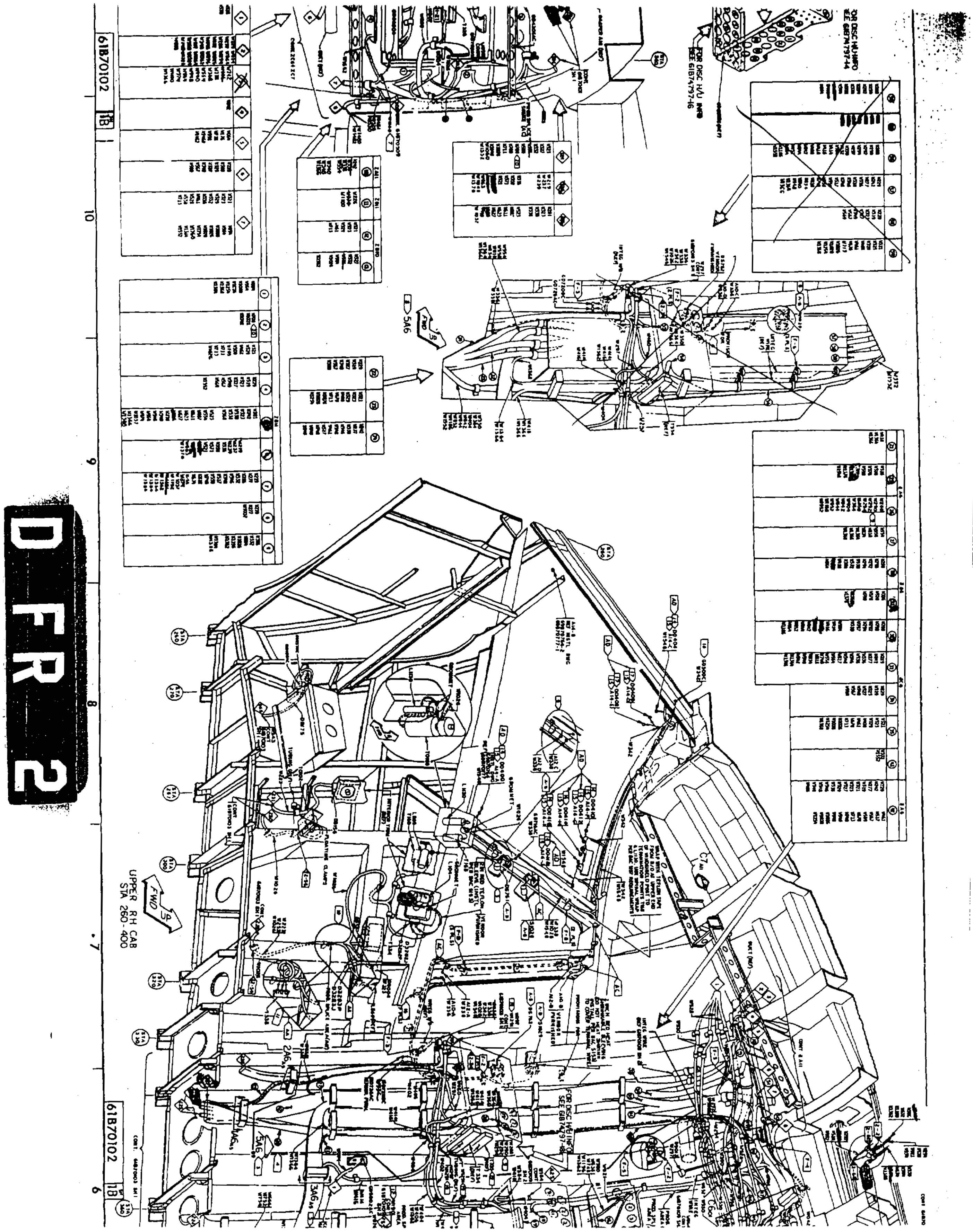
W.O.	FUEL FLOW METER-ENGINE 3 AND 4
TWA — DWG NO 1-84551 — SHT 1	EFFECTIVITY ALL
RA101-RA199	


FOR DISC HU SEE 61B74797-35
FOR DISC HU SEE 61B74797-67
FOR DISC HU SEE 61B74797-67
FOR DISC HU SEE 61 74797-67
A13
A9
61B70101
1B

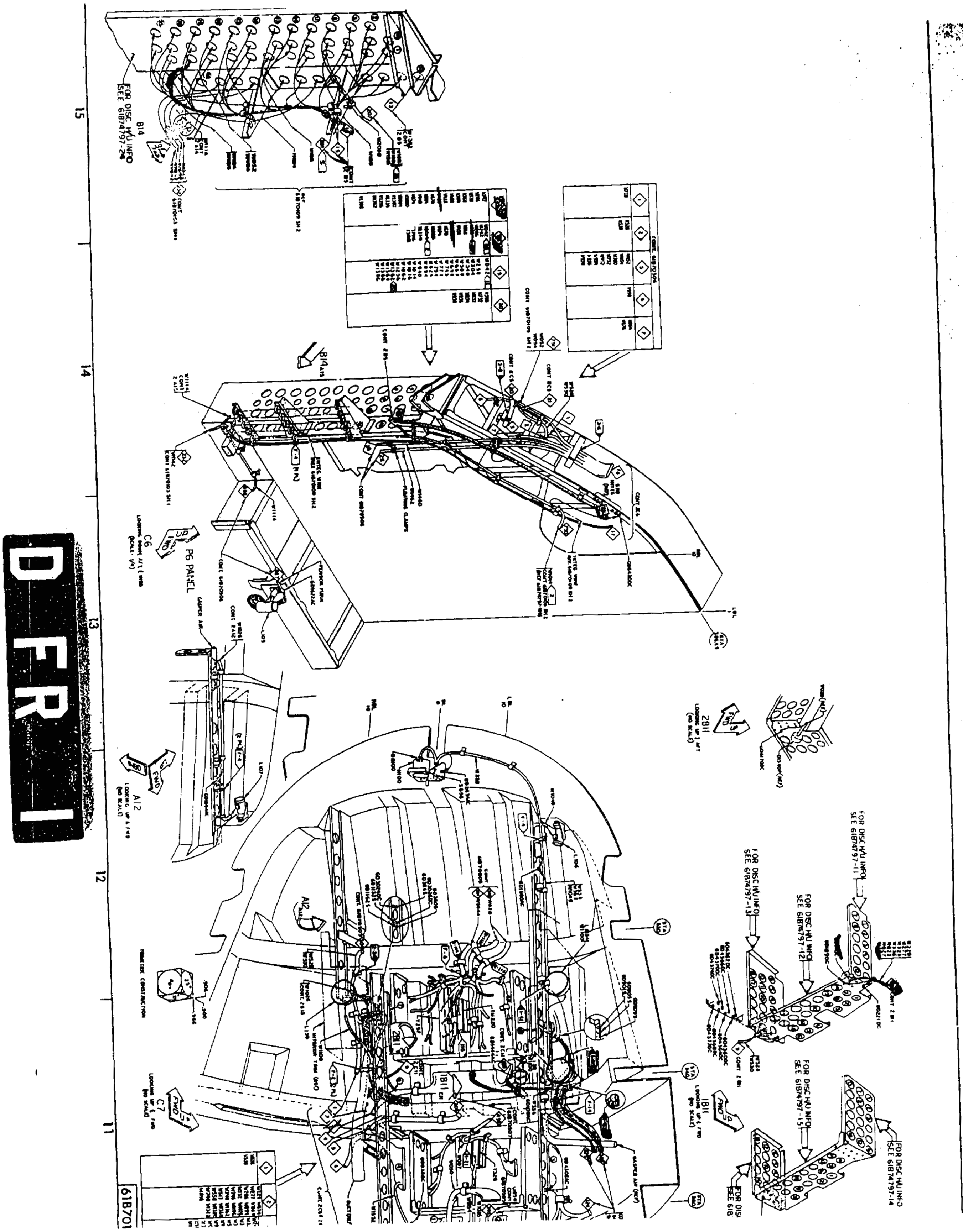

S-3
S-3A
S-4
S-5
S-6
S-7
S-7A
S-8
S-9
S-10
S-10A
S-11
STA 500
STA 480
STA 460
STA 440
STA 420
STA 400
STA 380
STA 360
STA 340
STA 330
STA 320
STA 300
SUPPORT ROD (REF)
FLOATING CLAMPS
CONT 61870102 SH2
CONT 61870102 SH1
CONT 2 A12
CONT 61870103 SH1
CONT 61870104 SH 2
CONT 61870105 SH1
WRAP WITH TEFLON TAPE FROM B/O AT UPPER END OF WINDSHIELD POST TO TERMINATION POINTS LH&RH (LL1131). USE SPIRAL WRAP PER BAC 5157 REQUIREMENTS
OXYGEN REGULATOR
VENDOR WIRE
SPLICE AREA
GROMMET
TUBING (REF)
FLOATING CLAMP
A9
9
8
7
6
5
1B
61870101


FR 3
61B70101
1B
F





D FR 2
61B70102
1B
UPPER RH CAB
STA 260-400



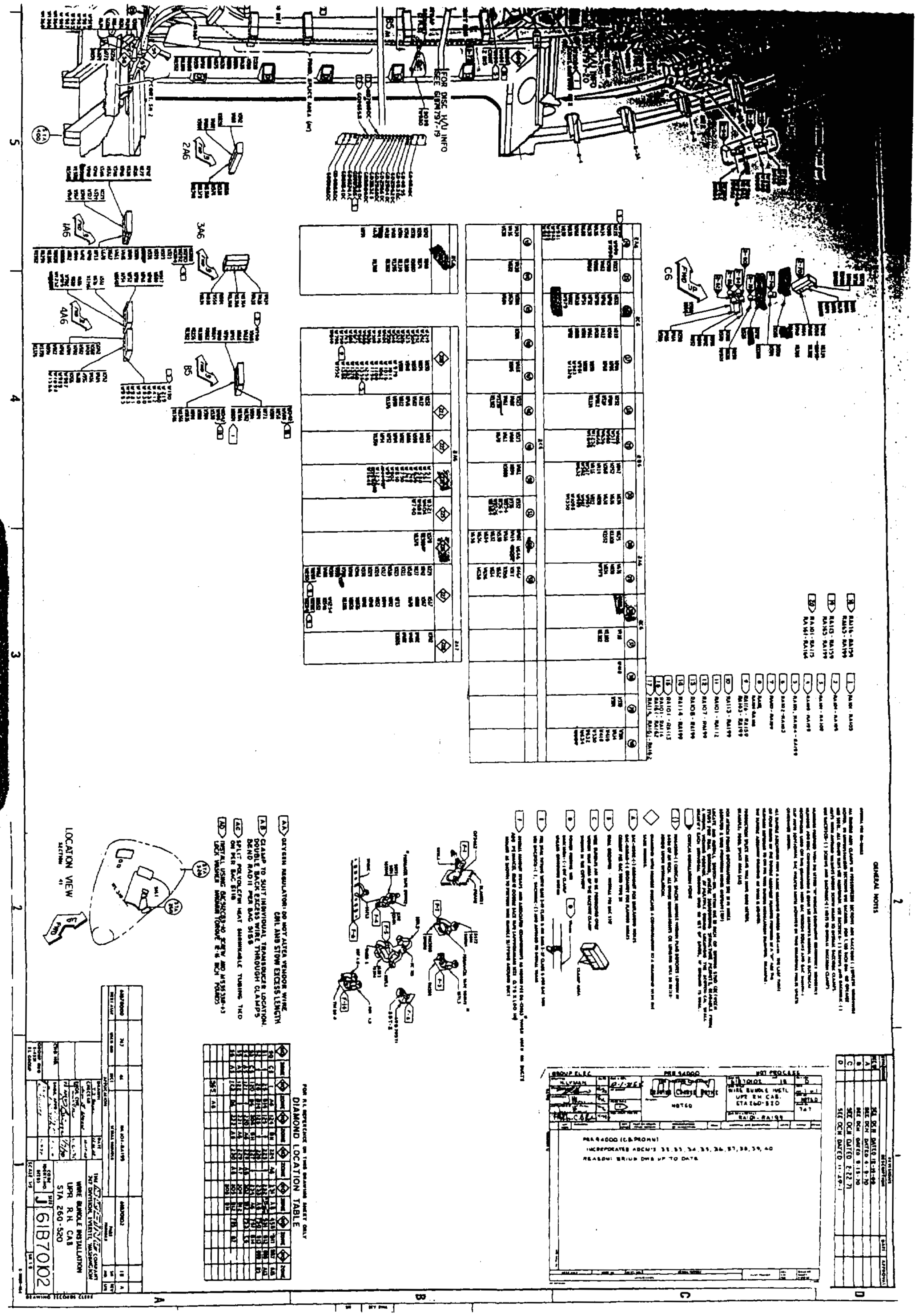
Order: 97994
DWG: 61B70102

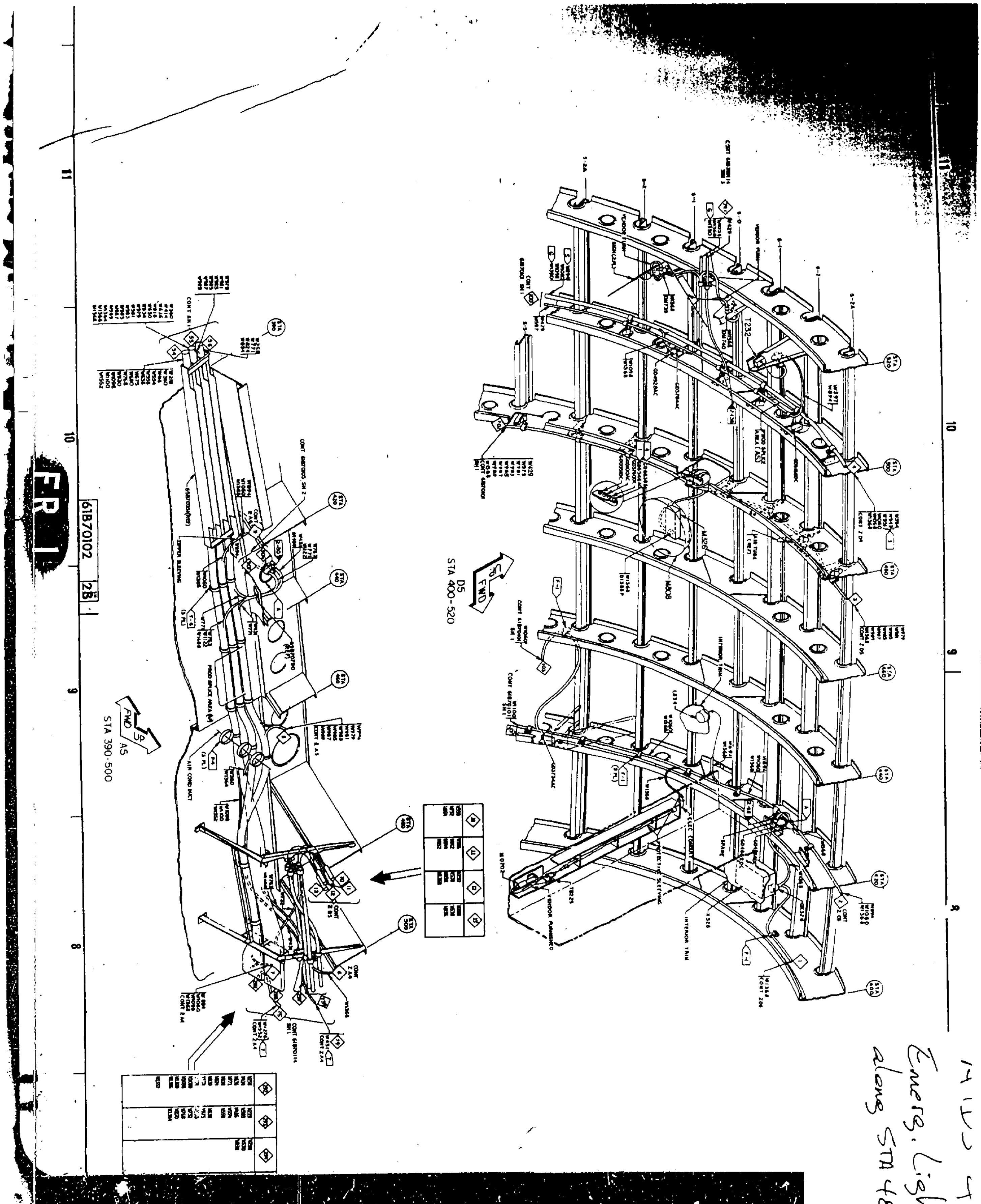
Boeing Proprietary
SH: 0001B REV: D

Not Valid After 05 08 199
Frame: 1 of

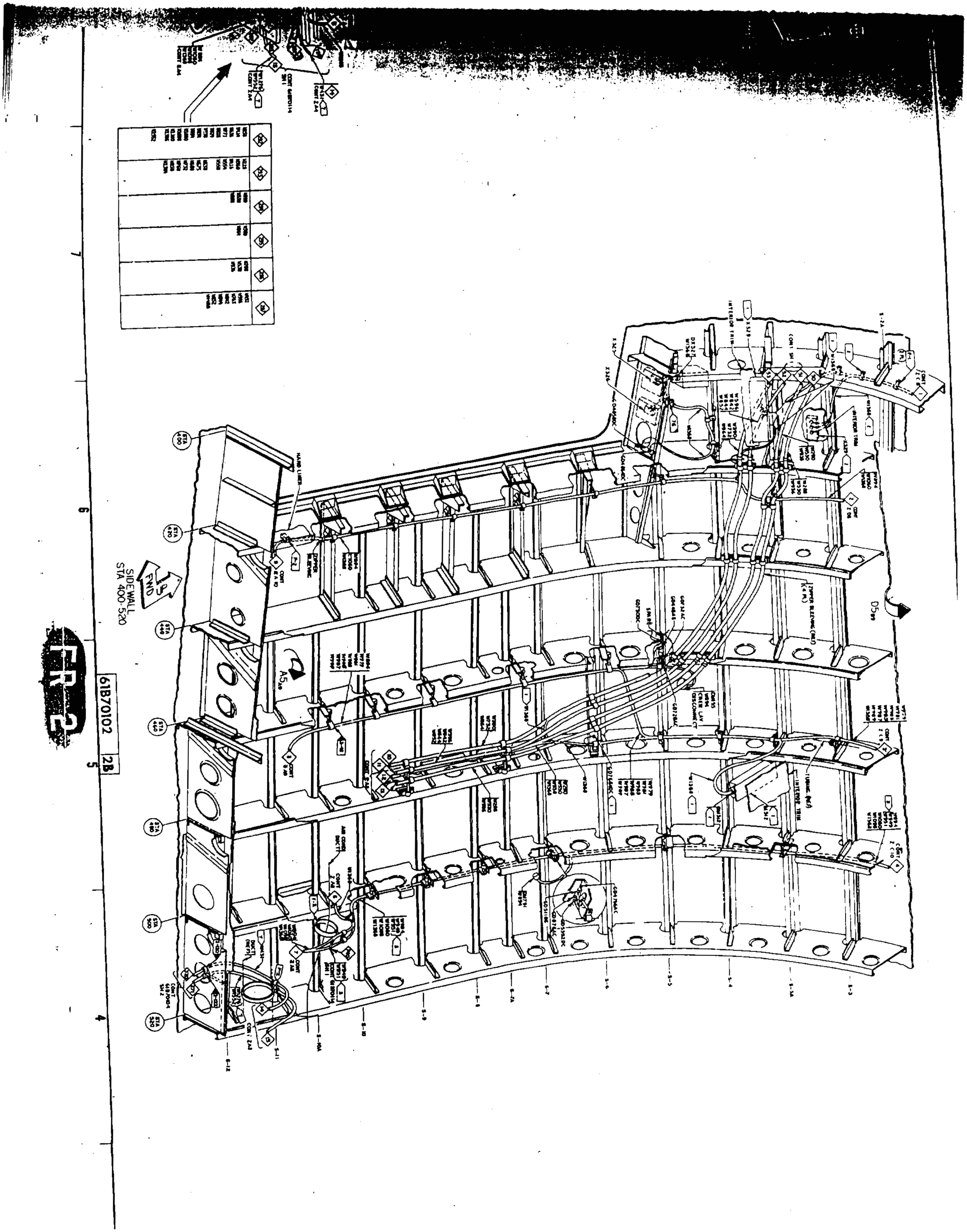
Commercial Data

D FR 3





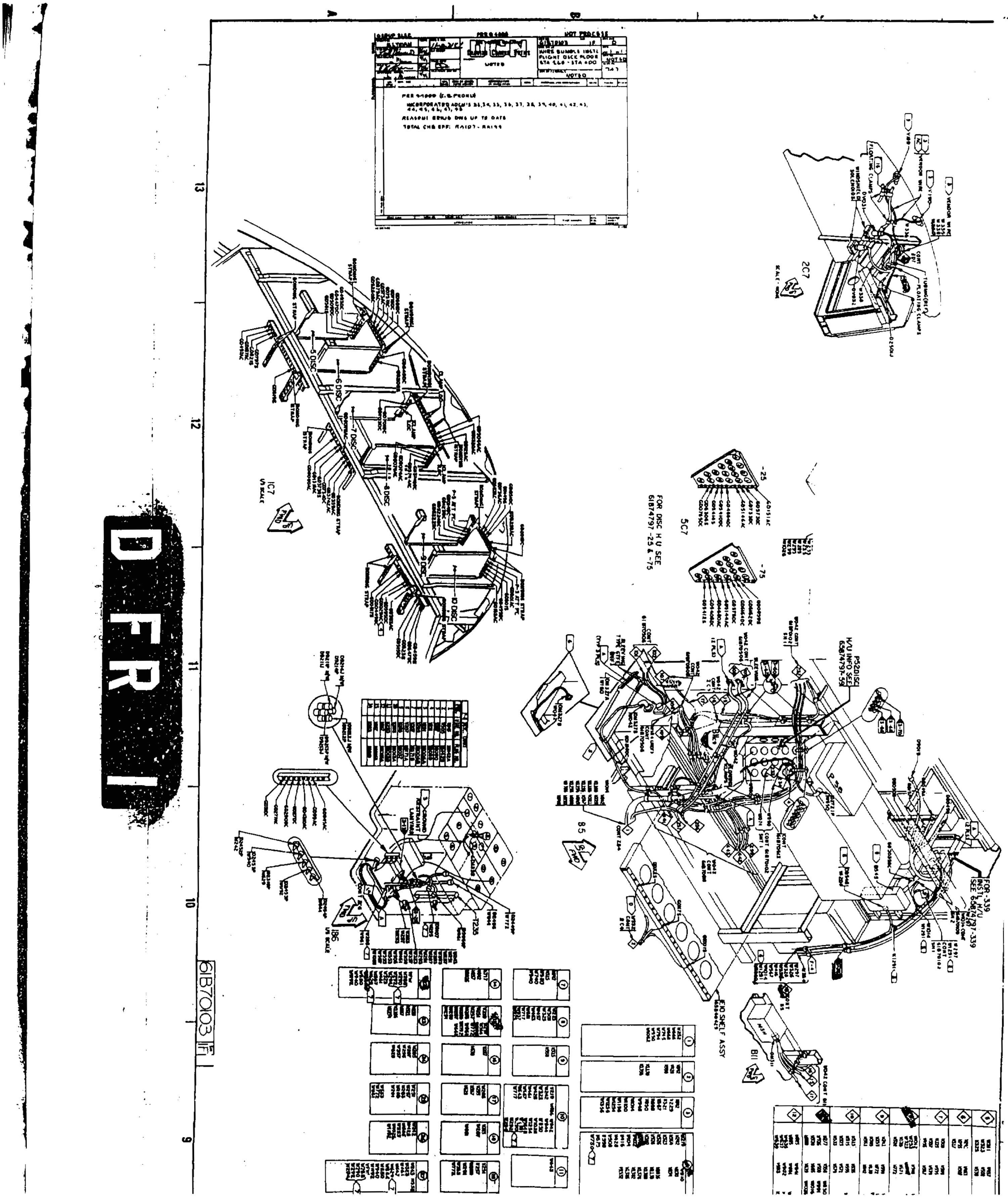
Emerg. Lighting along STA 480.

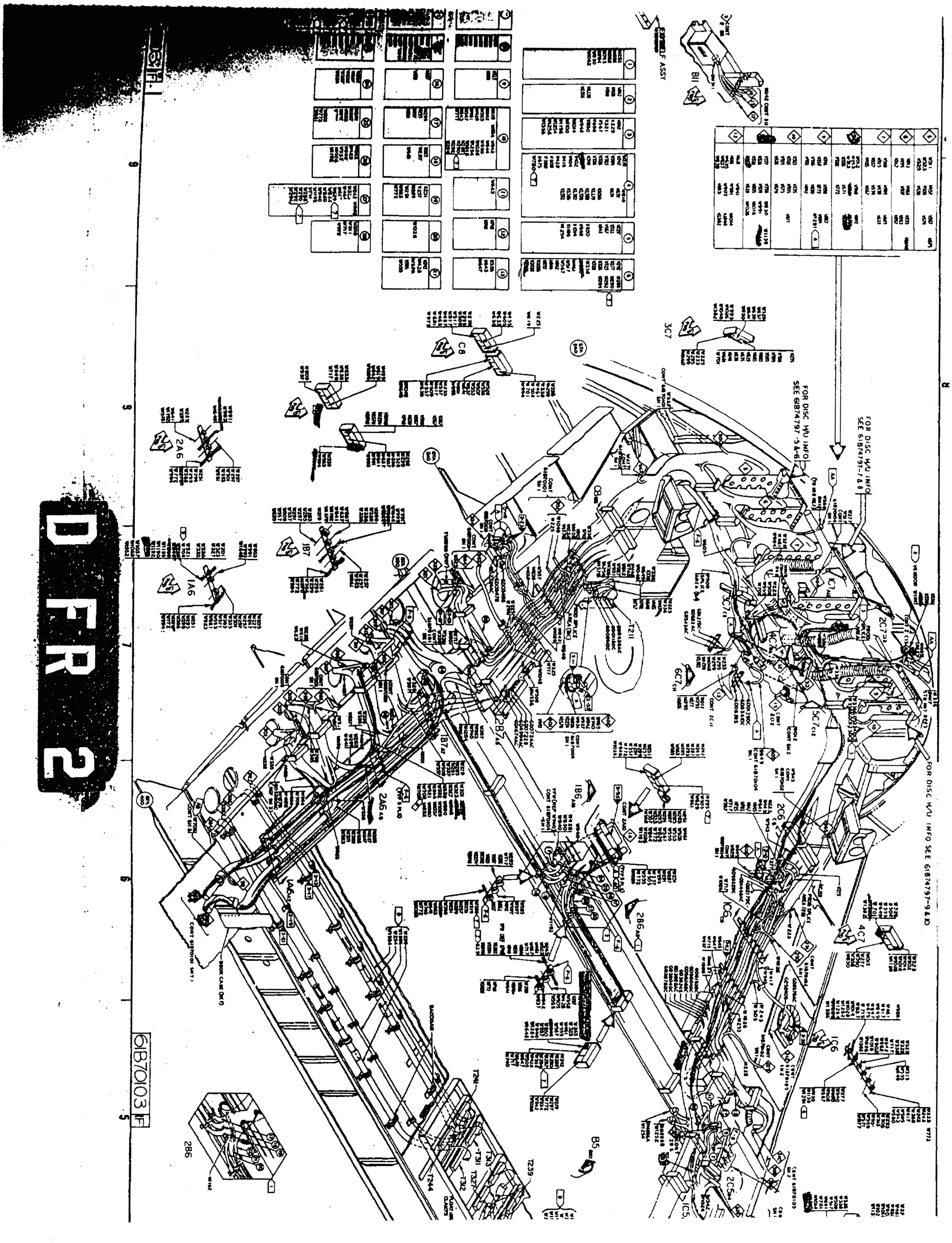


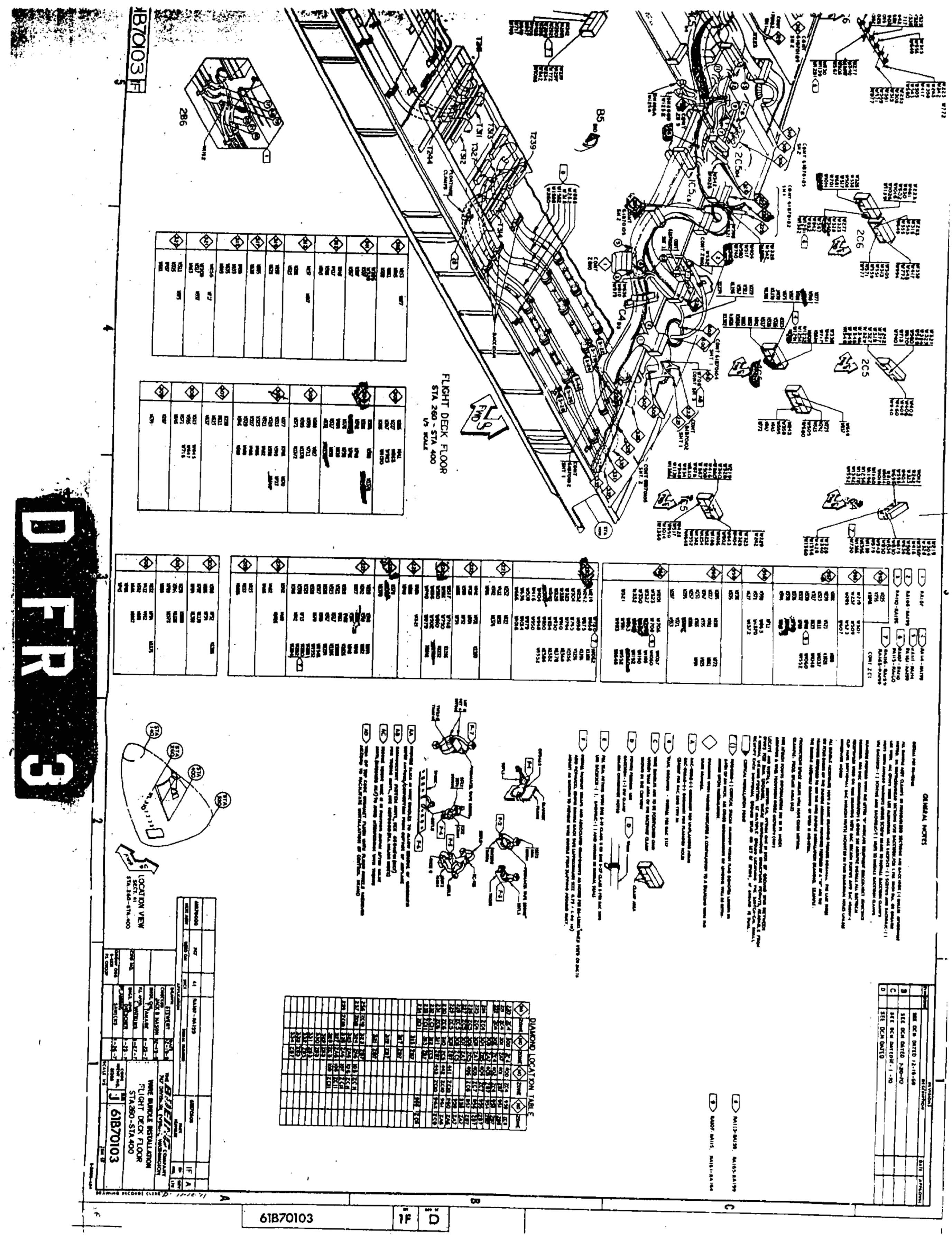
Order: 76089
DWG: 61B70102

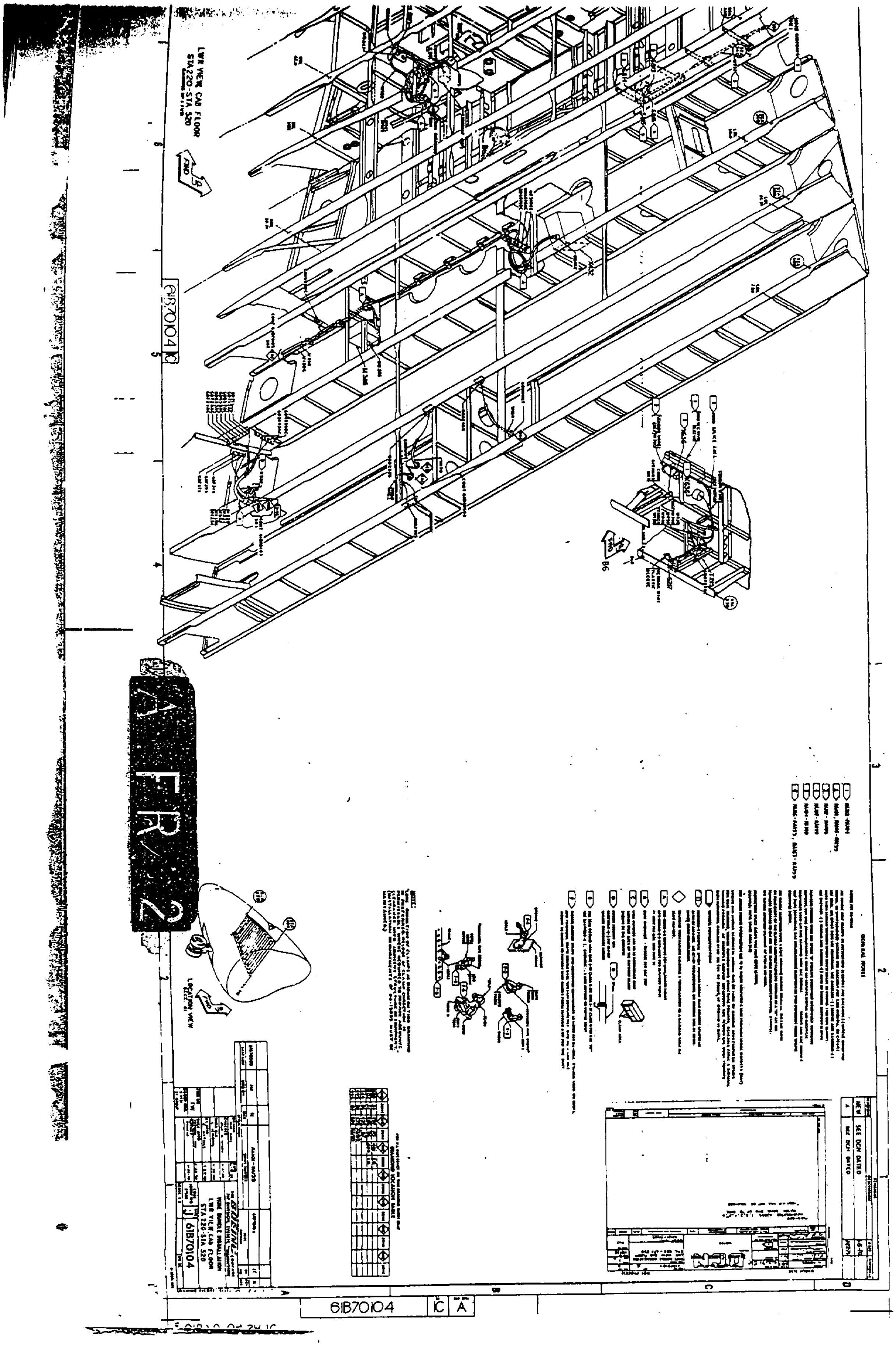
Boeing Proprietary
SH: 0002B REV: B

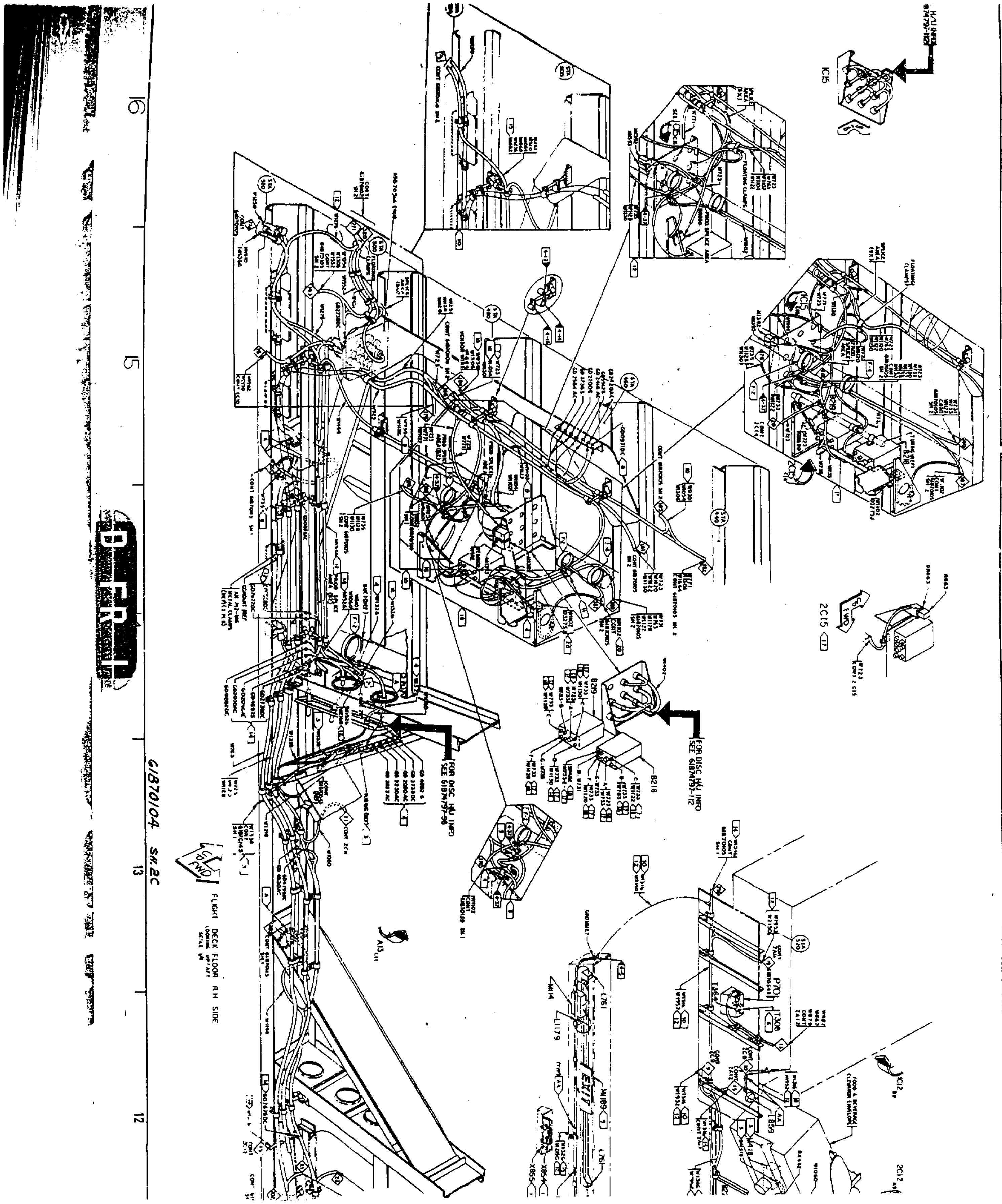
Not Val

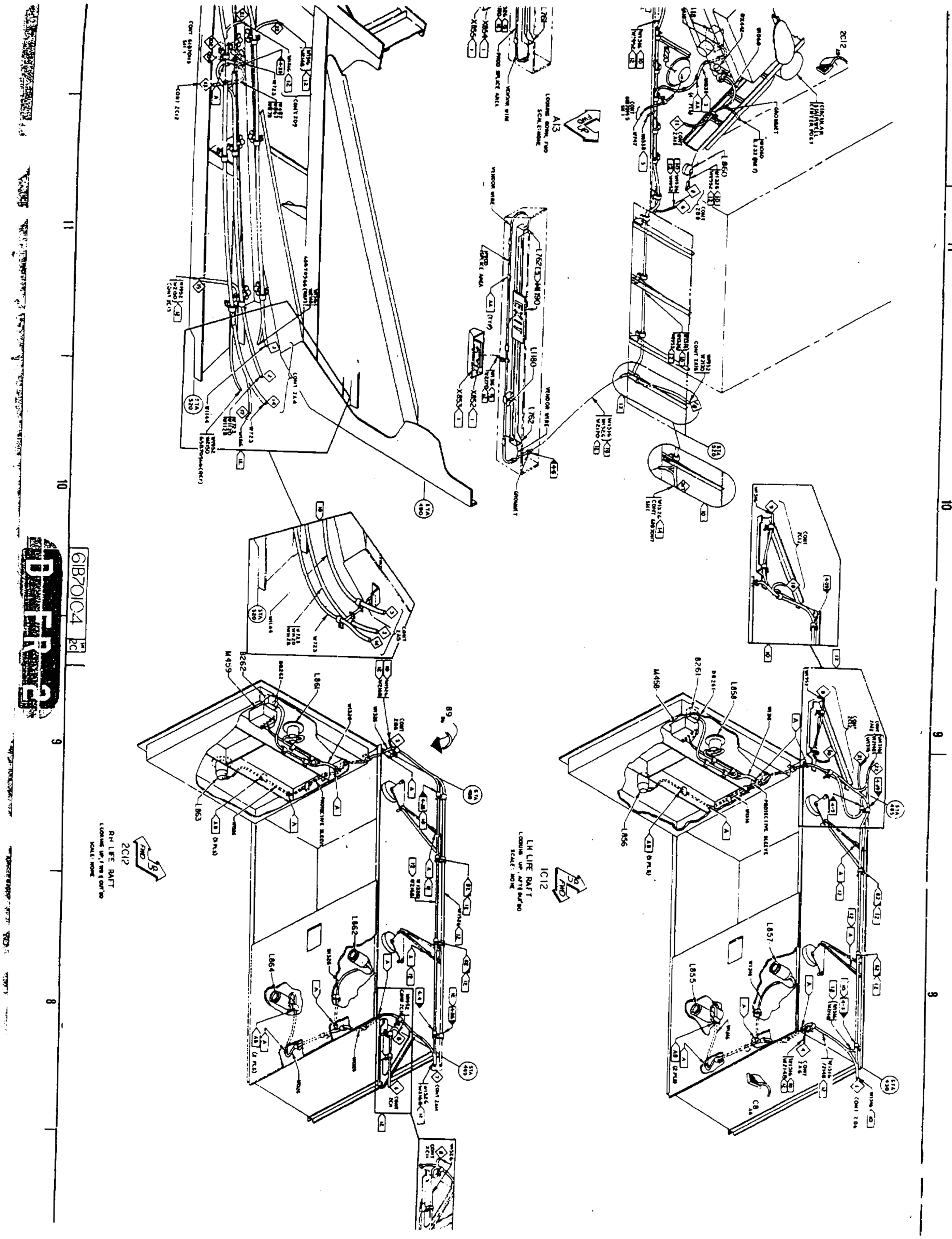

D F R I
6B70103
FOR DISC H/U SEE 61B74797 -25 & -75
5C7
E/D SHELF ASSY
1C7
2C7
1B6
B5
B11

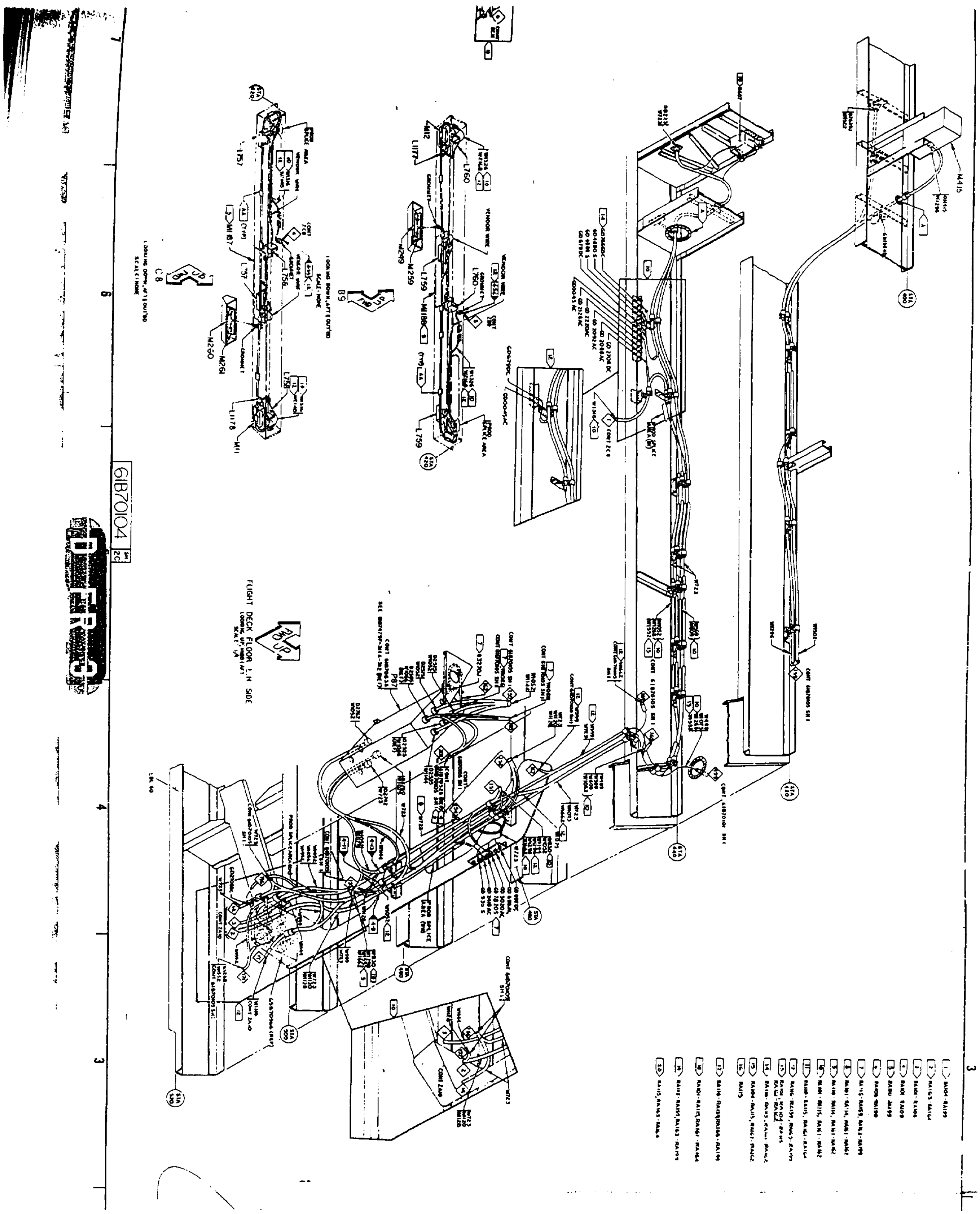

D FR 2
61B70103 F
FOR DISC H/U INFO SEE 61B74797-9 & 10

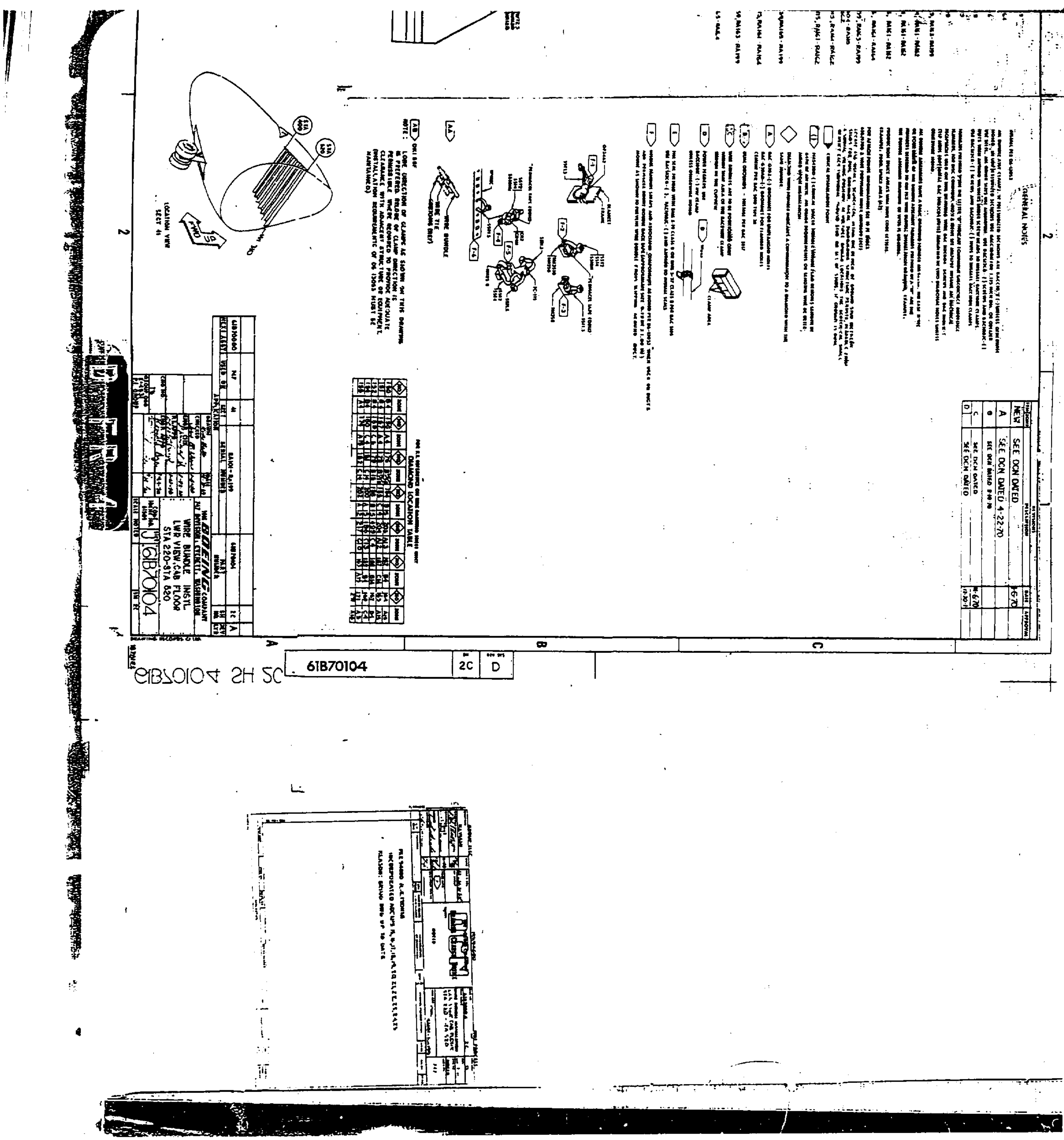

DFR 3
FLIGHT DECK FLOOR
STA 260 - STA 400
61B70103
1F
D


61B70104
IC
A

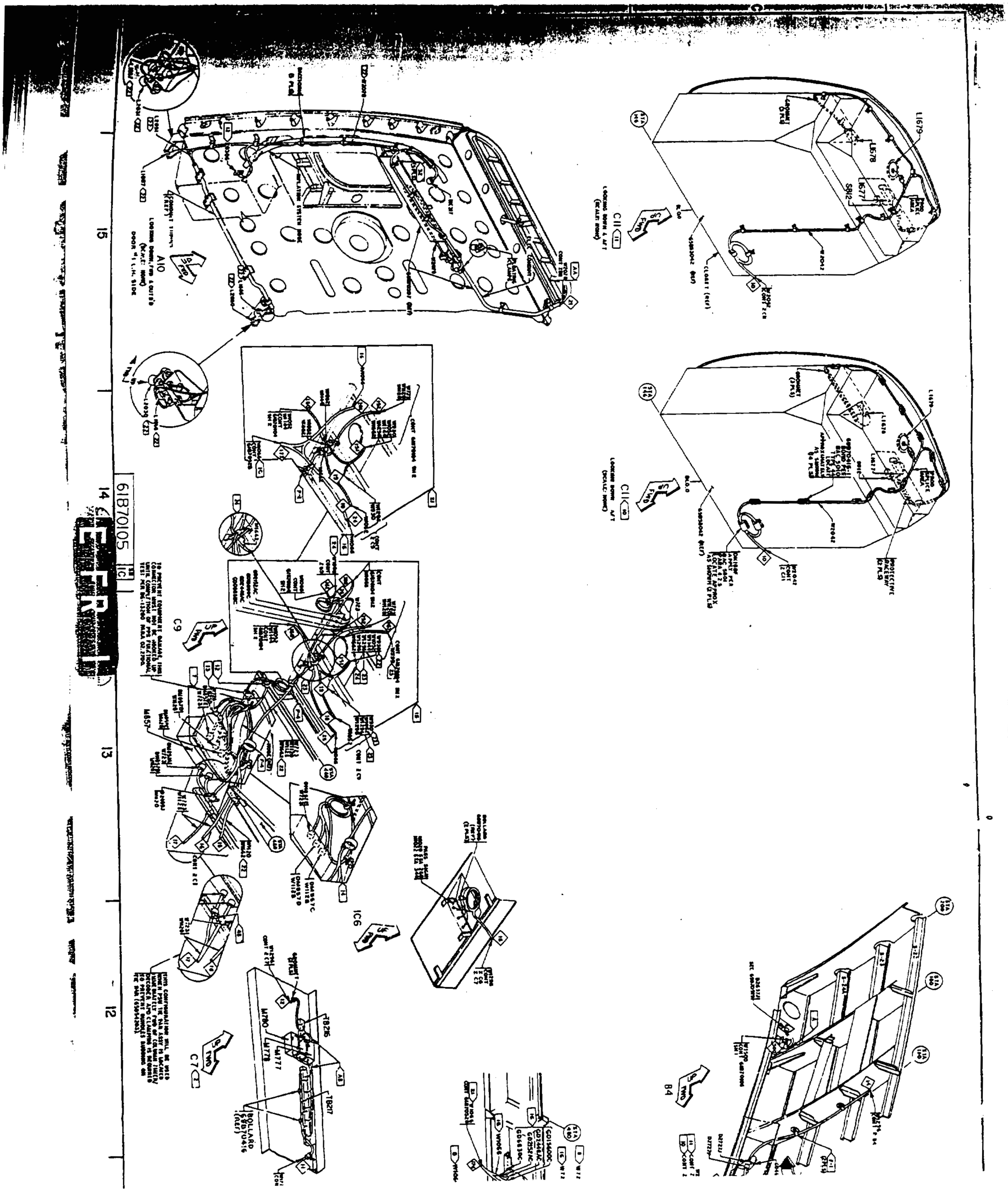

61B70104 SH 2C
FLIGHT DECK FLOOR RH SIDE
2C15
B218
B219
P701
T364
T308
L859
L761
L1179
M1189
FOR DISC H/J INFO SEE 61B74797-98

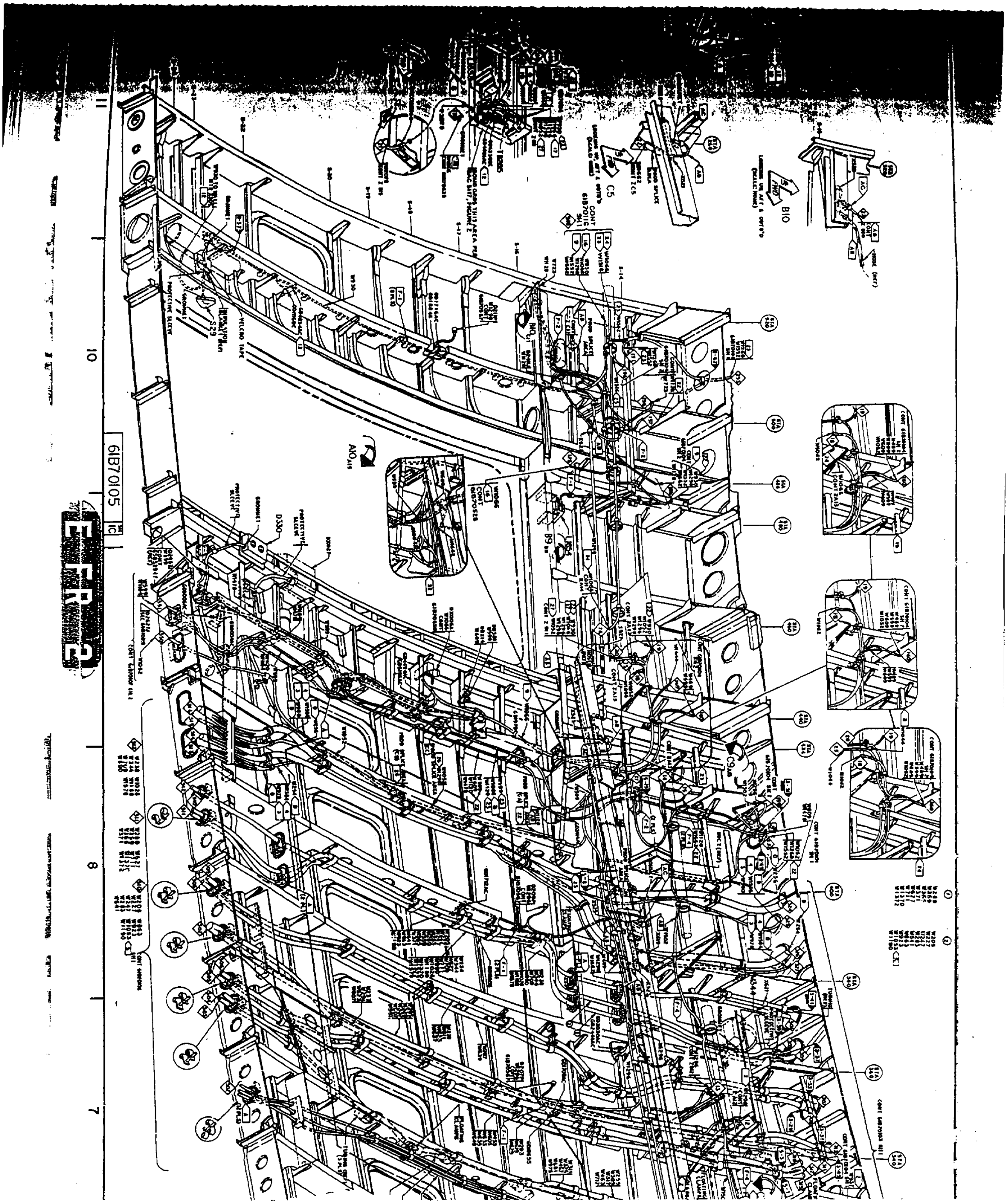


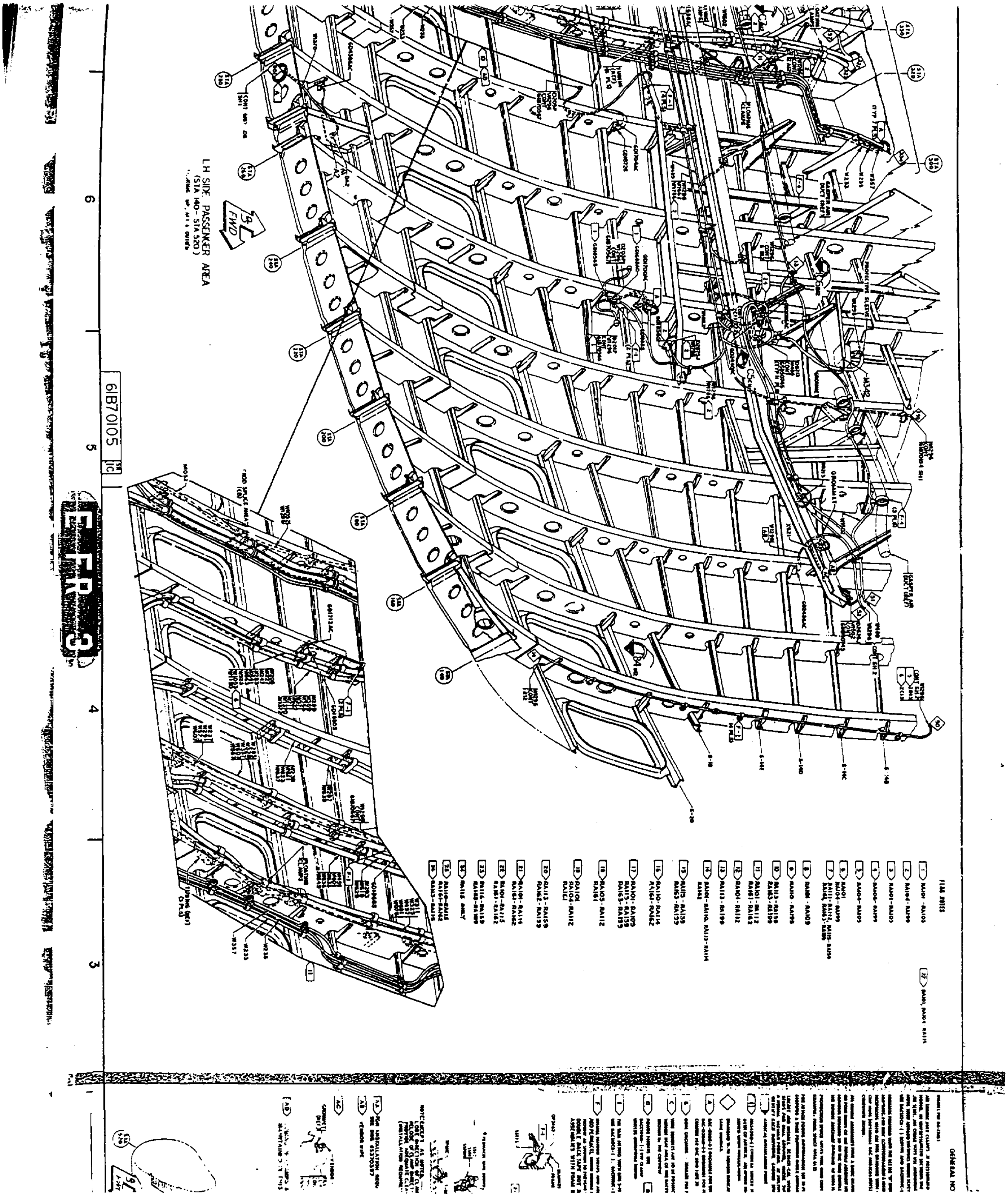

61B70104
2C
FLIGHT DECK FLOOR L.H SIDE

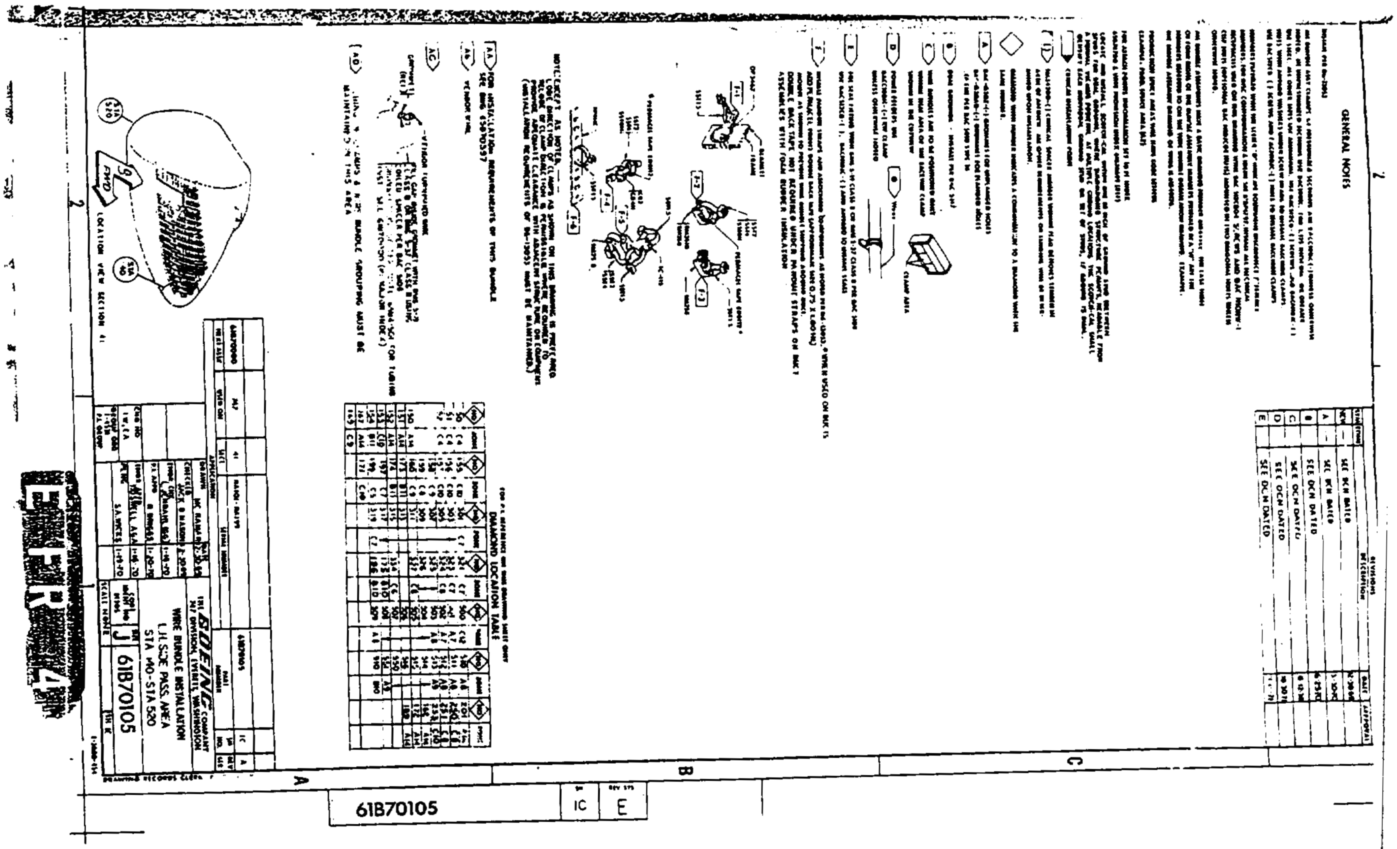


GENERAL NOTES
SEE OCN DATED
SEE OCN DATED 4-22-70
DIAMOND LOCATION TABLE
WIRE BUNDLE INSTL.
LWR VIEW, CAB FLOOR
STA 220-STA 830
LOCATION VIEW
61B70104
2C
D

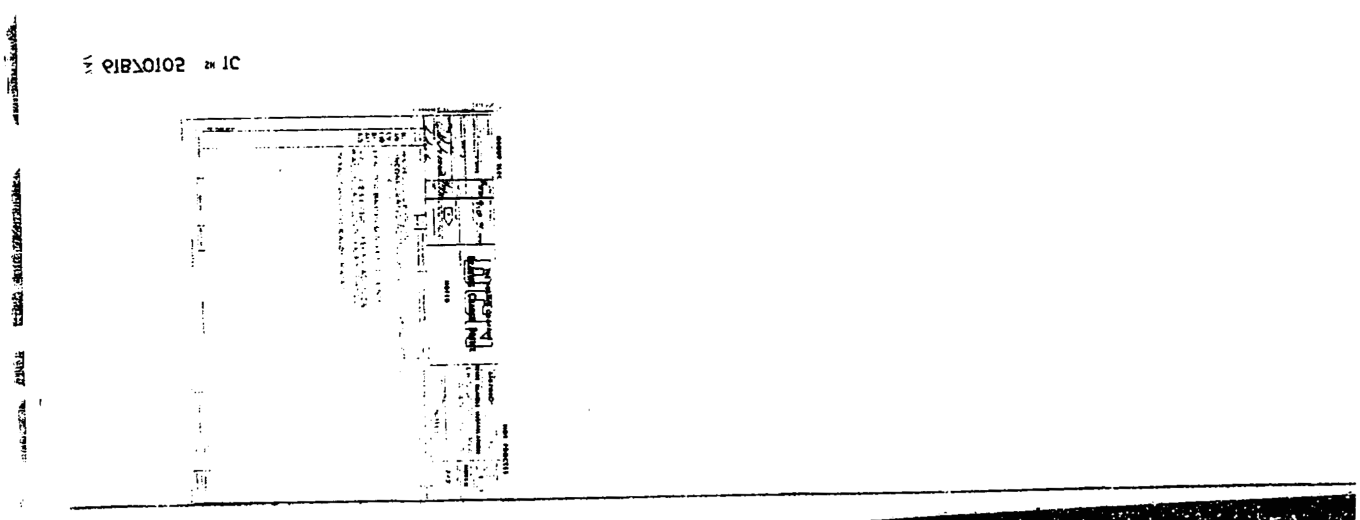

61B70105
A10
C11
C9
IC6
C7
B4
15
14
13
12

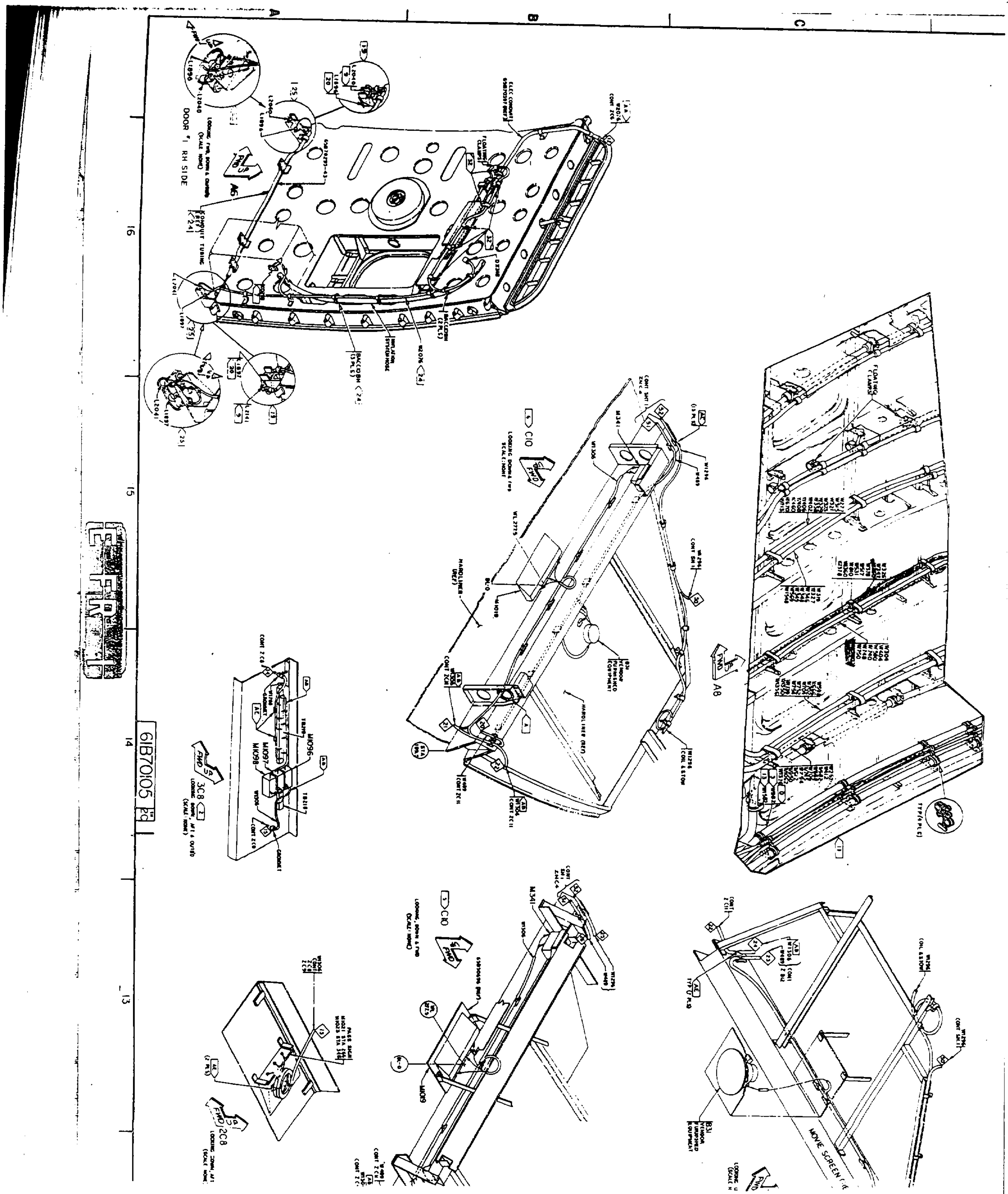


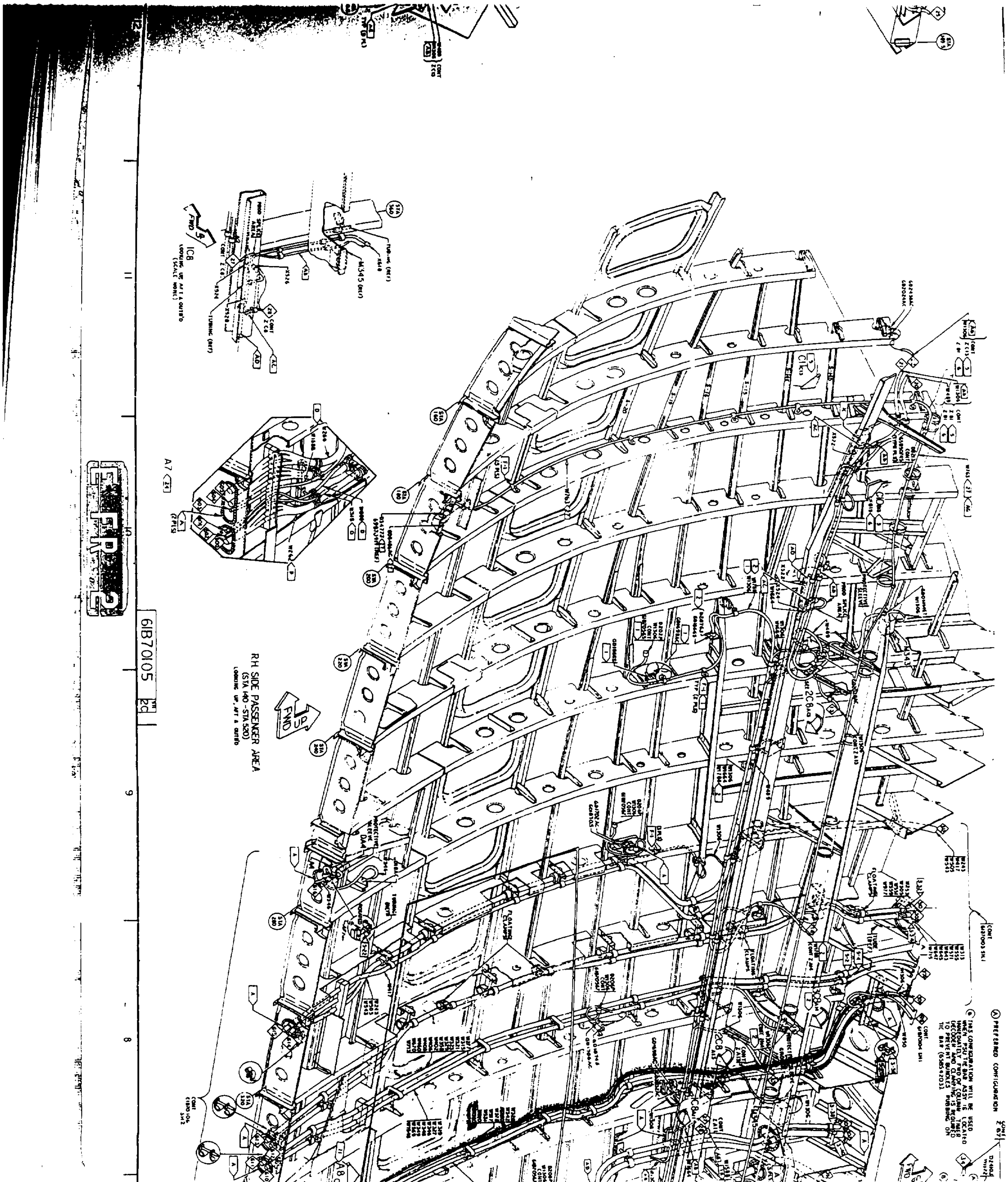

61B70105
LH SIDE PASSENGER AREA
(STA 140 - STA 520)
FWD

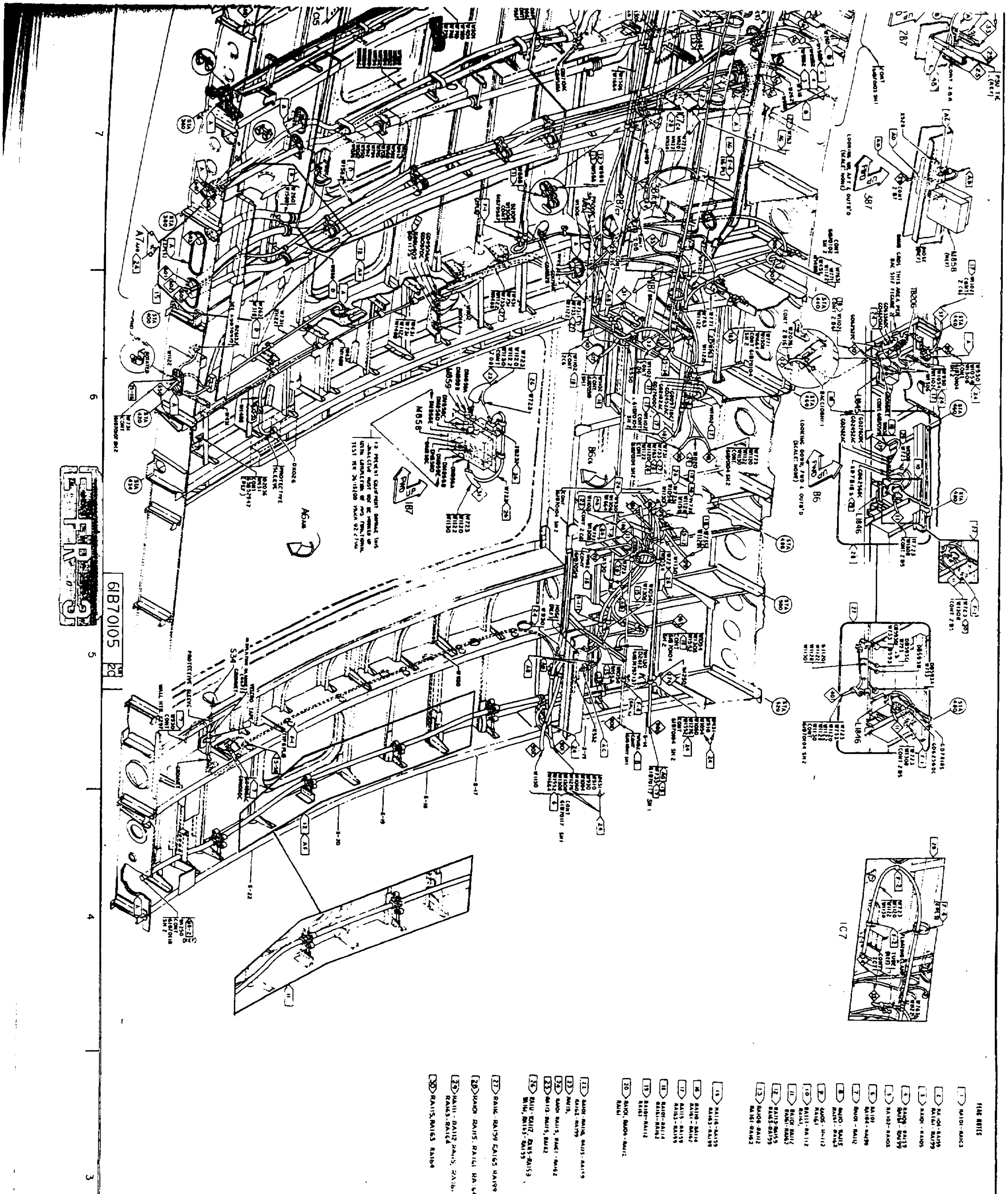


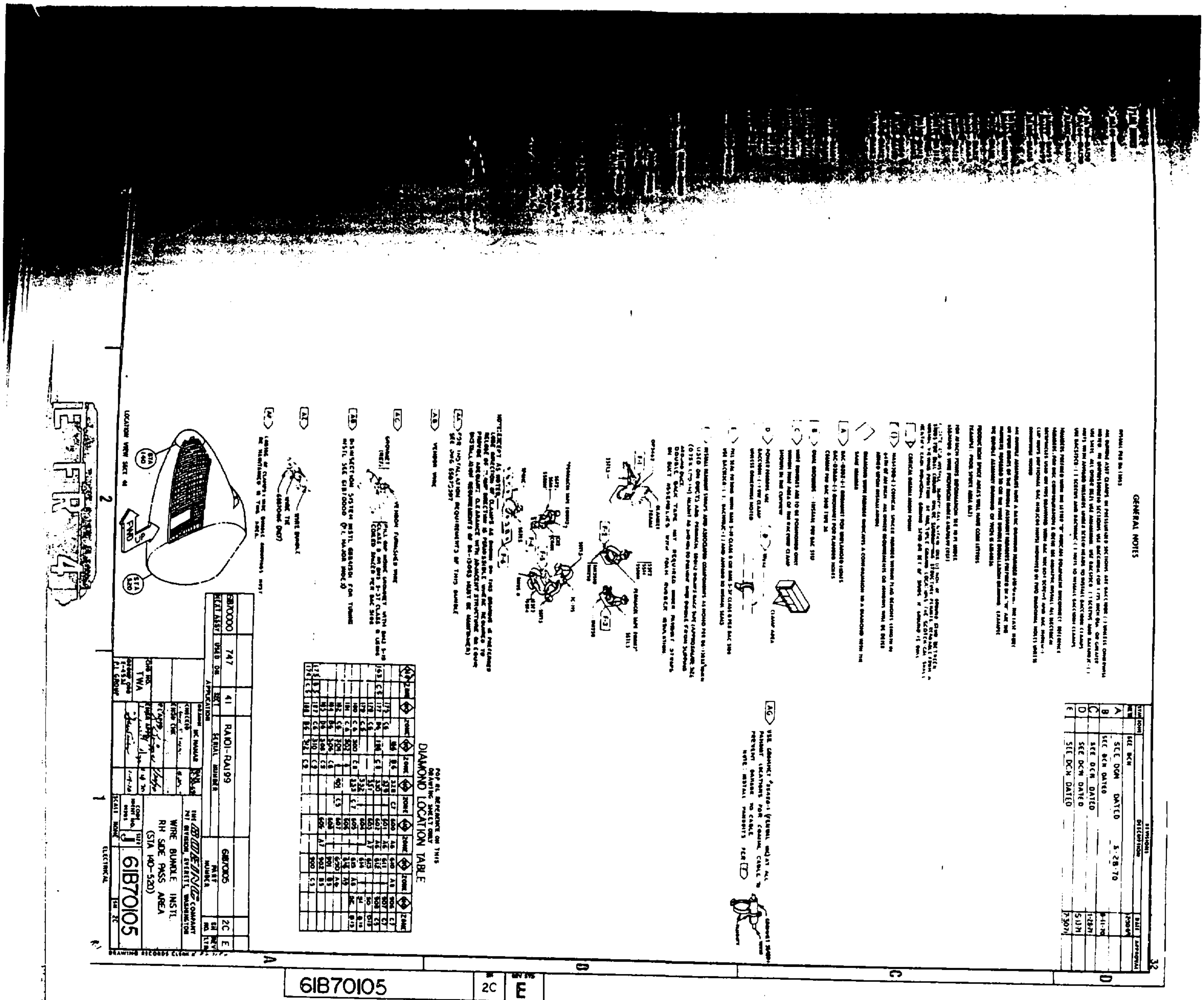
61B70105	1C	E

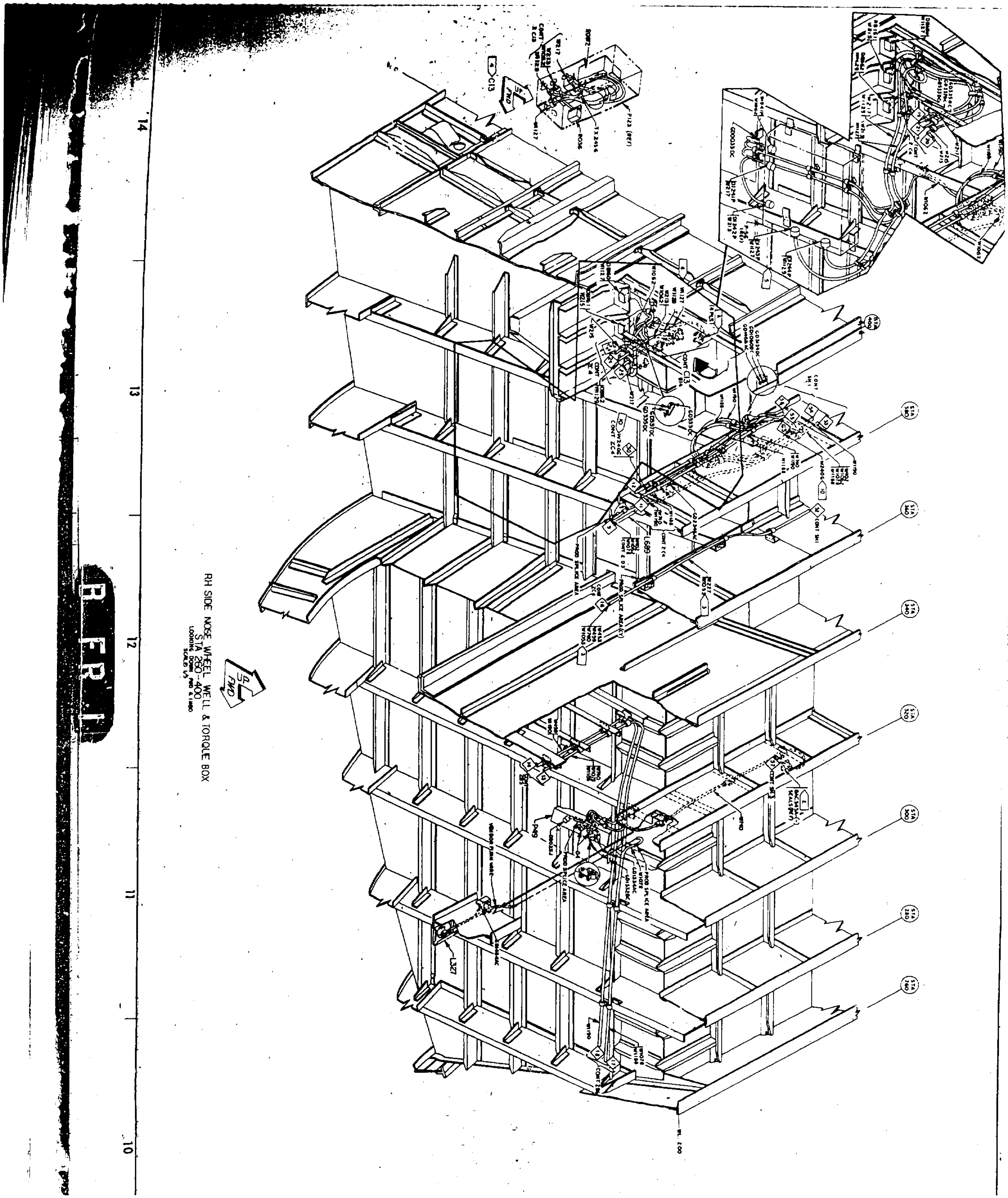


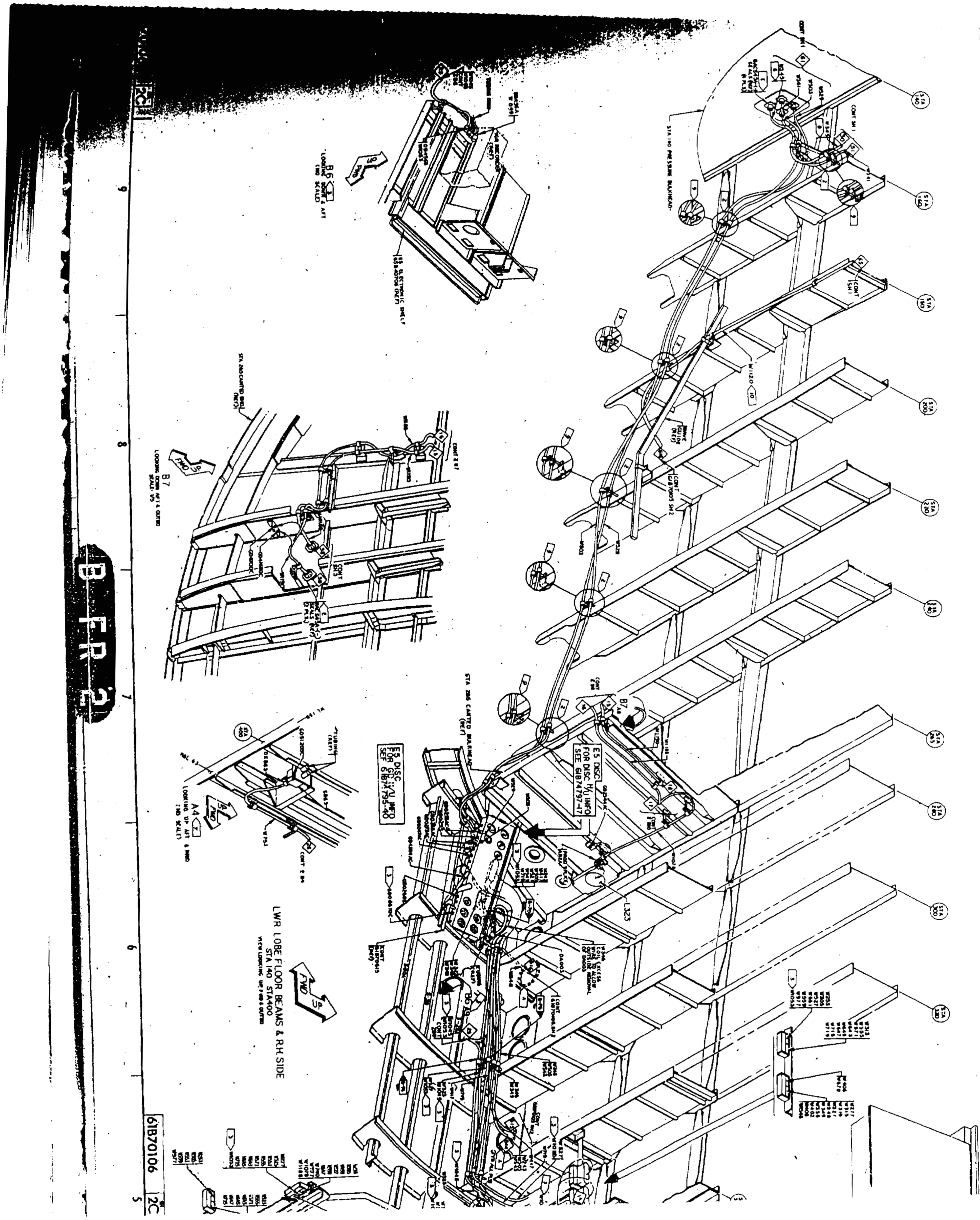


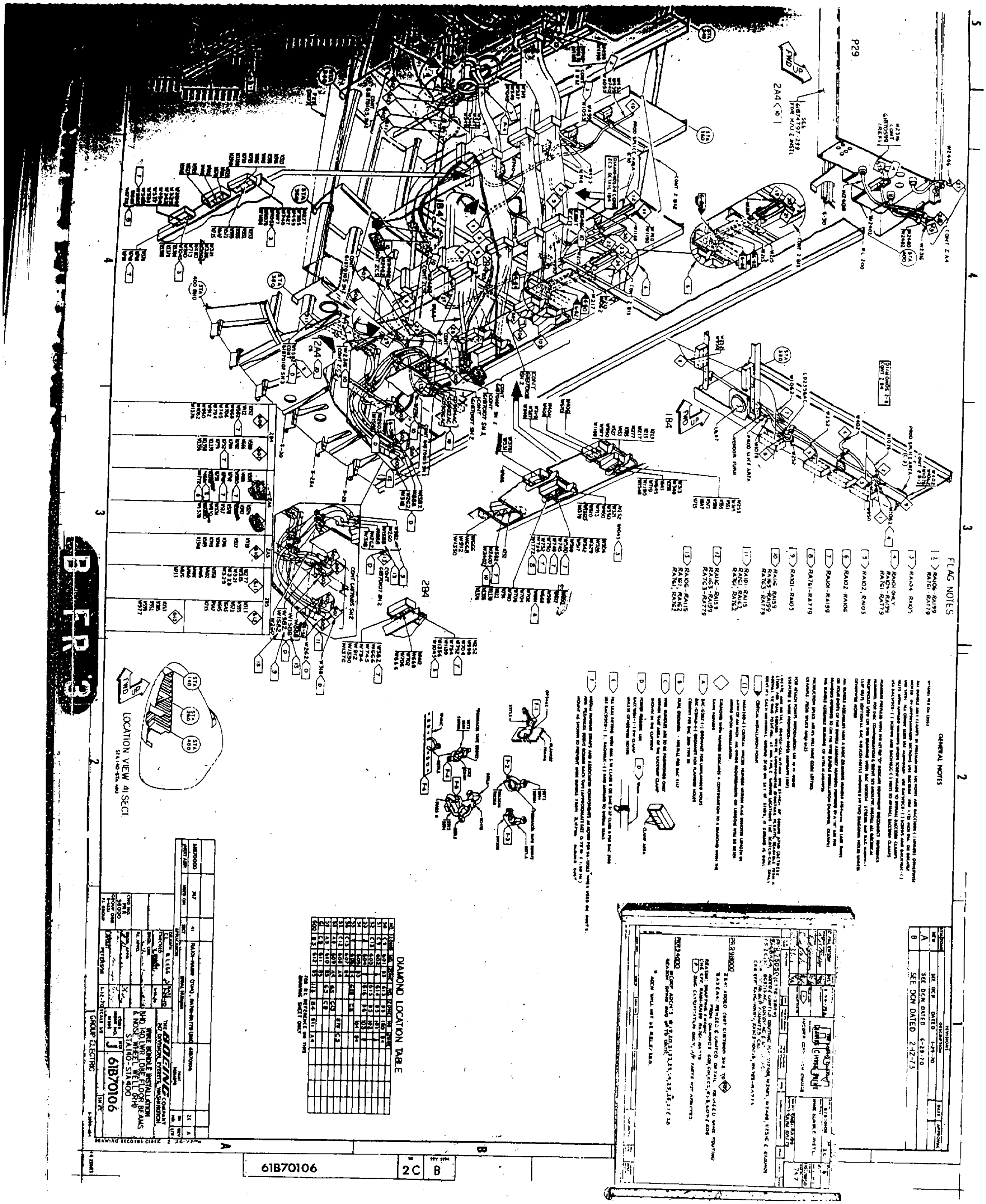

61B70105
RH SIDE PASSENGER AREA
(STA 140 - STA 520)
LOOKING UP, AFT & OUTBD
IC8
LOOKING UP AFT & OUTBD

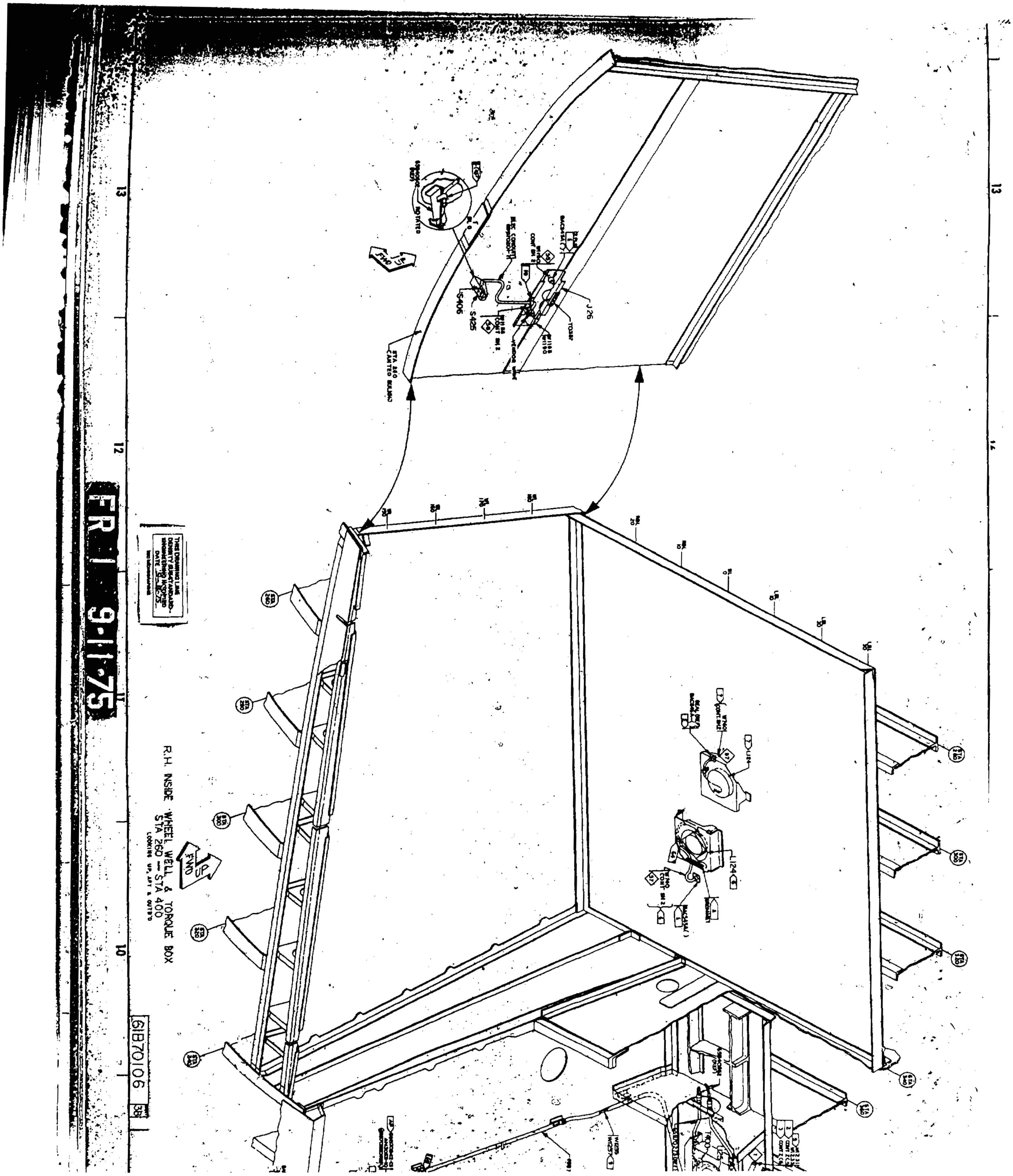


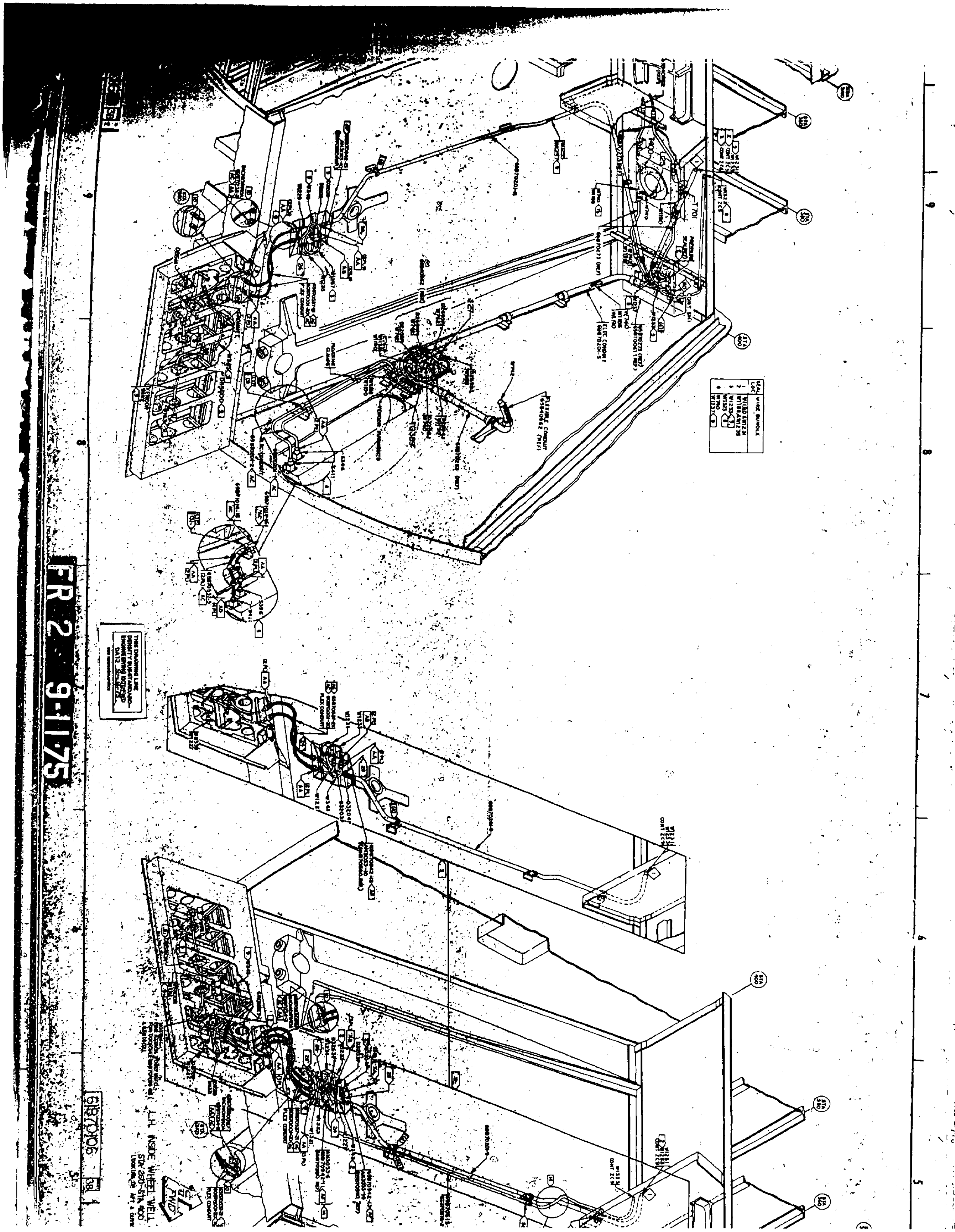

GENERAL NOTES
DIAMOND LOCATION TABLE
747
RA101-RA199
WIRE BUNDLE INSTL.
RH SIDE PASS AREA
(STA 140-520)
61B70105
2C
E

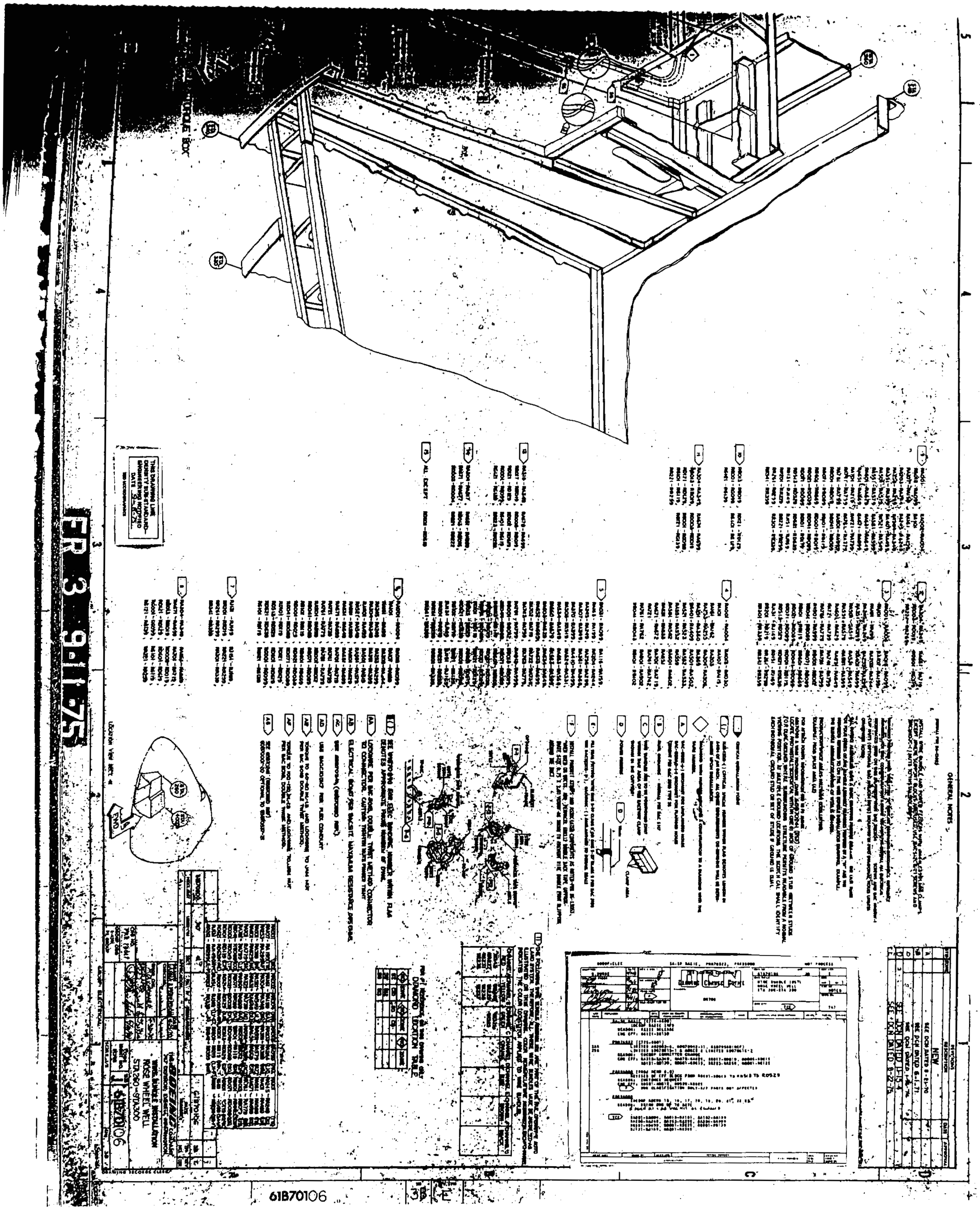

RH SIDE NOSE WHEEL WELL & TORQUE BOX
STA 260-400
STA 400
STA 380
STA 360
STA 340
STA 320
STA 300
STA 280
STA 260
CONT C13
L327
P49
14
13
12
11
10


LWR LOBE FLOOR BEAMS & R.H SIDE
STA 140 STA400
61B70106
2C

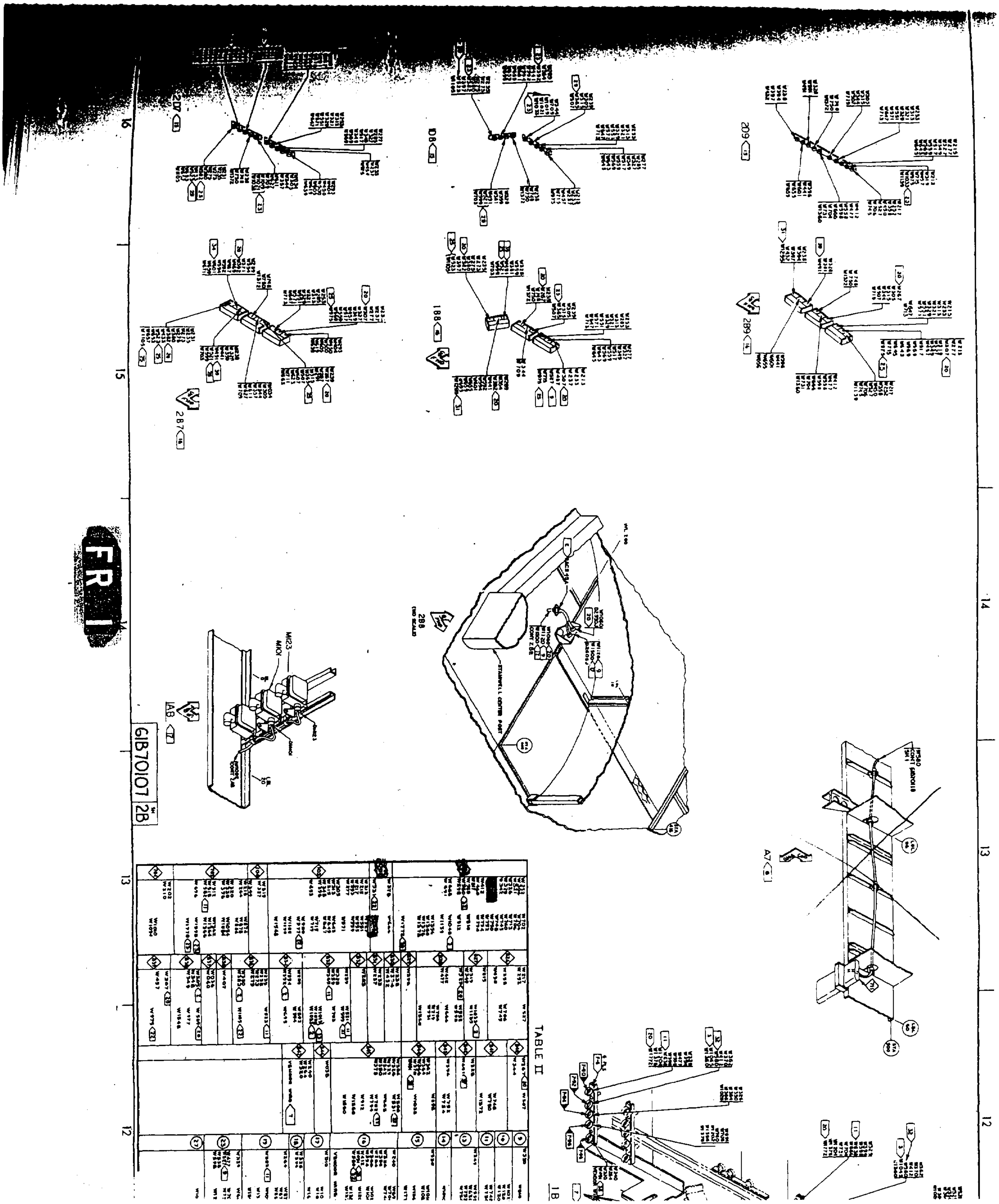

FLAG NOTES
GENERAL NOTES
DIAMOND LOCATION TABLE
LOCATION VIEW 41 SECT
61B70106
2C
B

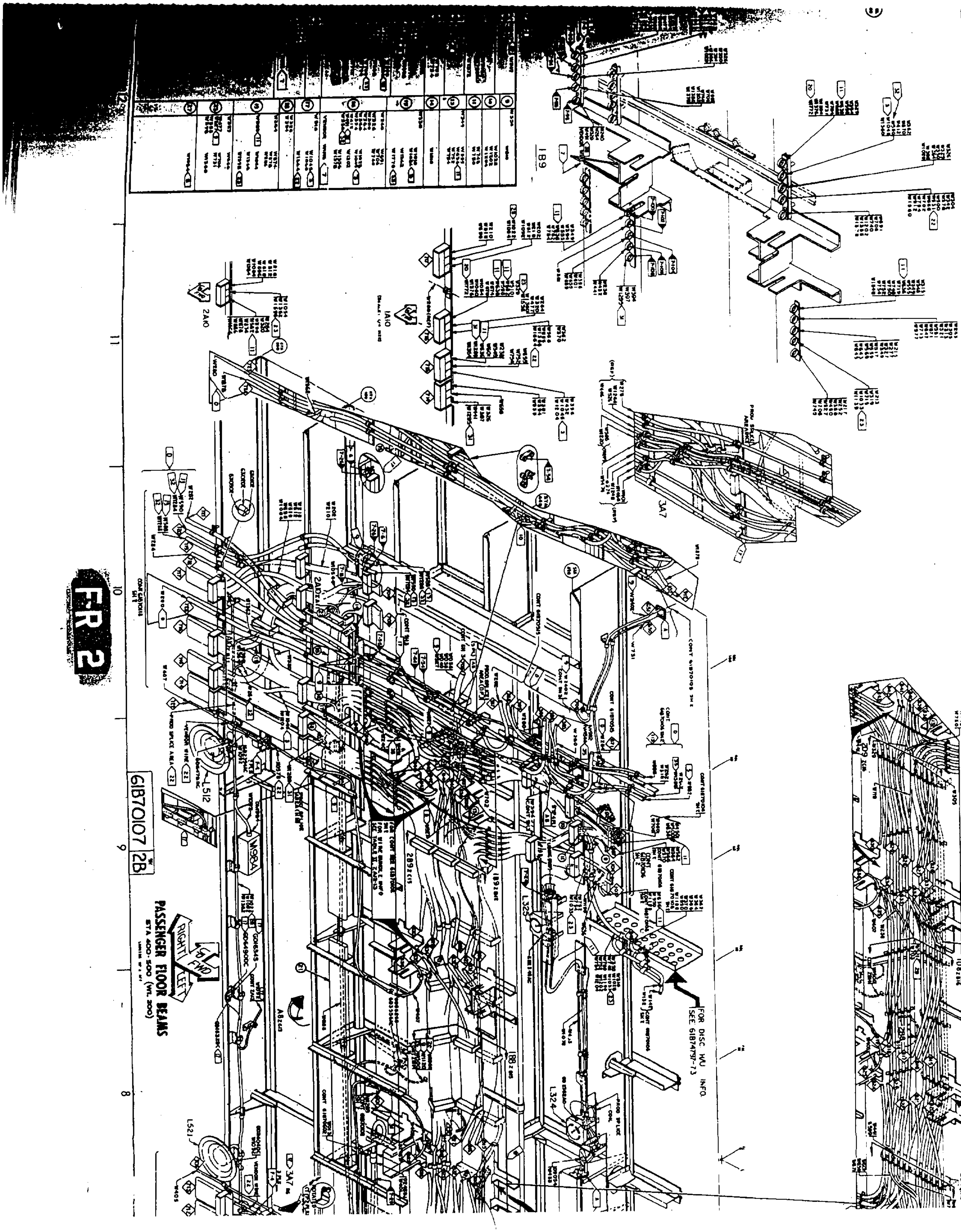

FR 1 9-11-75
R.H. INSIDE WHEEL WELL & TORQUE BOX
STA 260 — STA 400
61B70106
J26
S406
S425
FWD
UP

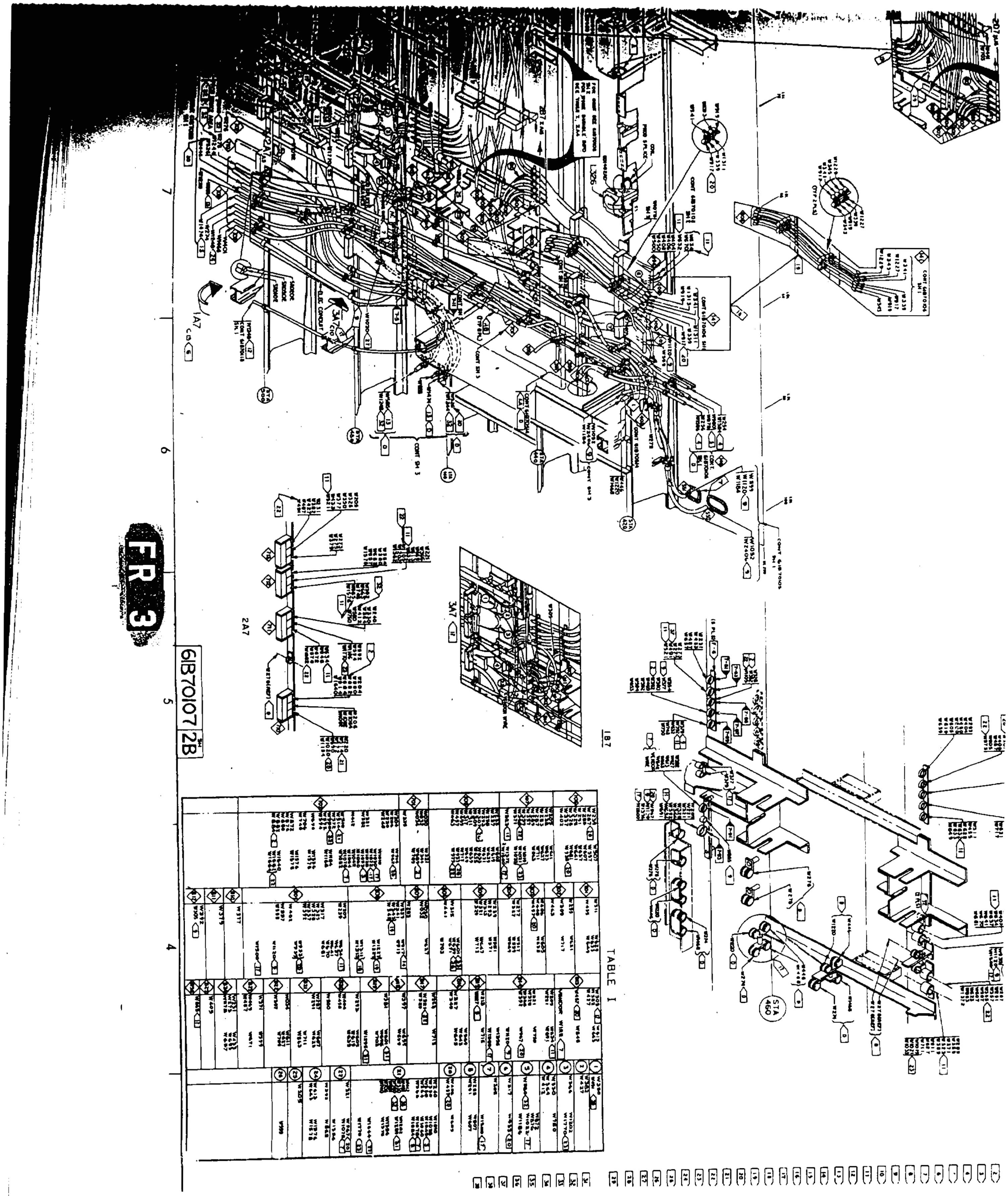

FR 2 9-11-75
61B70106

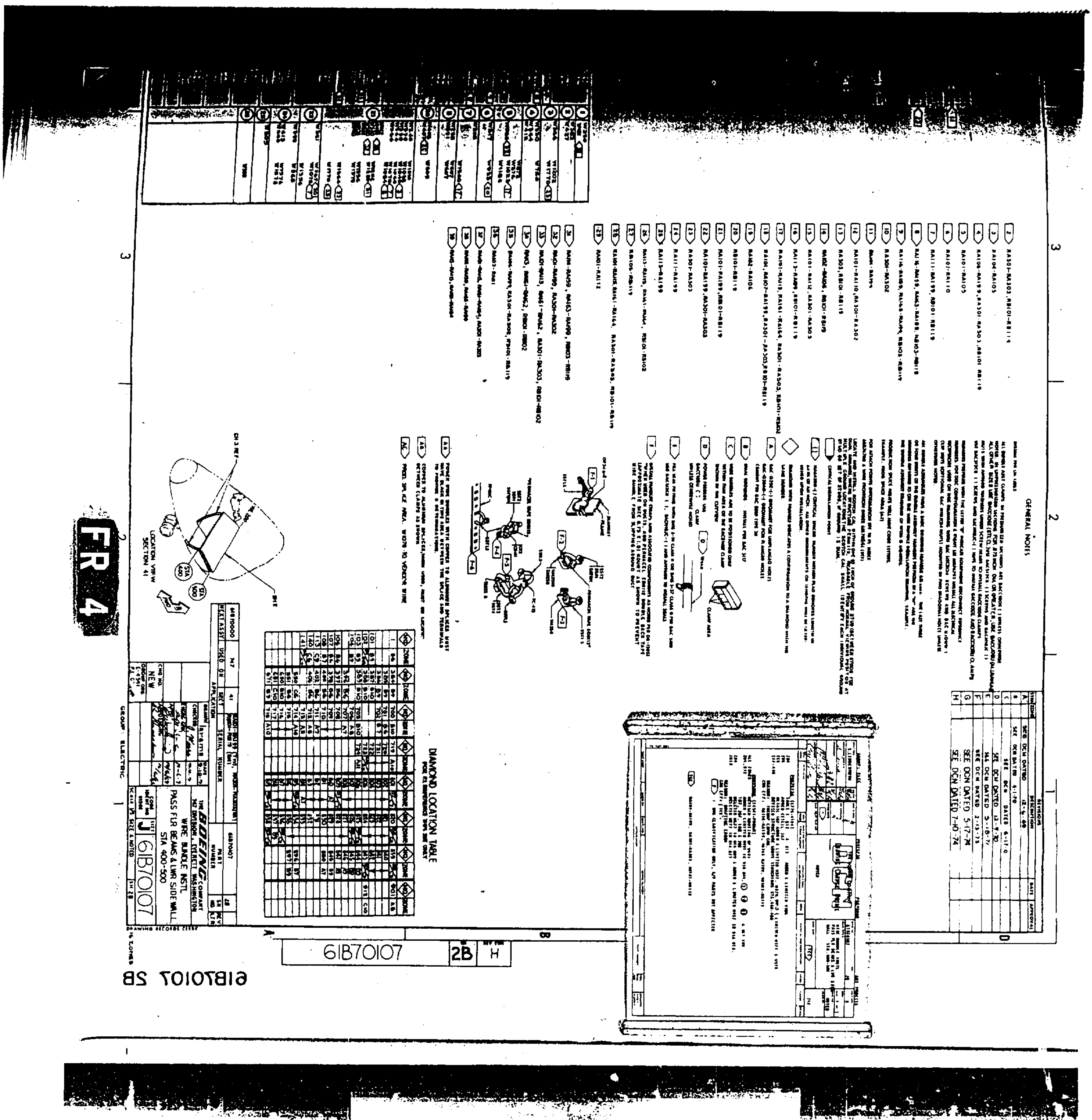


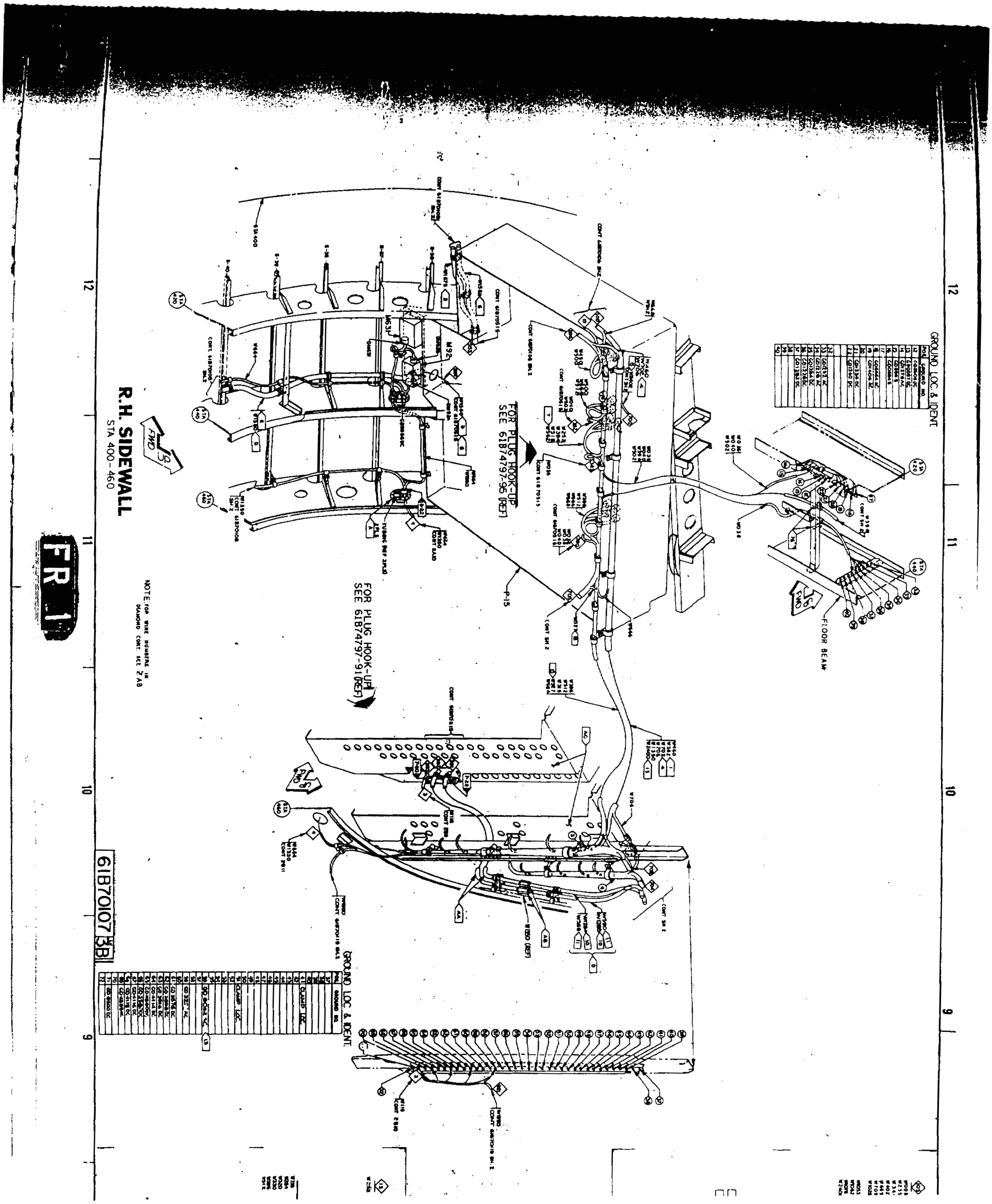
FR 3 9-11-75
61B70106
3B E

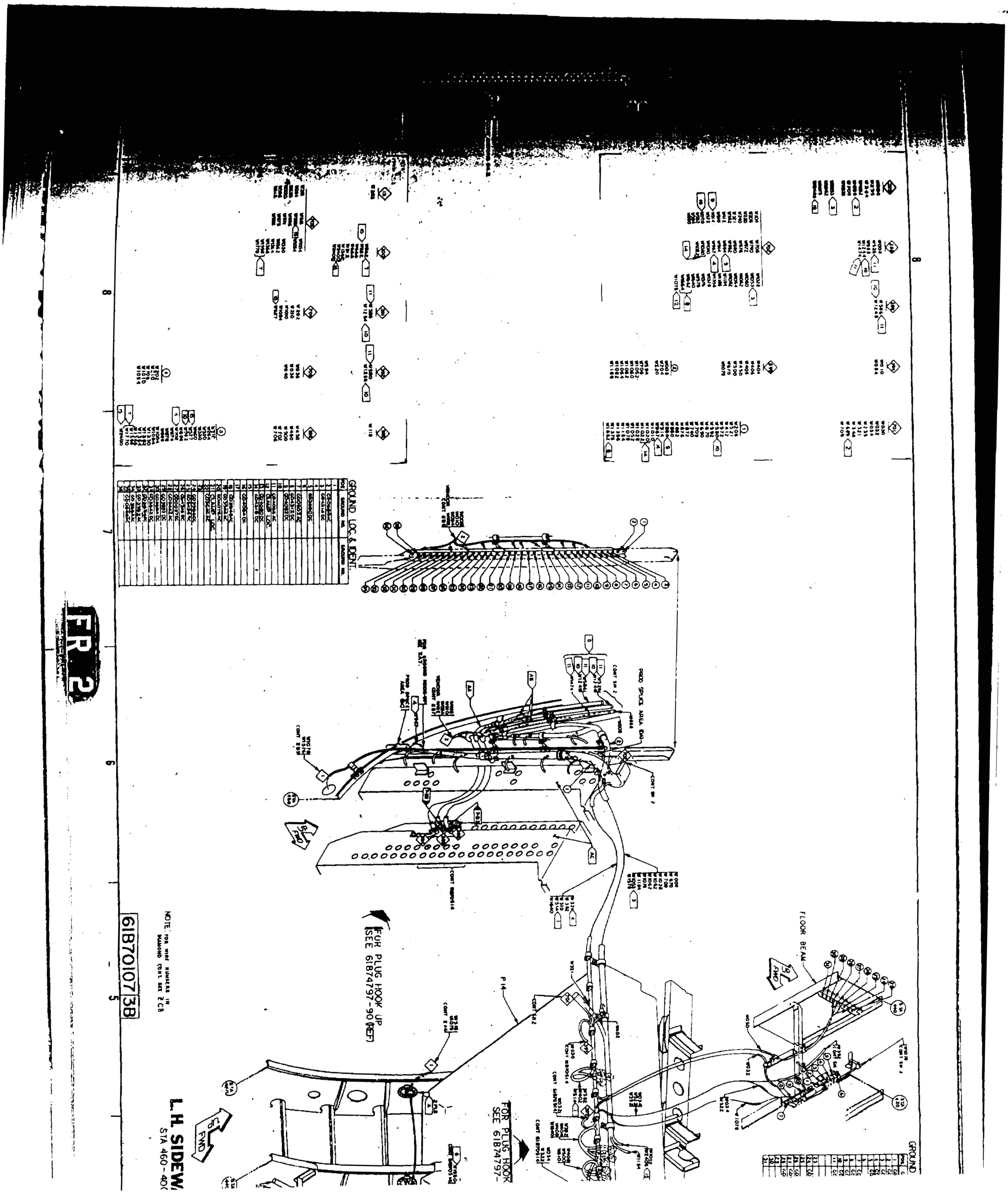

FR 1
61B70107
2B
TABLE II

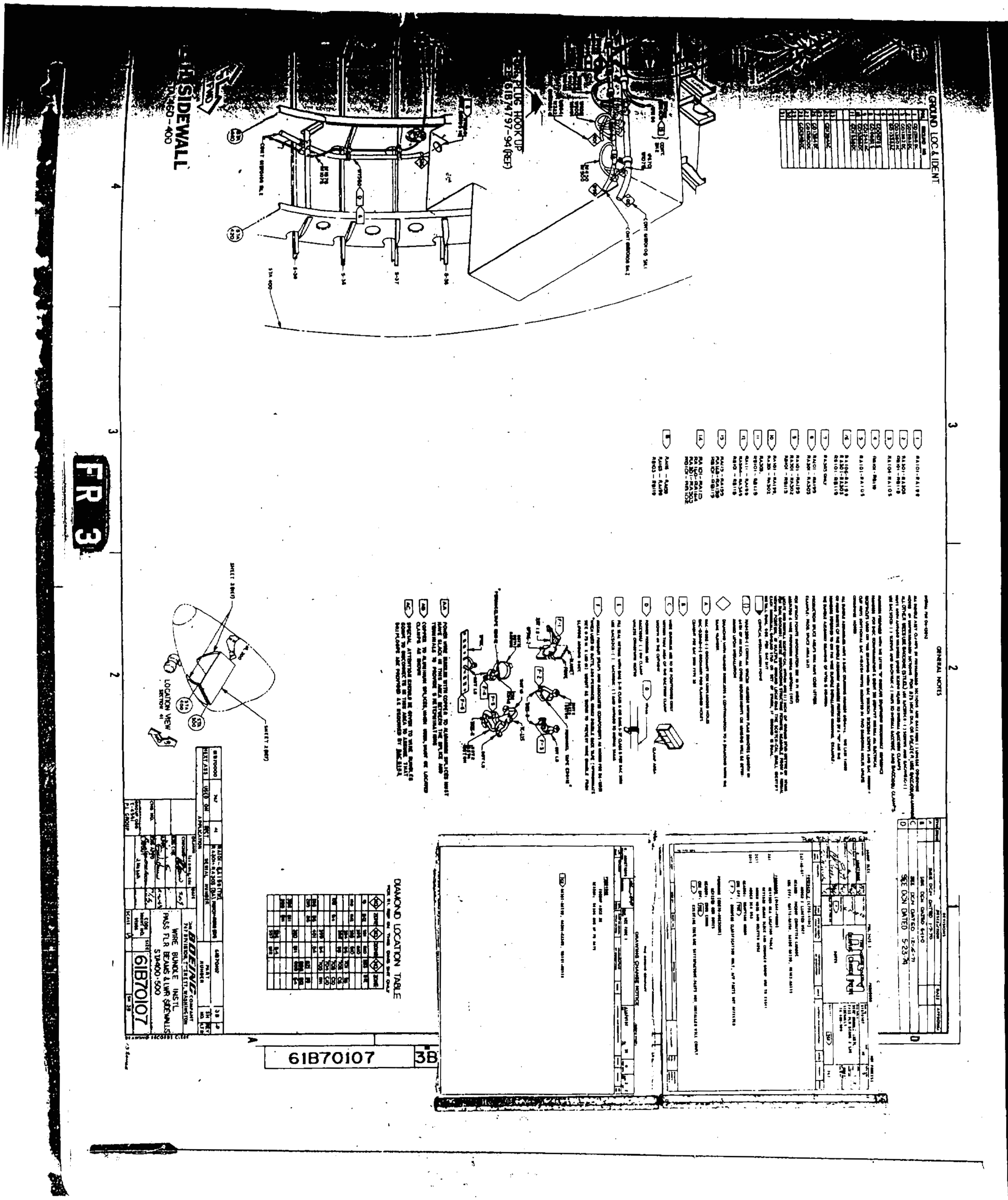

FR 2
PASSENGER FLOOR BEAMS
STA 400-500
RIGHT
LEFT
FWD
61B70107
2B
FOR DISC HW INFO SEE 61B74797-73
3A7
2A10
1A10
L512
L521
L324
L325

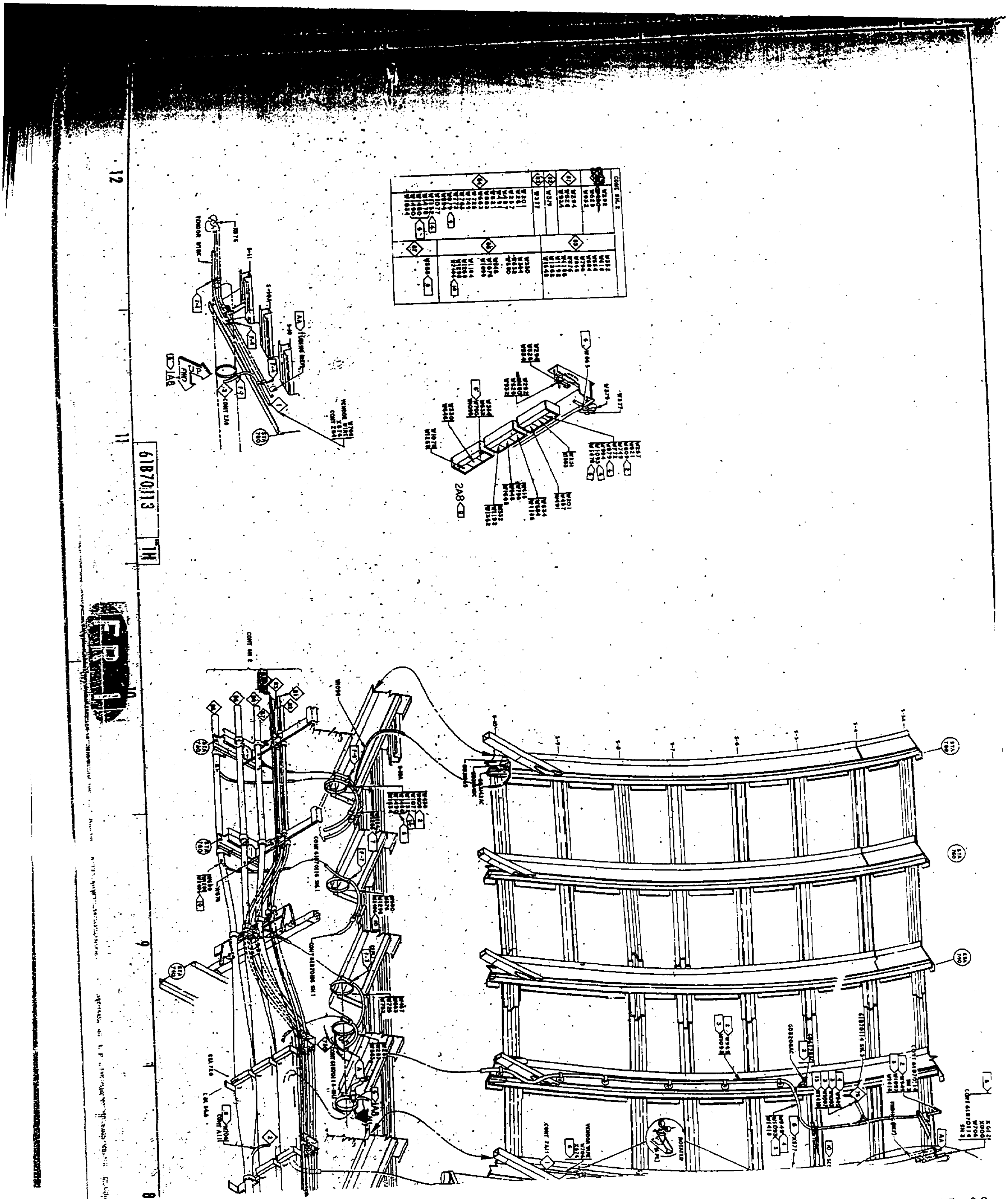

FR 3
61B70107
2B
TABLE I
2A7
3A7
1B7
STA 460

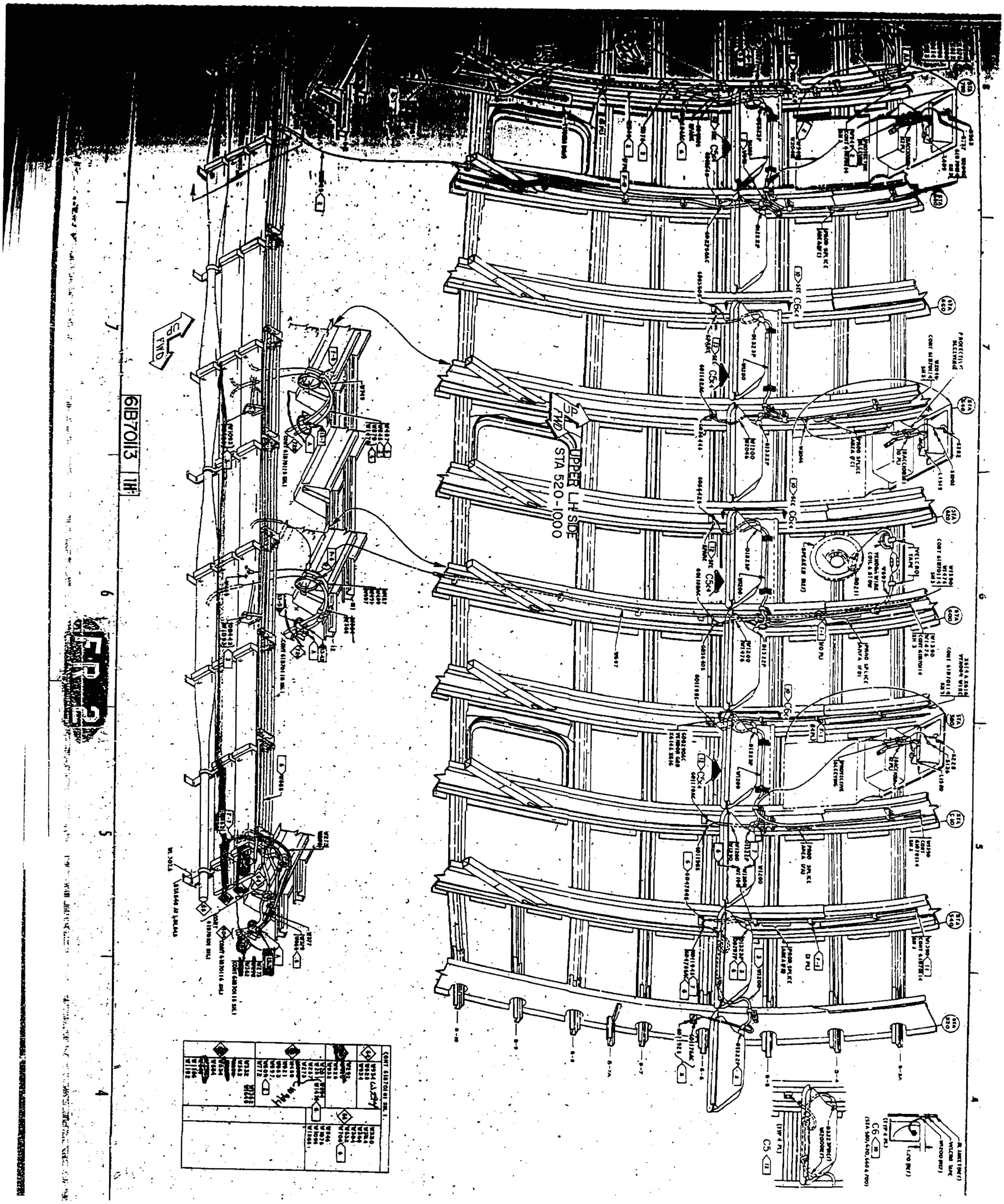

FR 4
61B70107
2B
H


R.H. SIDEWALL
STA 400-460
FOR PLUG HOOK-UP
SEE 61B74797-96 (REF)
FOR PLUG HOOK-UP
SEE 61B74797-91 (REF)
GROUND LOC. & IDENT.
FLOOR BEAM
FR 1
61B70107 3B

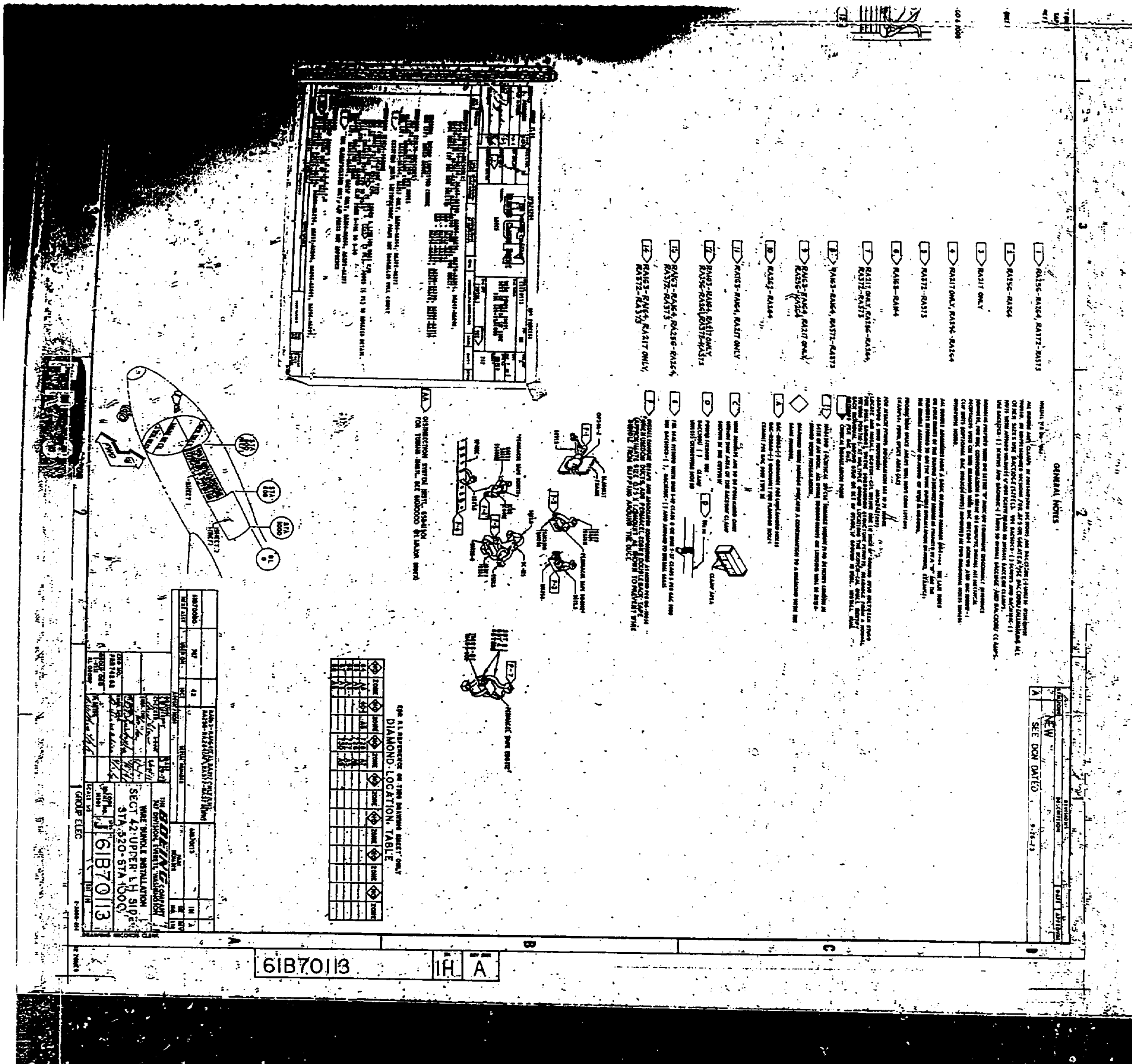

FR 2
61B70107 3B
GROUND LOC & IDENT.
FLOOR BEAM

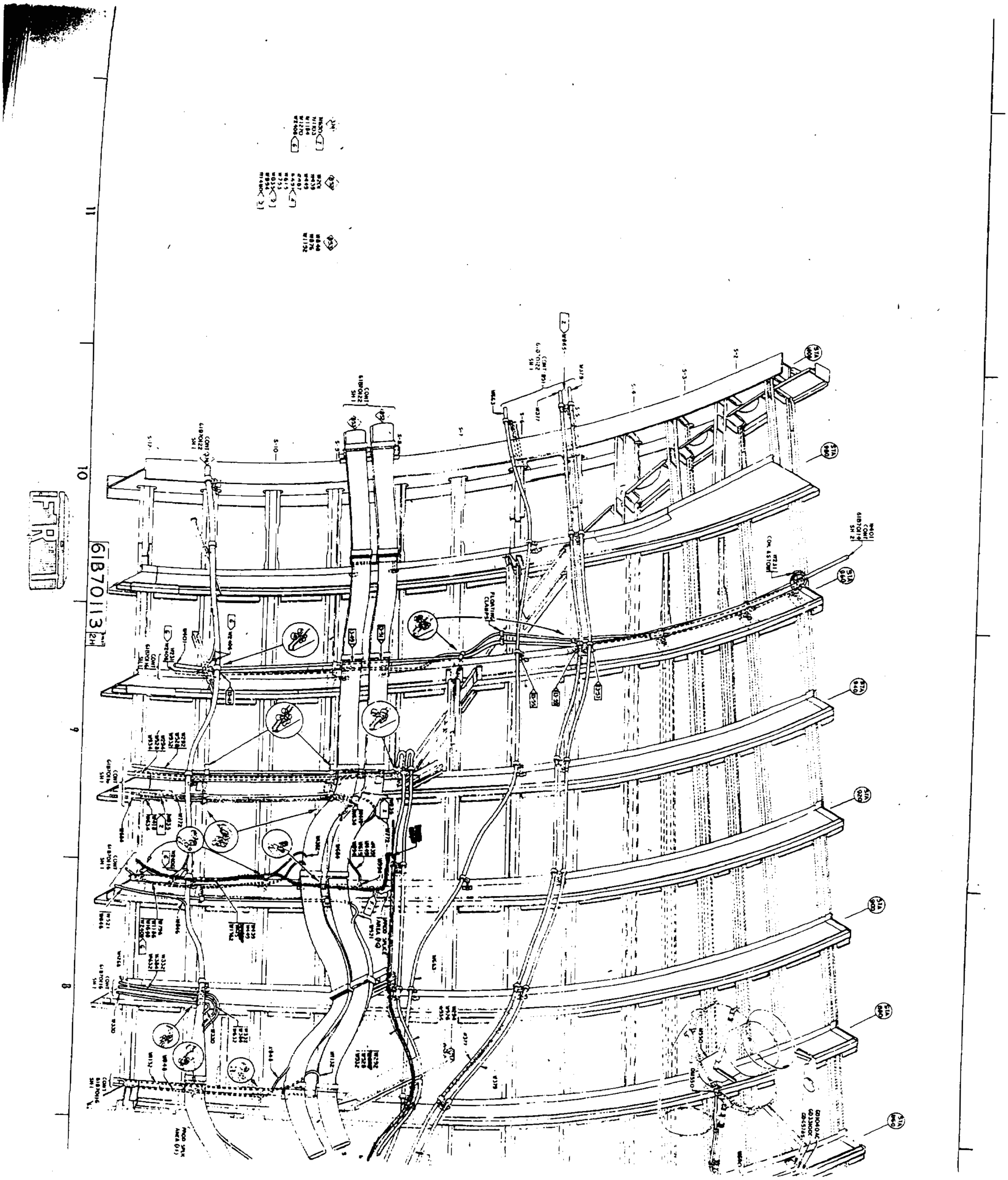

GROUND LOC & IDENT
GENERAL NOTES
DIAMOND LOCATION TABLE
FR 3
61B70107
3B

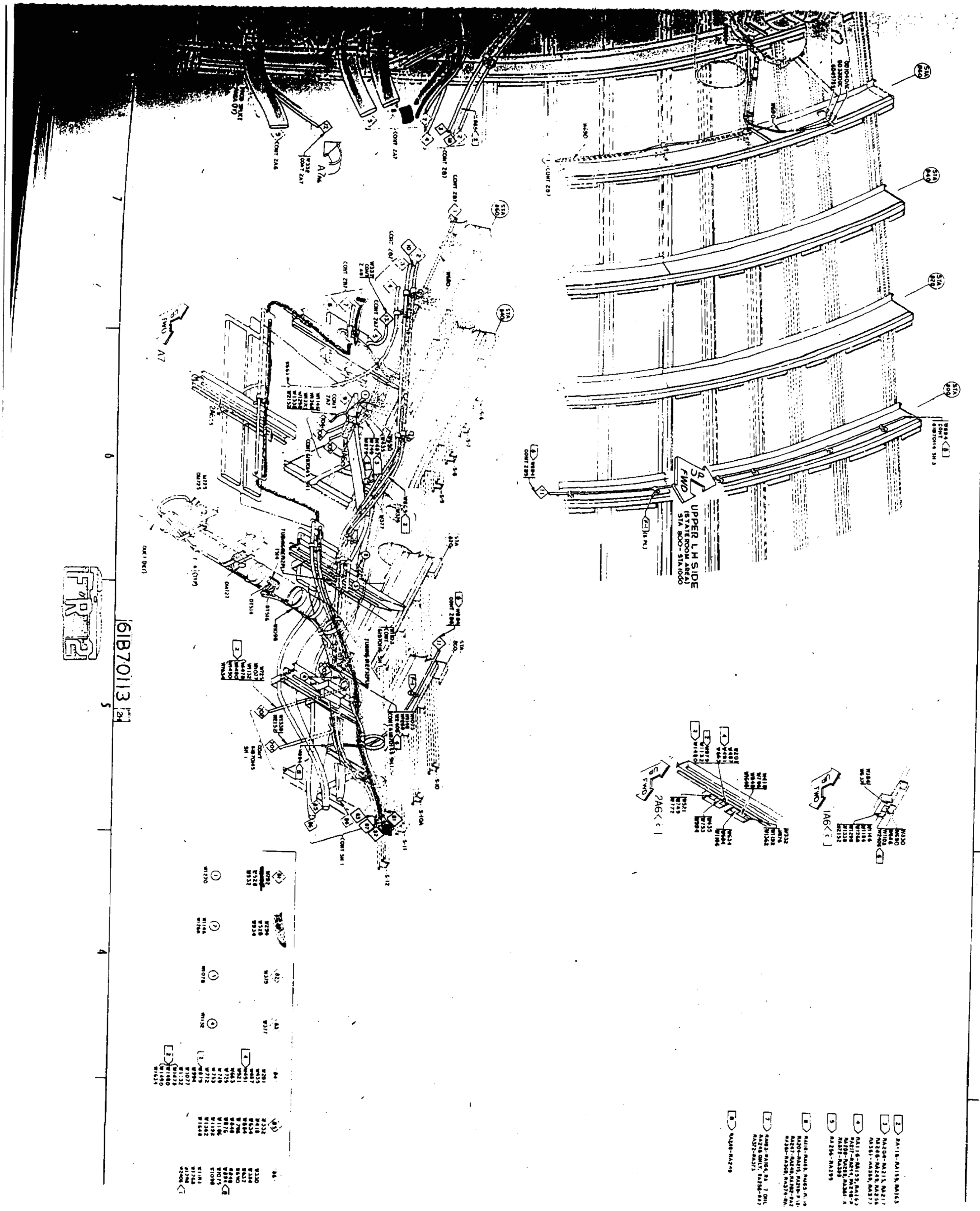


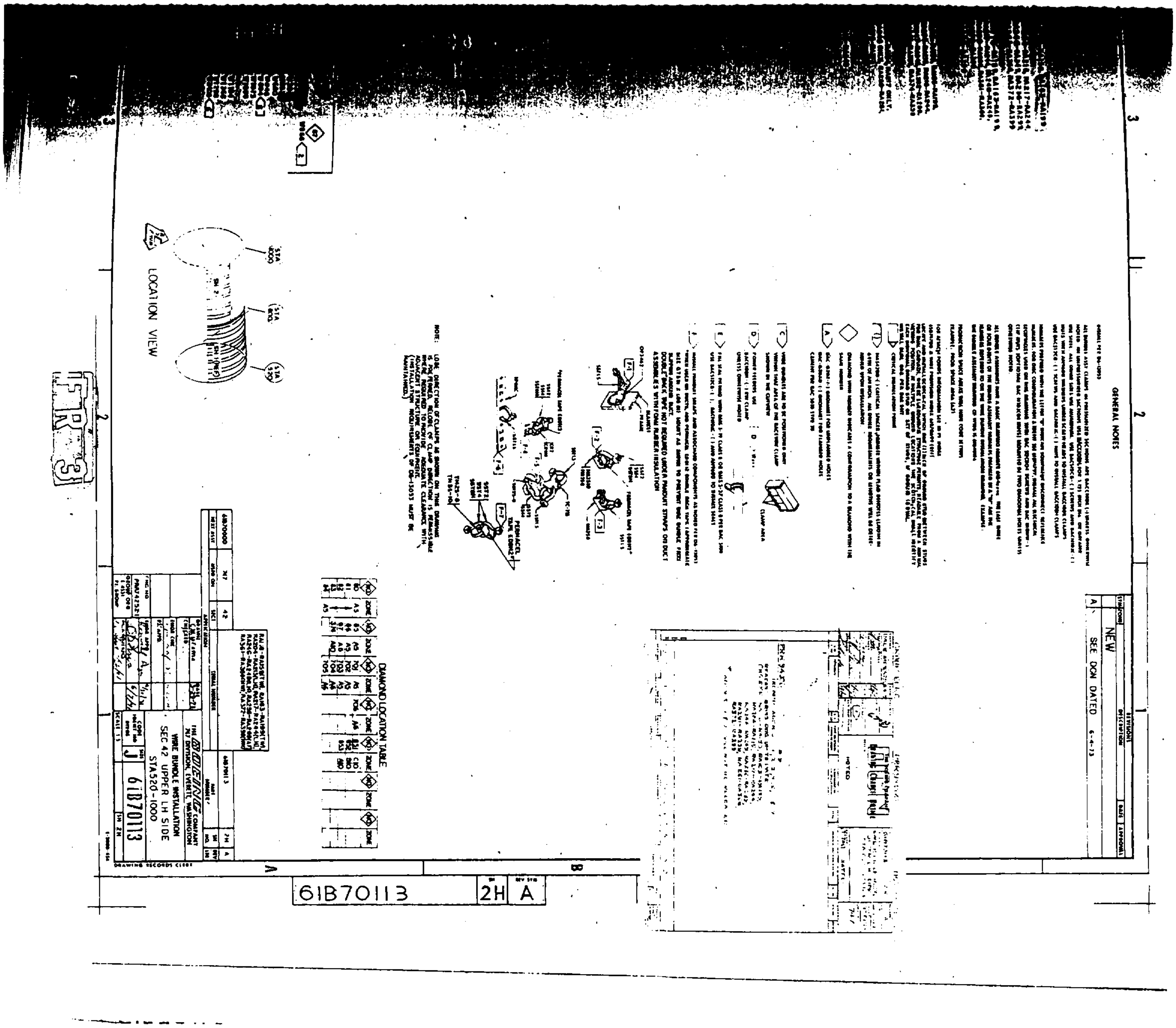


UPPER LH SIDE
STA 520-1000
61B70113
UP
FWD

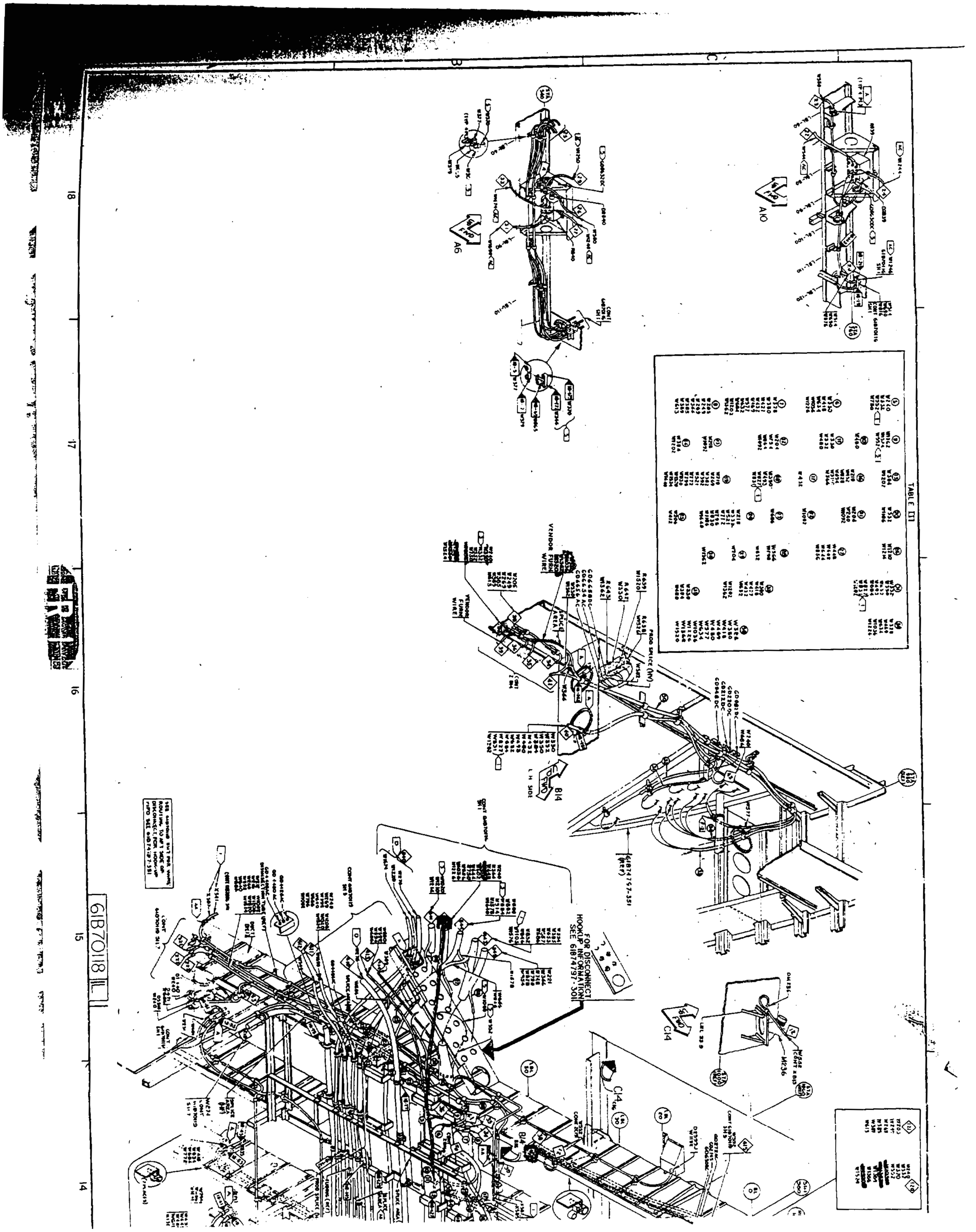

61B70113
1H
A


61B70113


61B70113
UPPER LH SIDE
FWD



61B70113
2H
A
GENERAL NOTES
NEW
SEE DCN DATED 6-4-73
DIAMOND LOCATION TABLE
LOCATION VIEW
WIRE BUNDLE INSTALLATION
SEC 42 UPPER LH SIDE
STA520-1000



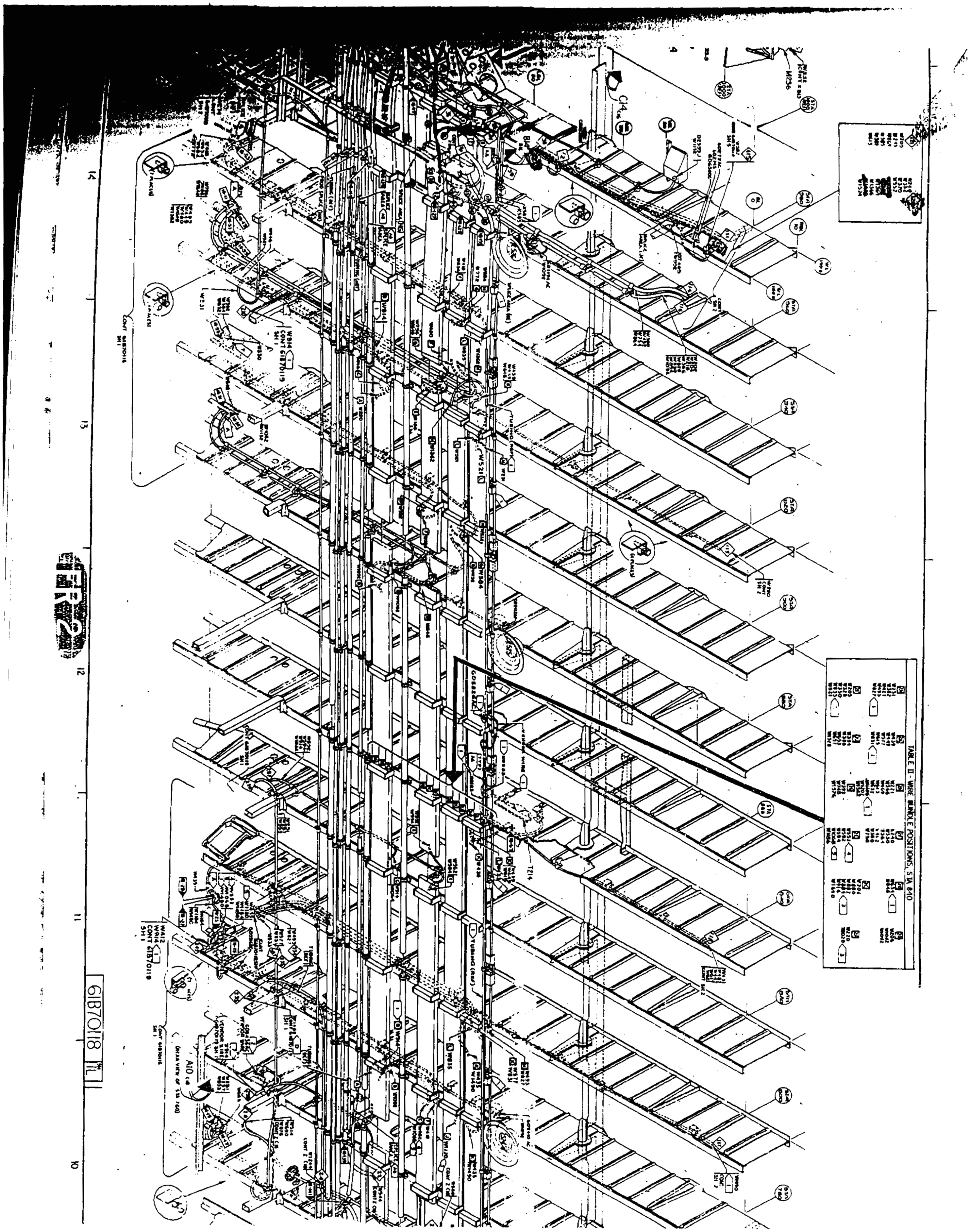
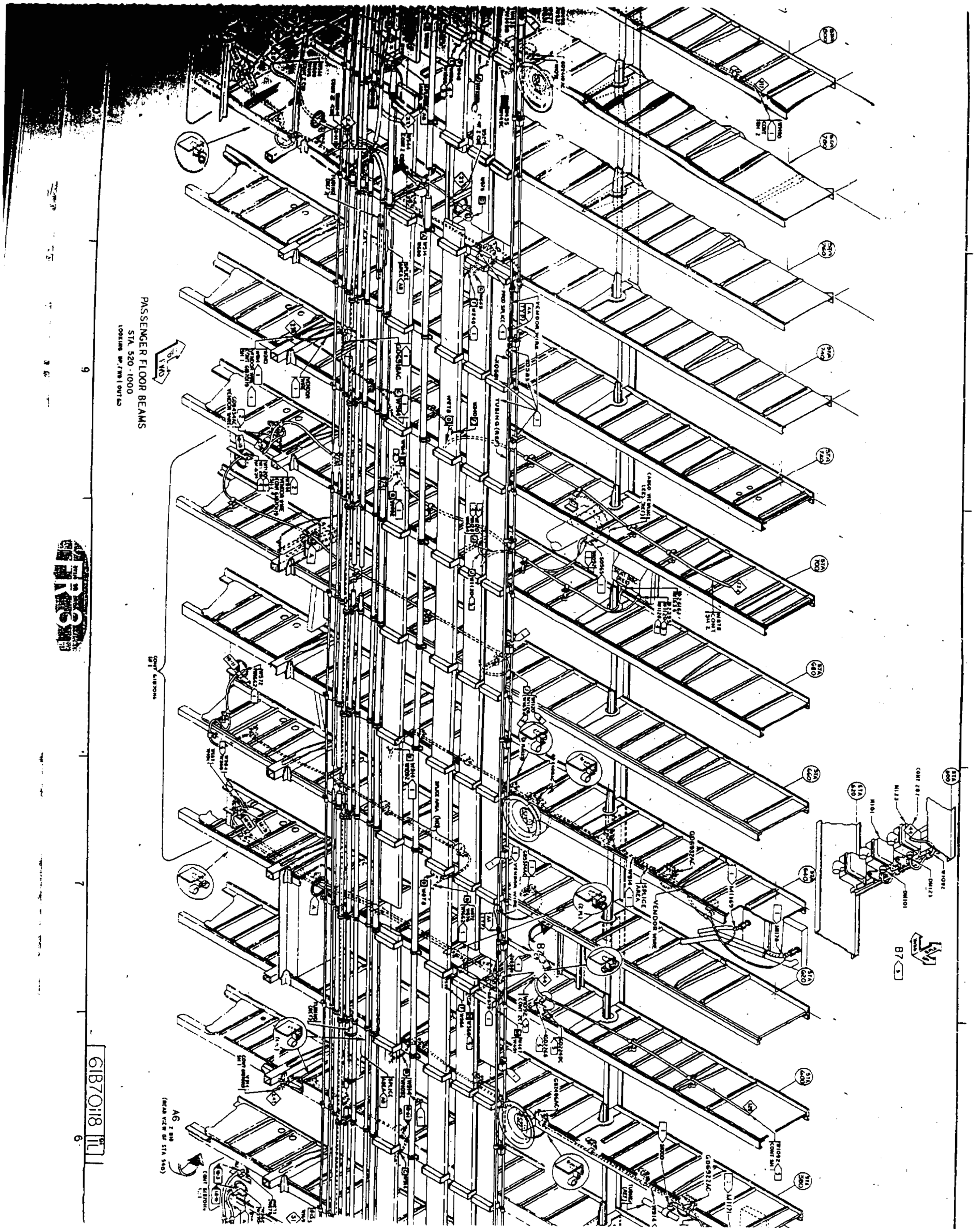
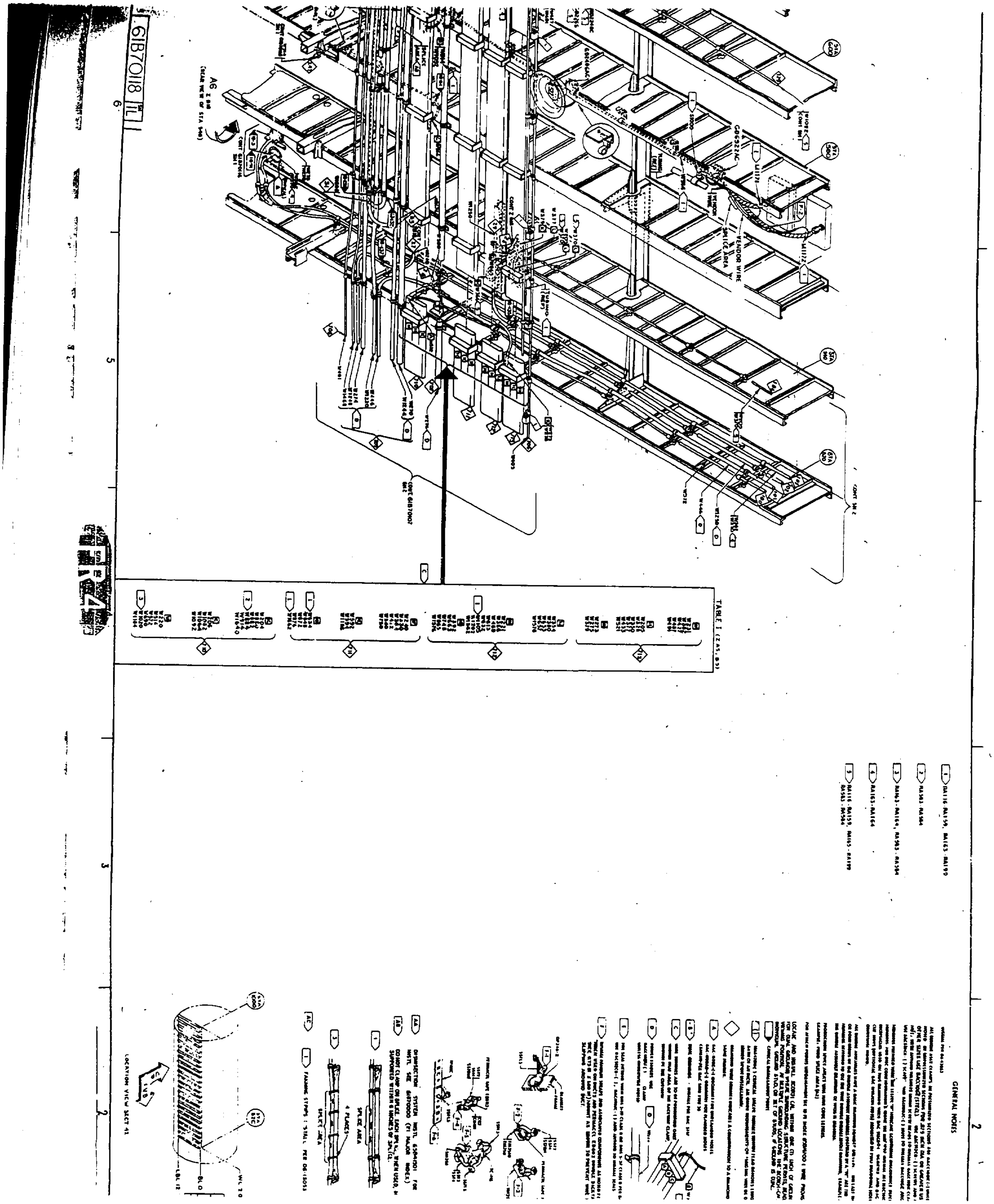
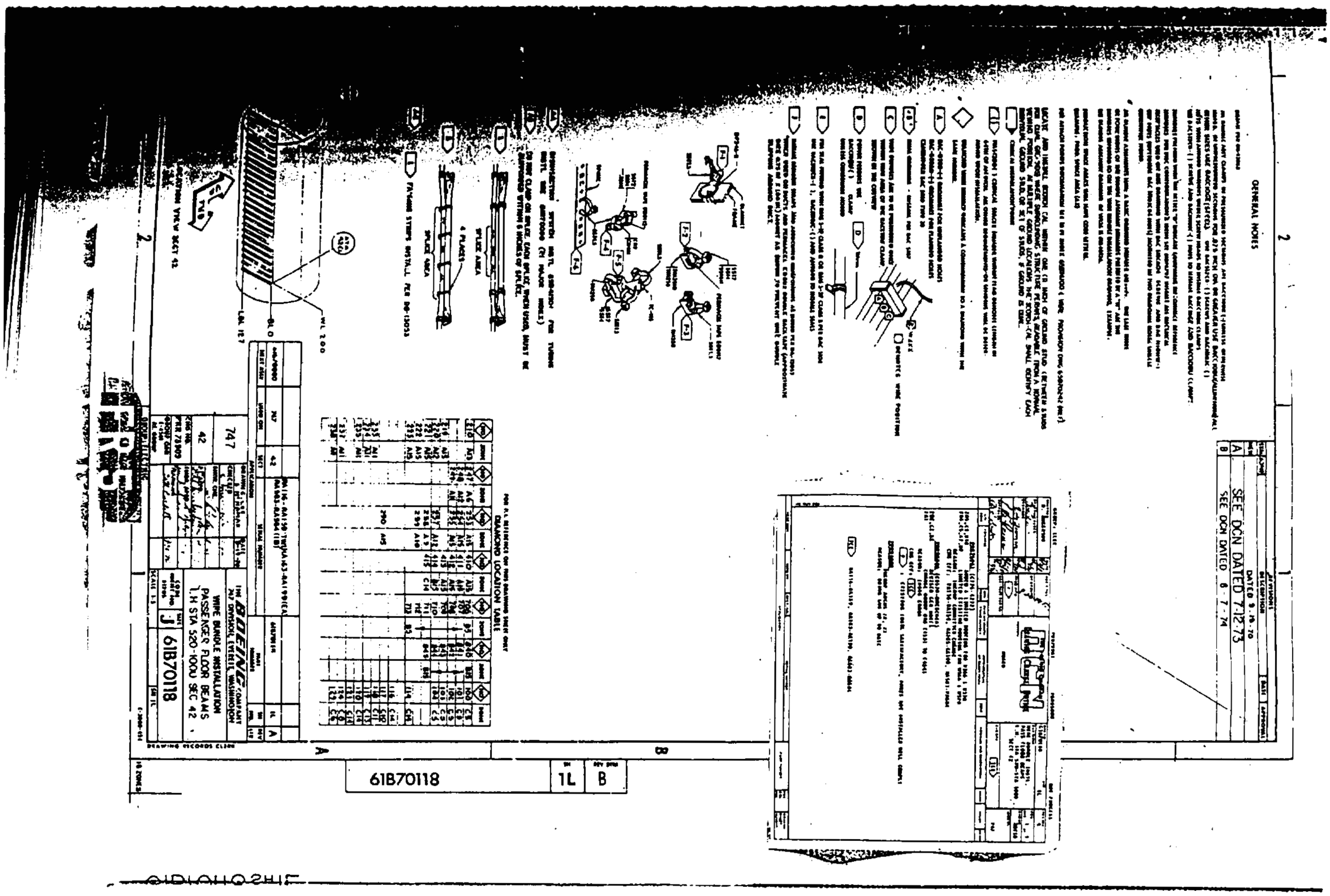
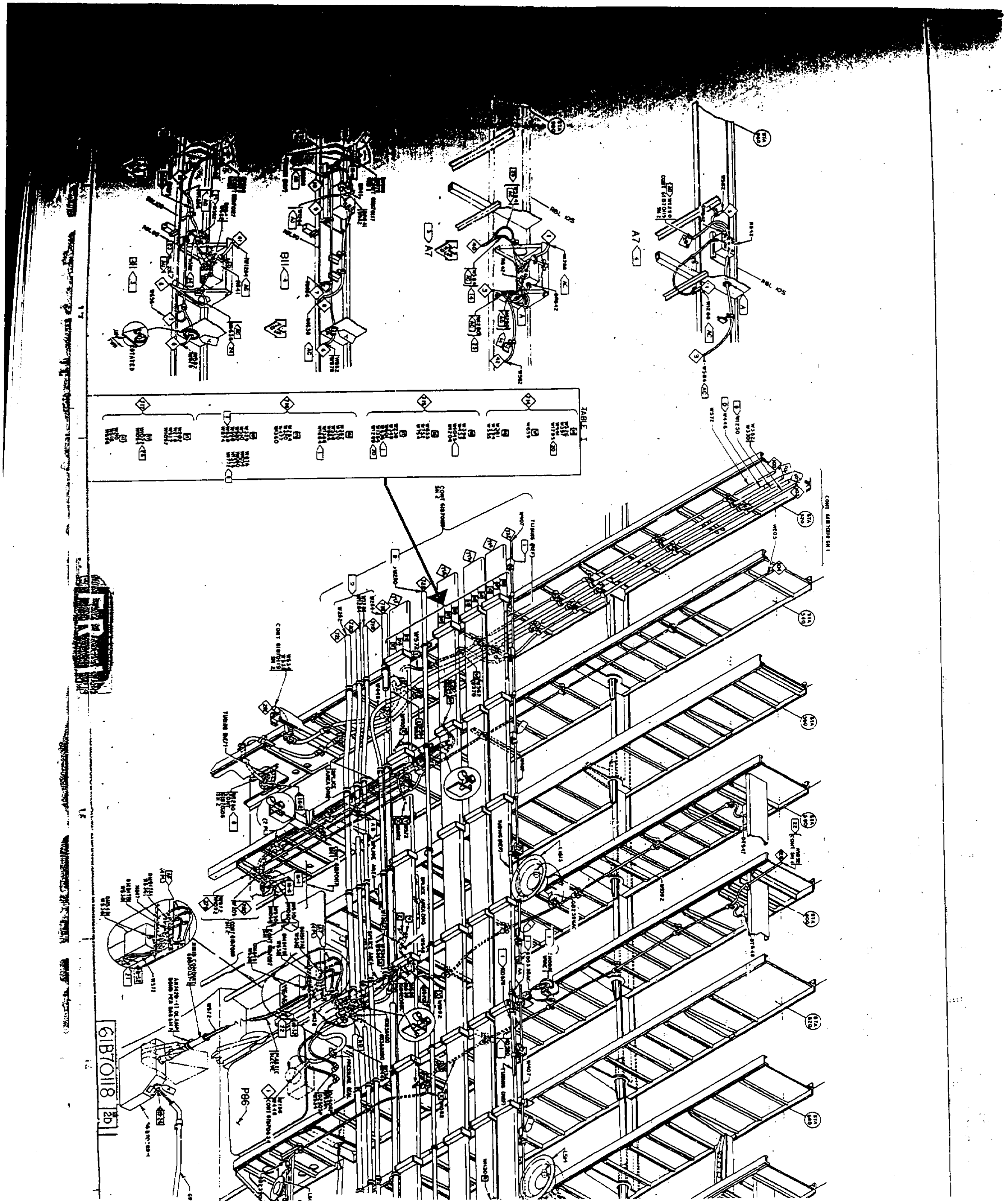


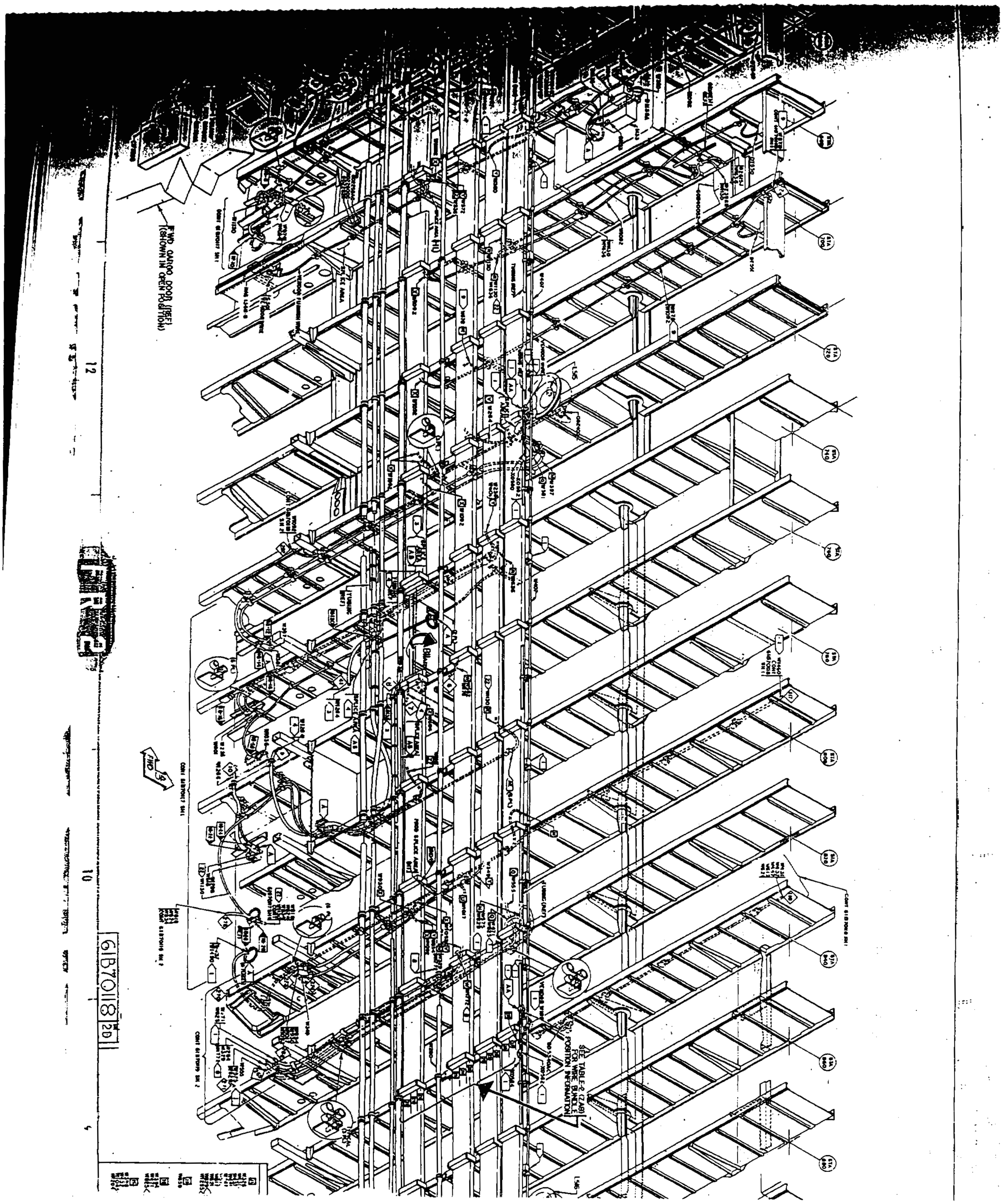
TABLE II - WIRE BUNDLE POSITIONS, STA 840
61B70118
A10 (REAR VIEW OF STA 760)
TUBING (REF)


PASSENGER FLOOR BEAMS
STA. 520-1000
61B70118




GENERAL NOTES
SEE DCN DATED 7-12-73
SEE DCN DATED 6-7-74
DIAMOND LOCATION TABLE
747
BOEING
WIRE BUNDLE INSTALLATION
PASSENGER FLOOR BEAMS
LH STA 520-1000 SEC 42
61B70118
61B70118
1L
B




FWD CARGO DOOR (REF)
(SHOWN IN OPEN POSITION)
SEE TABLE-2 (Z48)
FOR WIRE BUNDLE
POSITION INFORMATION
FWD
61B70118
2D

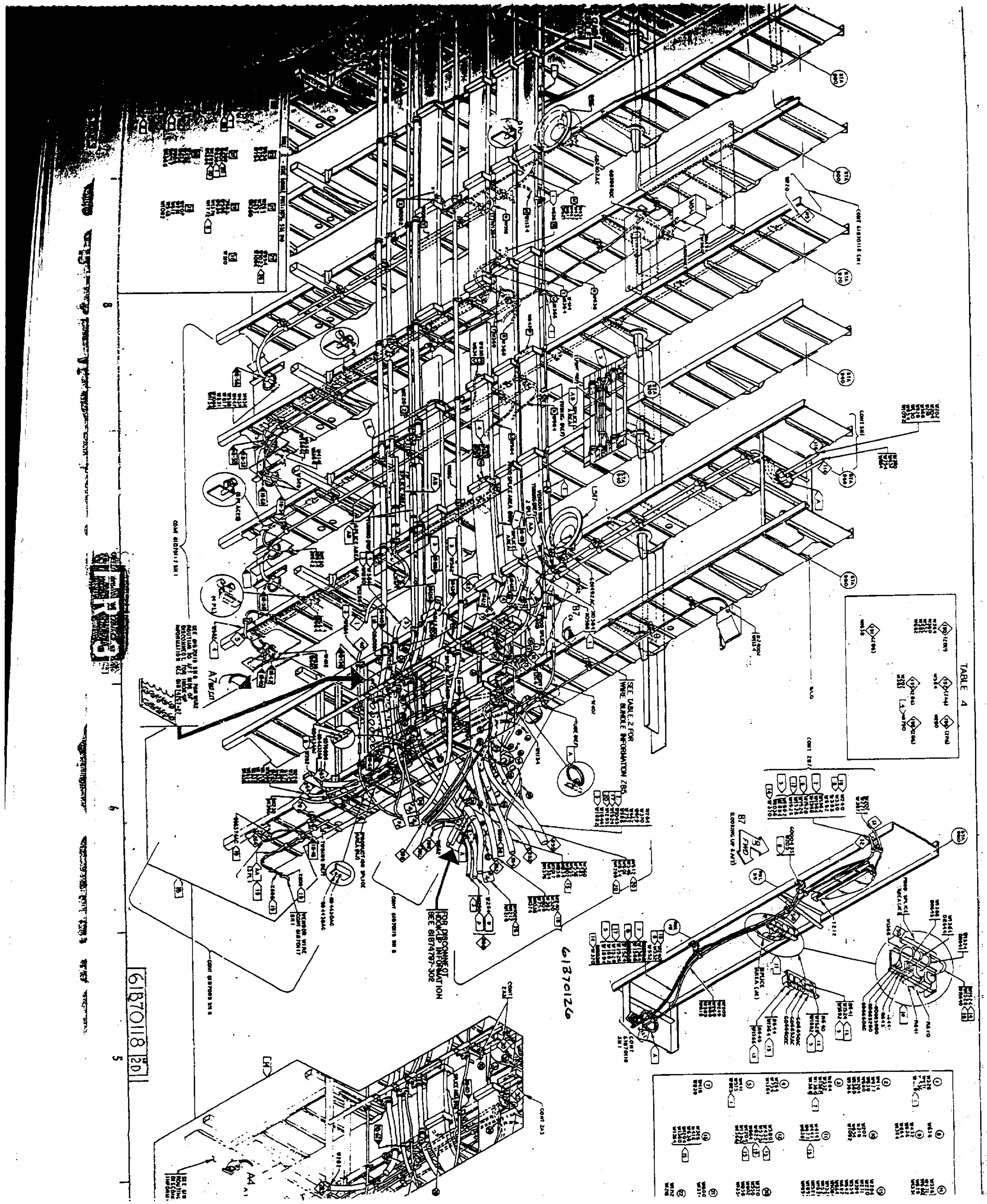
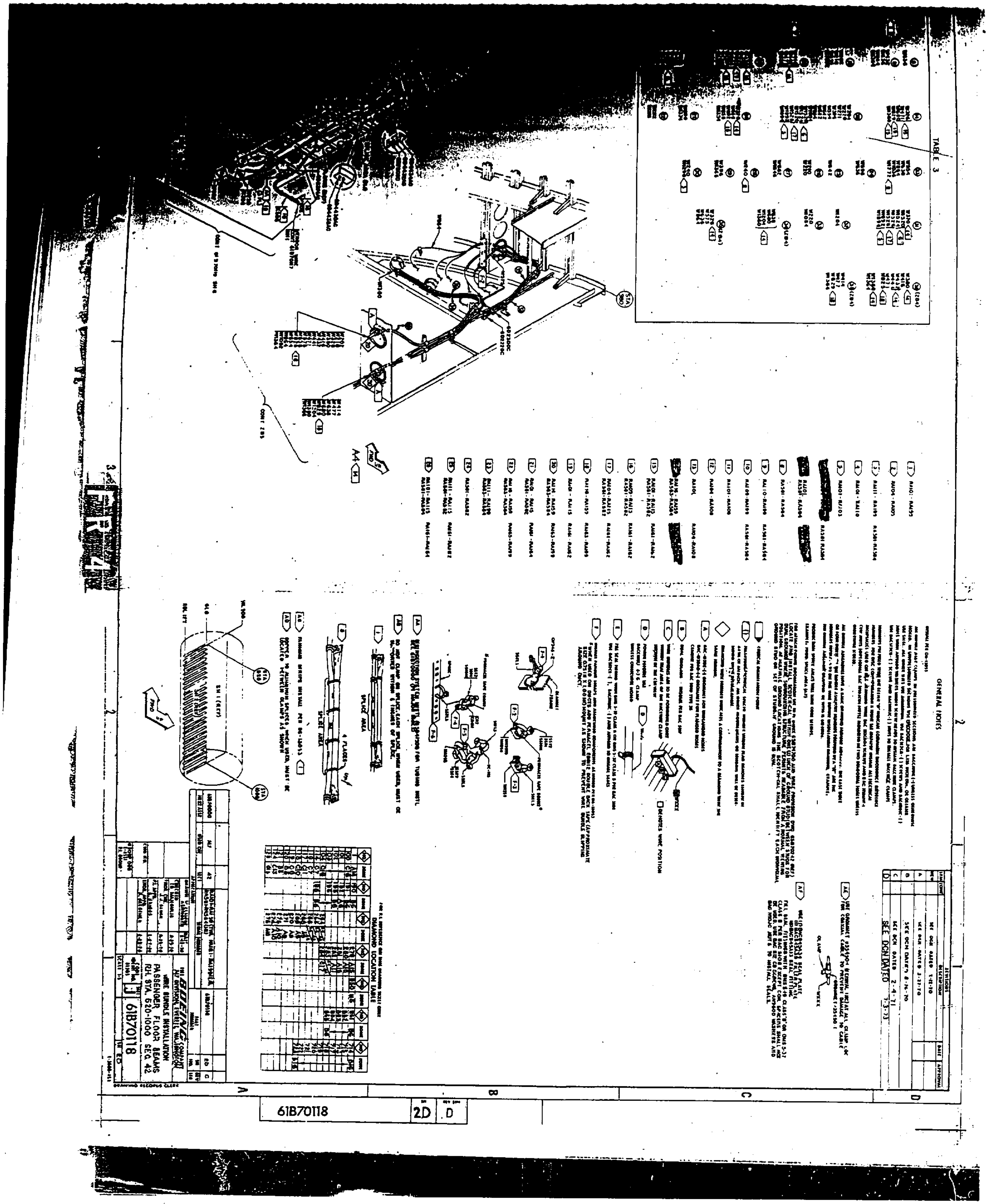
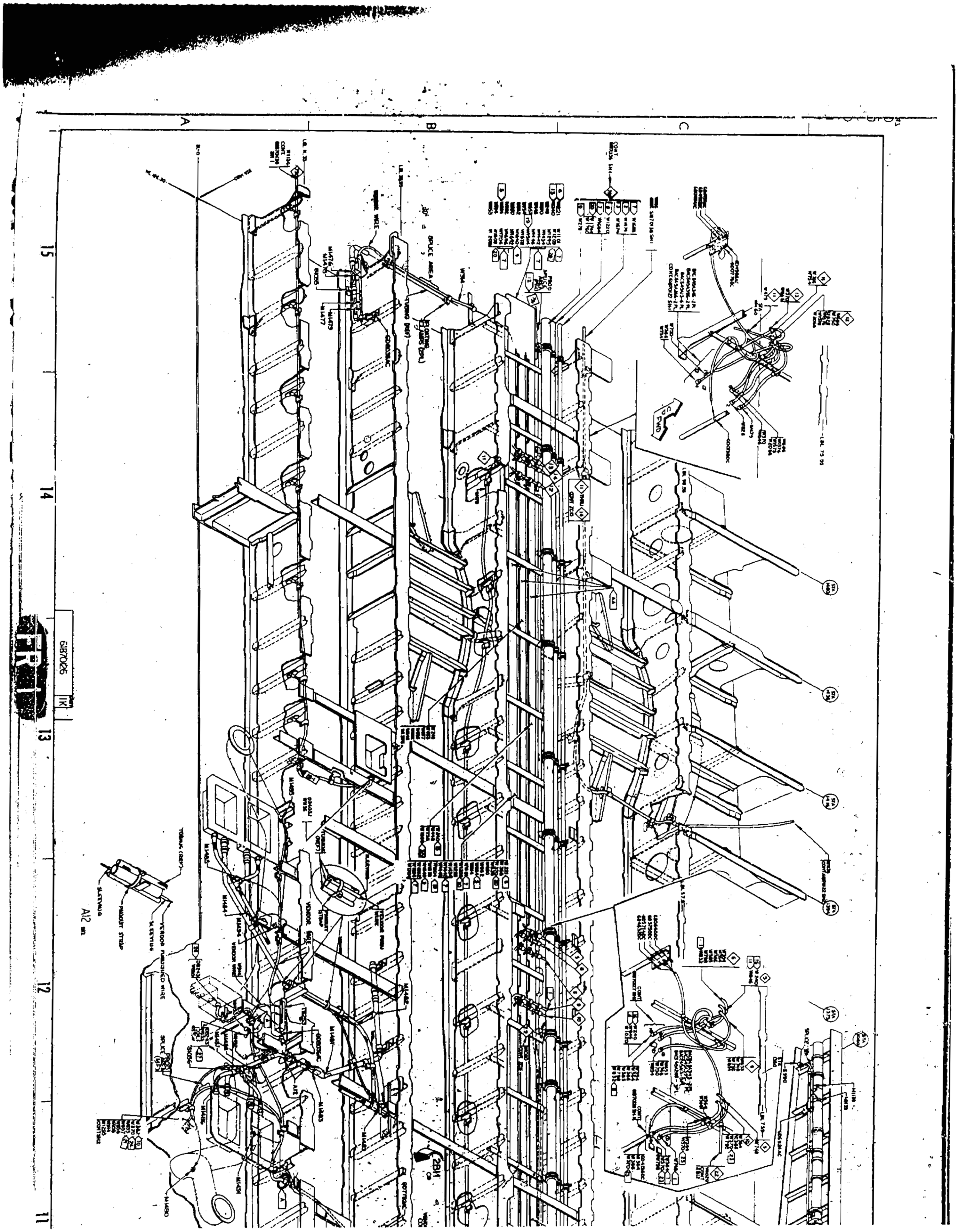
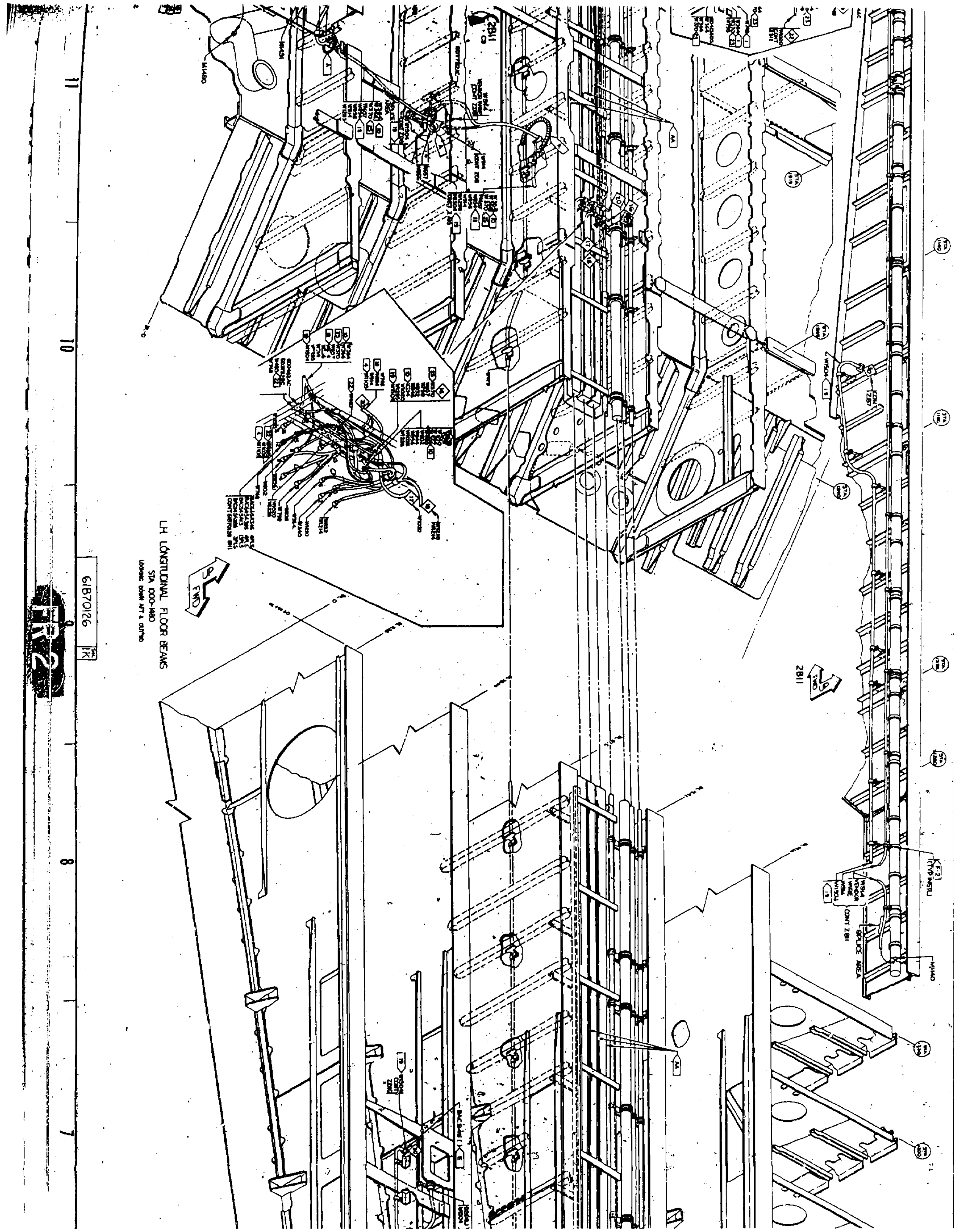
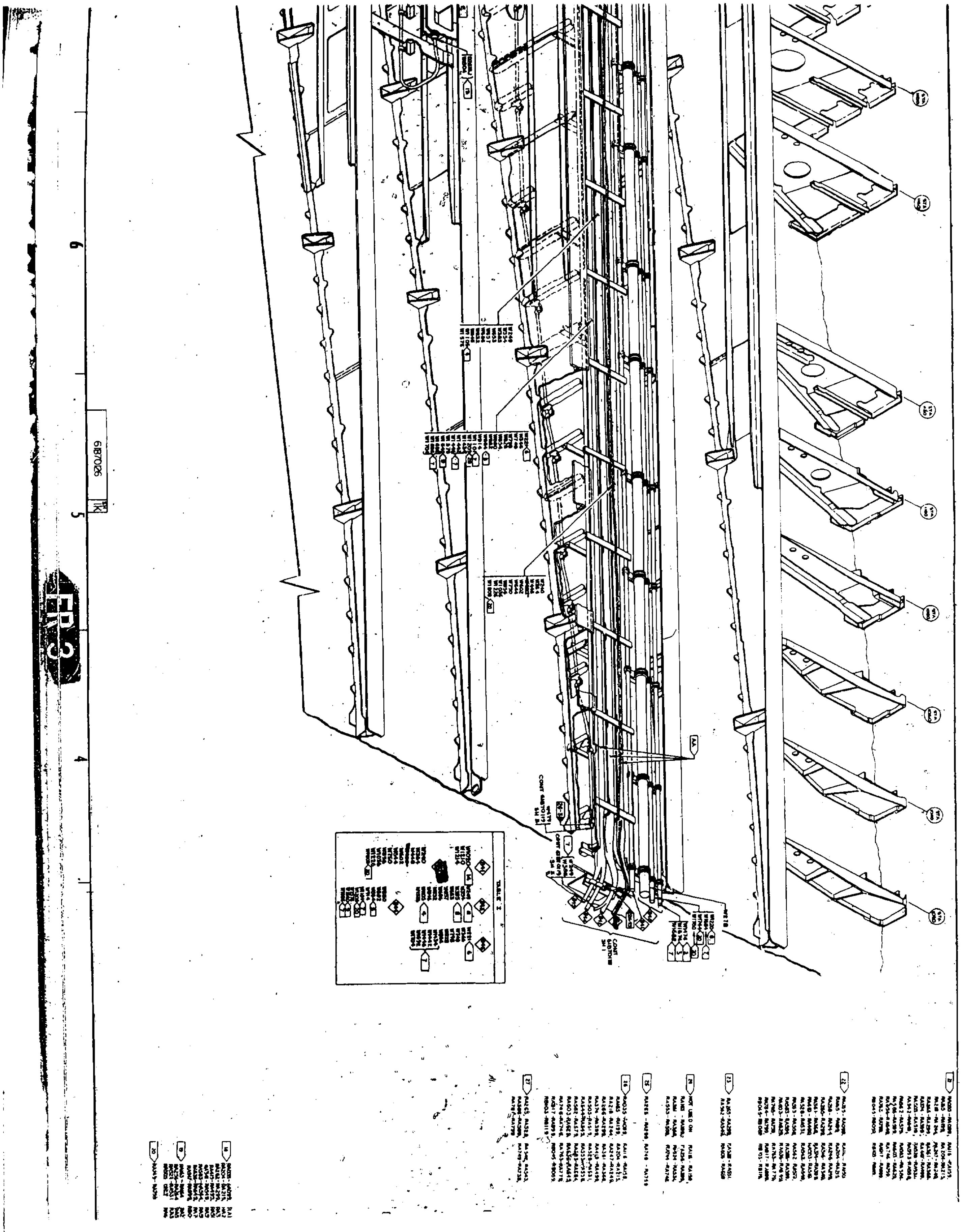


TABLE 4
61B70118
61B70126


GENERAL NOTES
TABLE 3
DIAMOND LOCATION TABLE
SPLICE AREA
THE BOEING COMPANY
WIRE BUNDLE INSTALLATION
PASSENGER FLOOR BEAMS
R.H. STA. 620-1000 SEC. 42
61B70118
2D
D




LH LONGITUDINAL FLOOR BEAMS
STA 1000-1480
61B70126
FR 2
SPLICE AREA



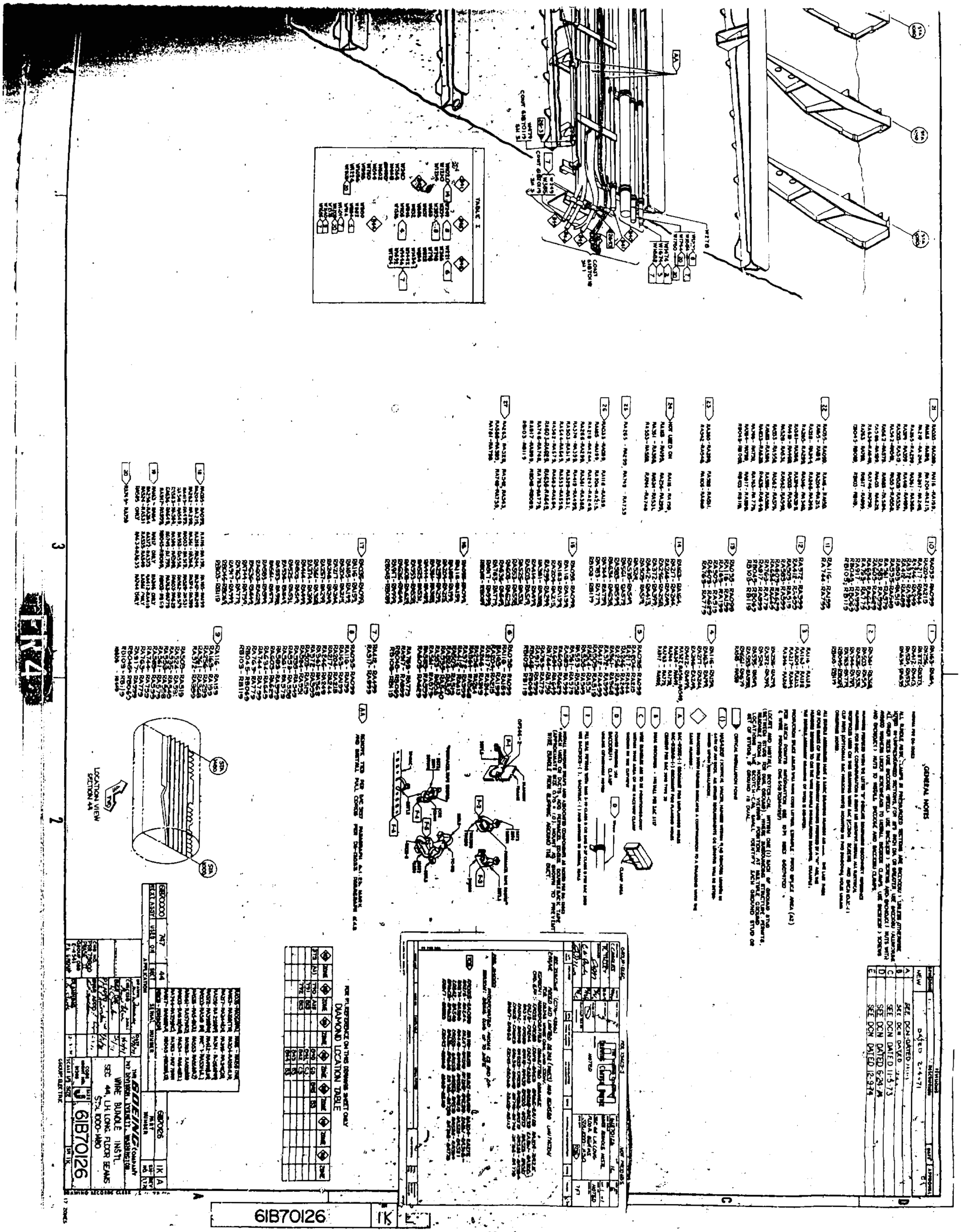
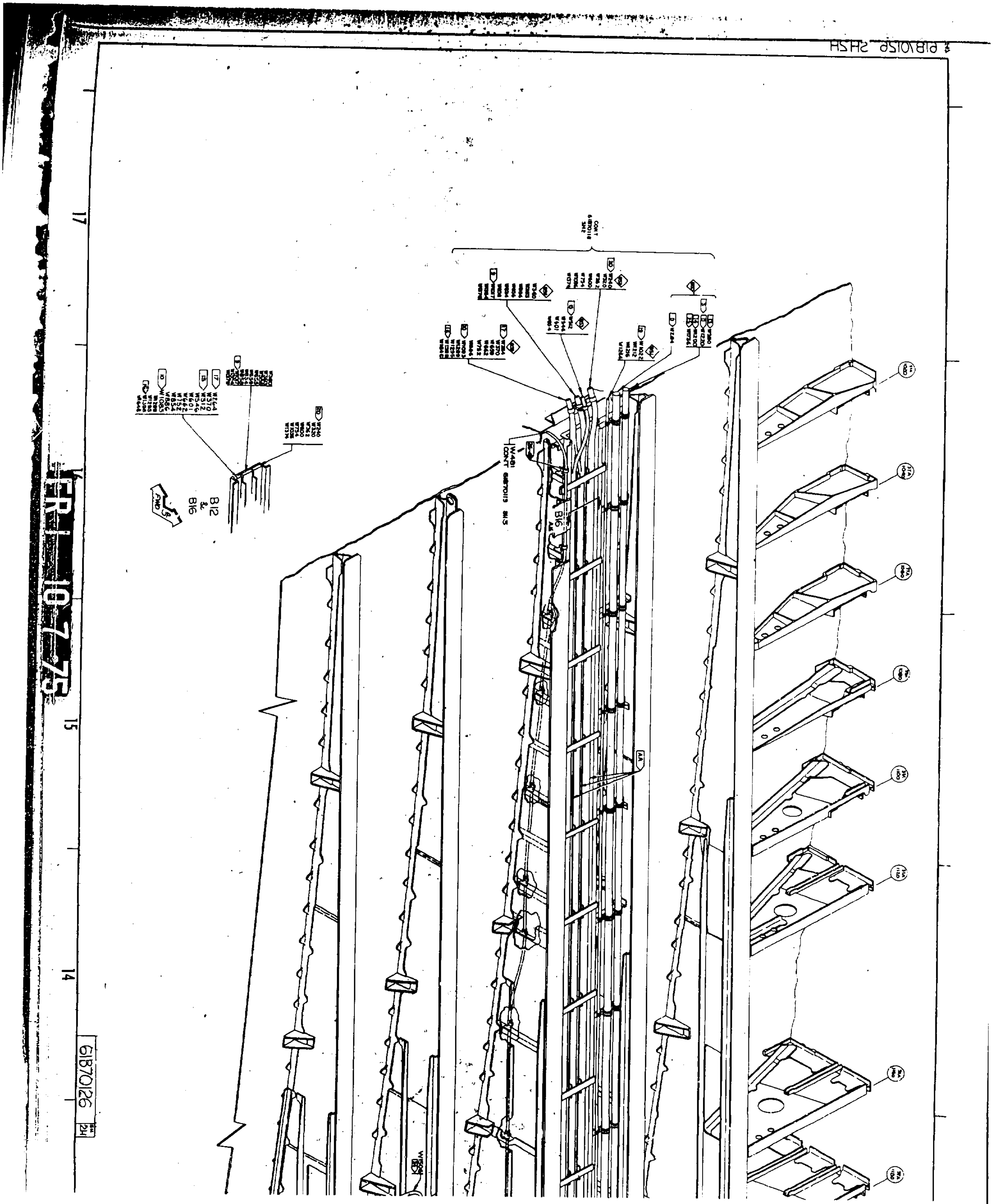
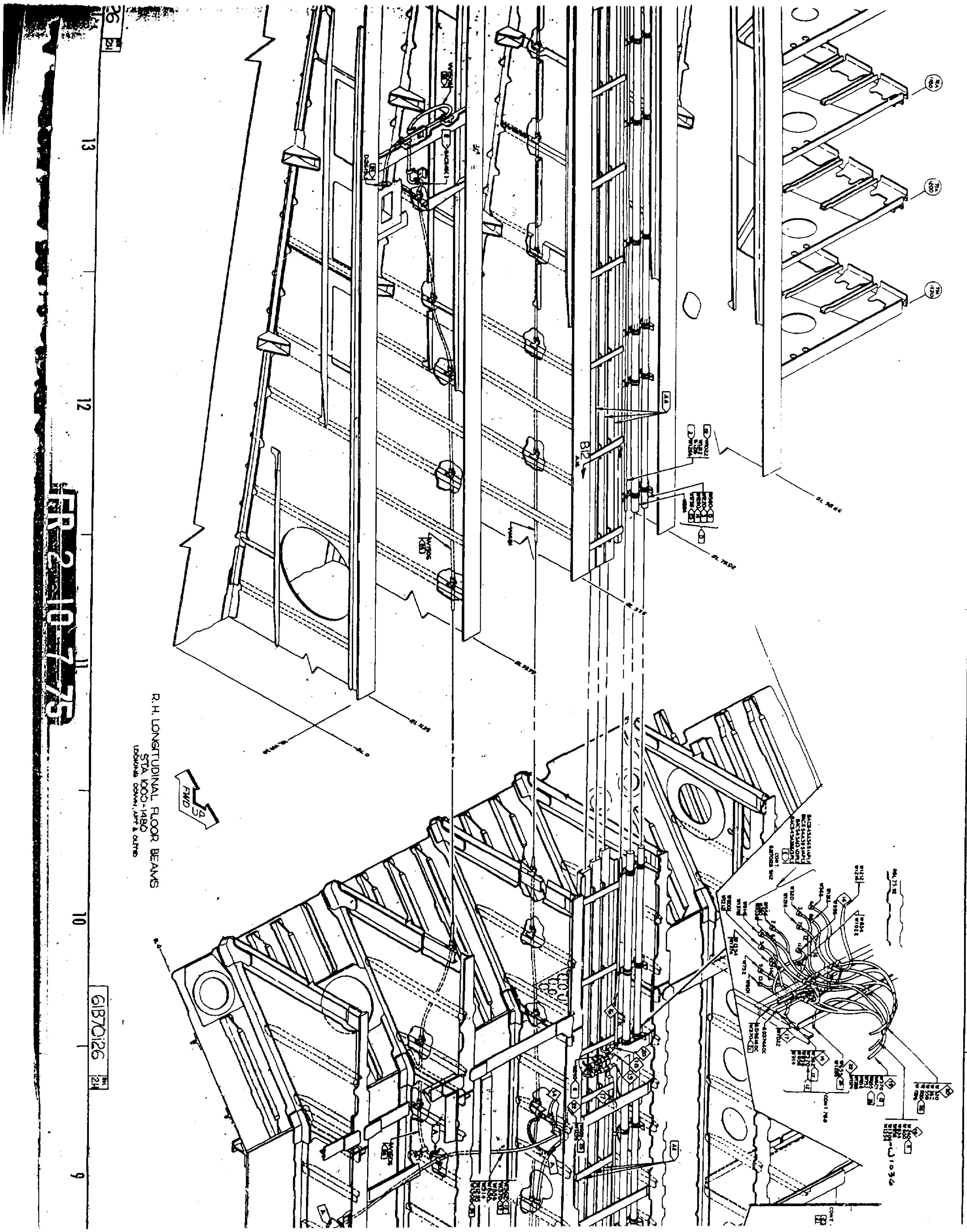
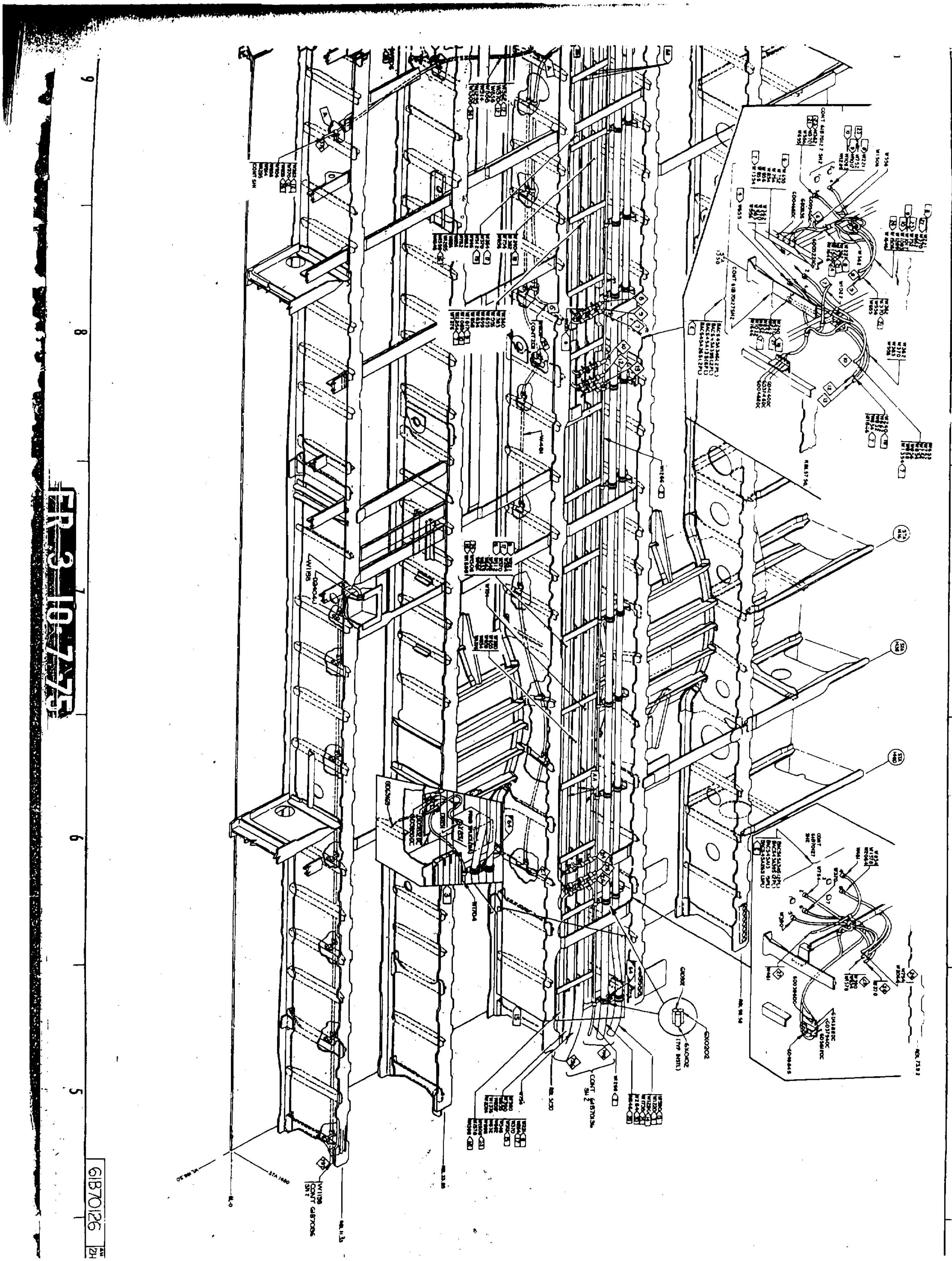
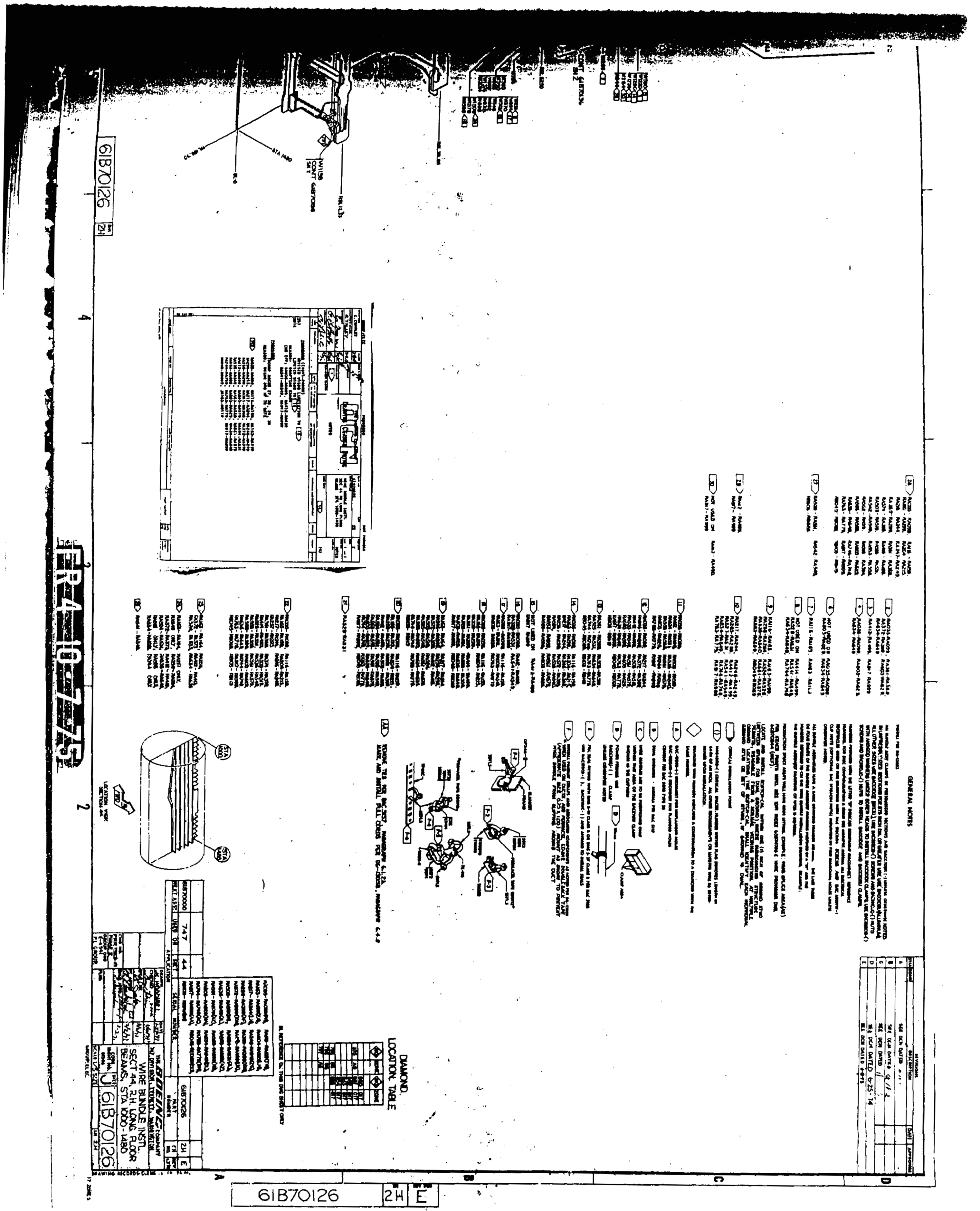


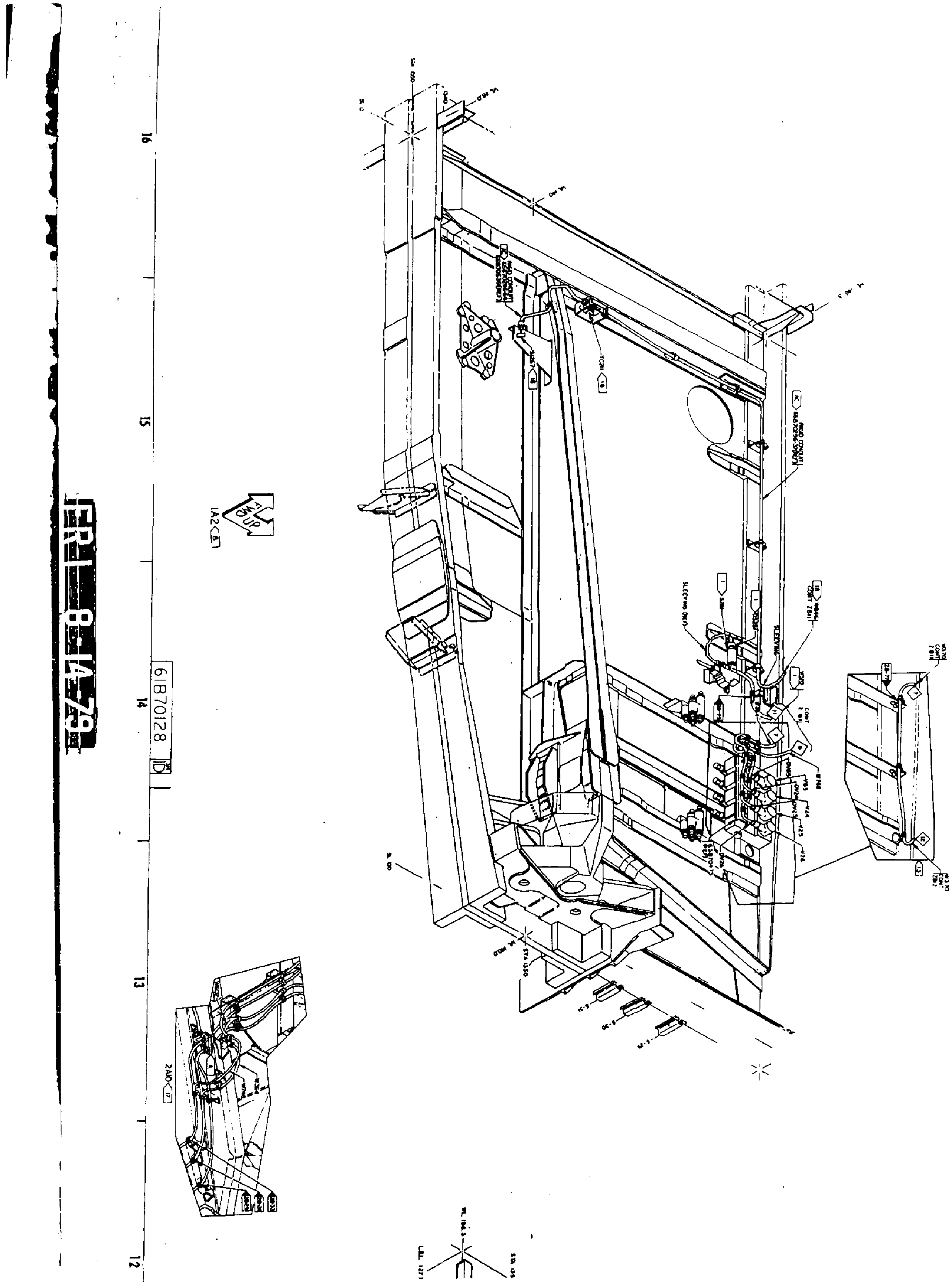
TABLE I
GENERAL NOTES
DIAMOND LOCATION TABLE
LOCATION VIEW SECTION 44
WIRE BUNDLE INSTL
SEC 44, LH LONG FLOOR BEAMS
61B70126
61B70126
IK




R.H. LONGITUDINAL FLOOR BEAMS
STA 1000-1480
LOOKING DOWN, AFT & OUTBD
FWD
UP
61B70126
13
12
11
10
9




GENERAL NOTES
DIAMOND LOCATION TABLE
747
44
61B70126
2H
E
THE BOEING COMPANY
WIRE BUNDLE INSTL.
SECT 44, 2.H. LONG FLOOR
BEAMS, STA 1000-1480
J
61B70126
2H
E

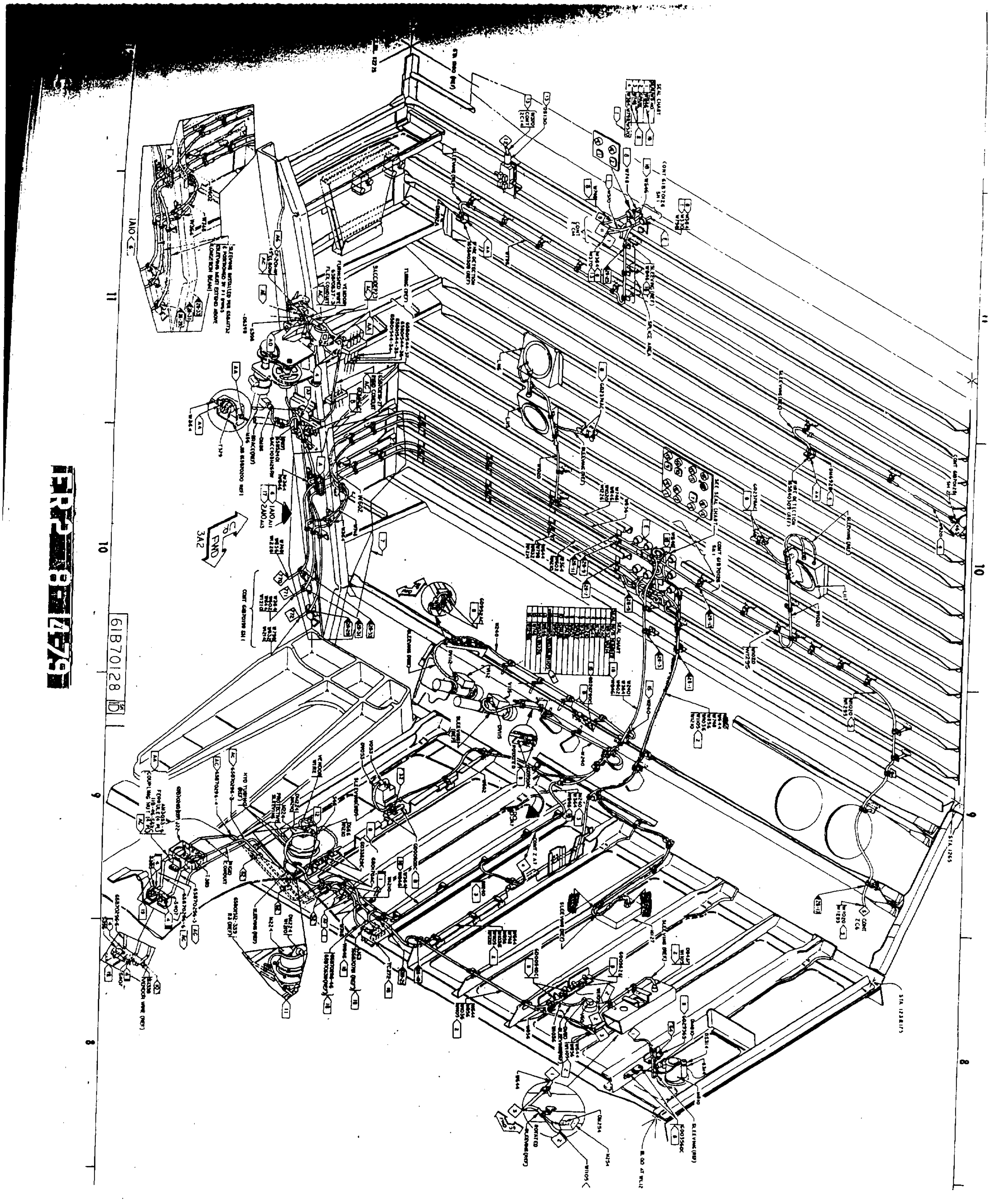


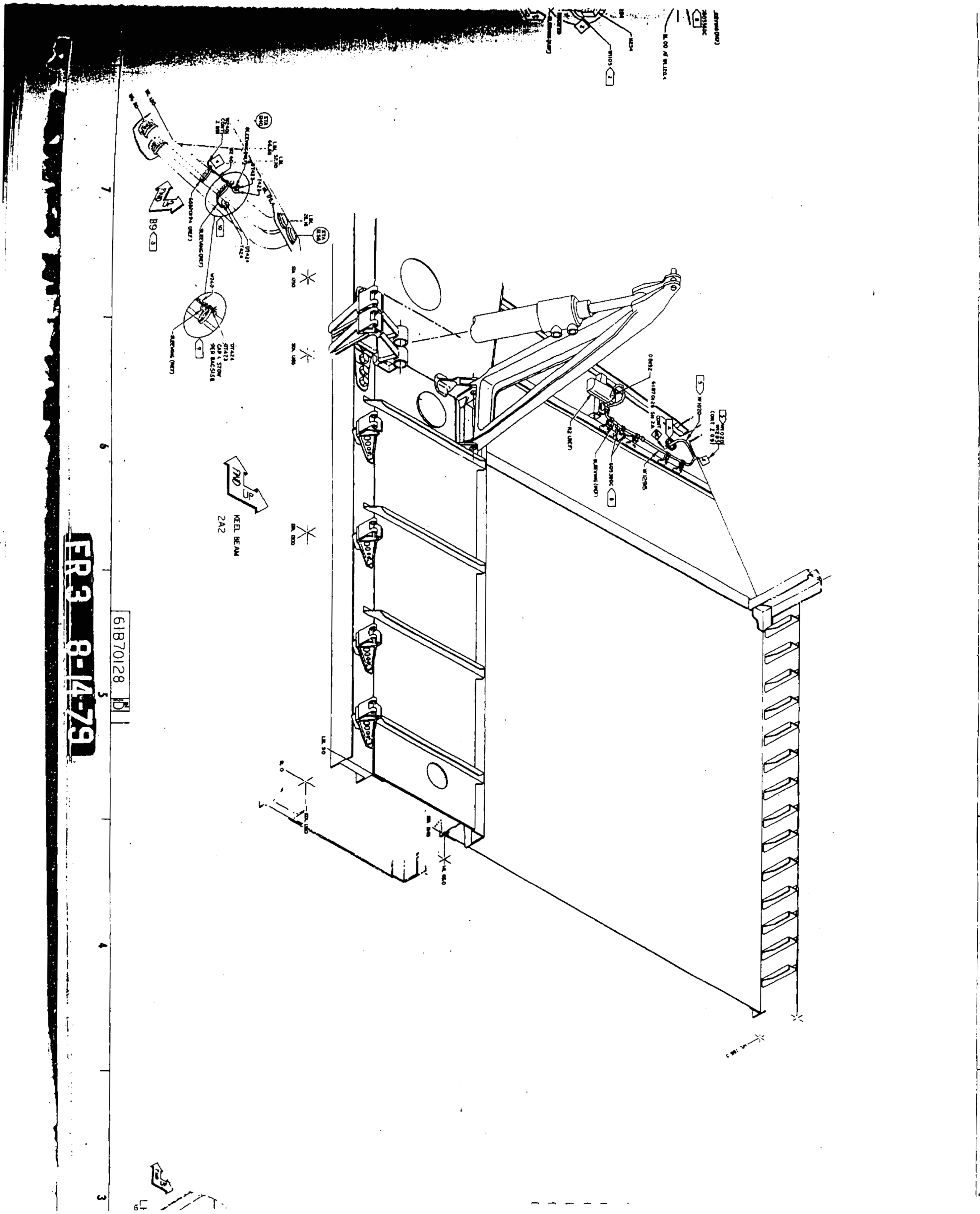
Order: 82628
DWG: 61B70128

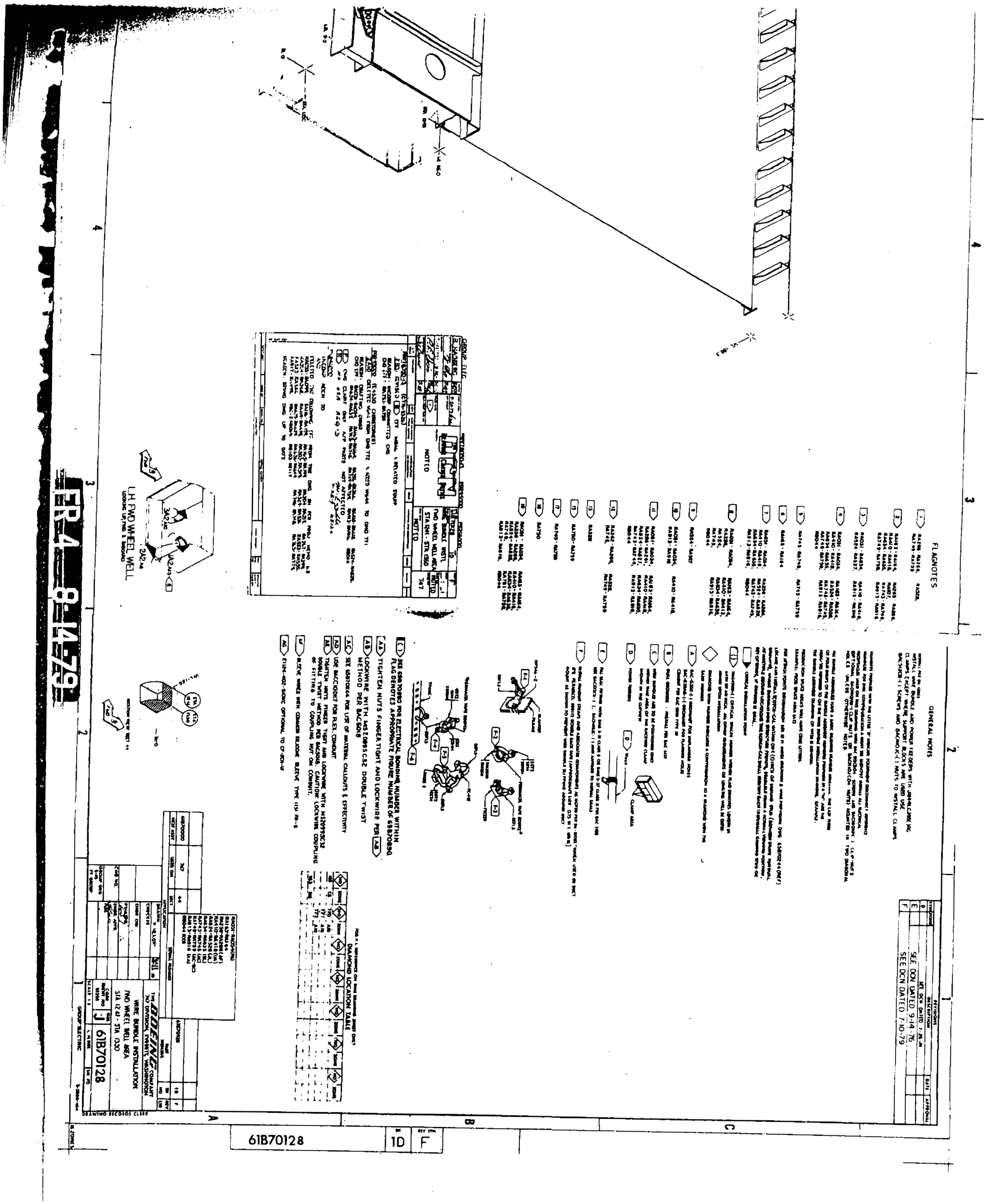
Boeing Proprietary
SH: 0001D REV: F

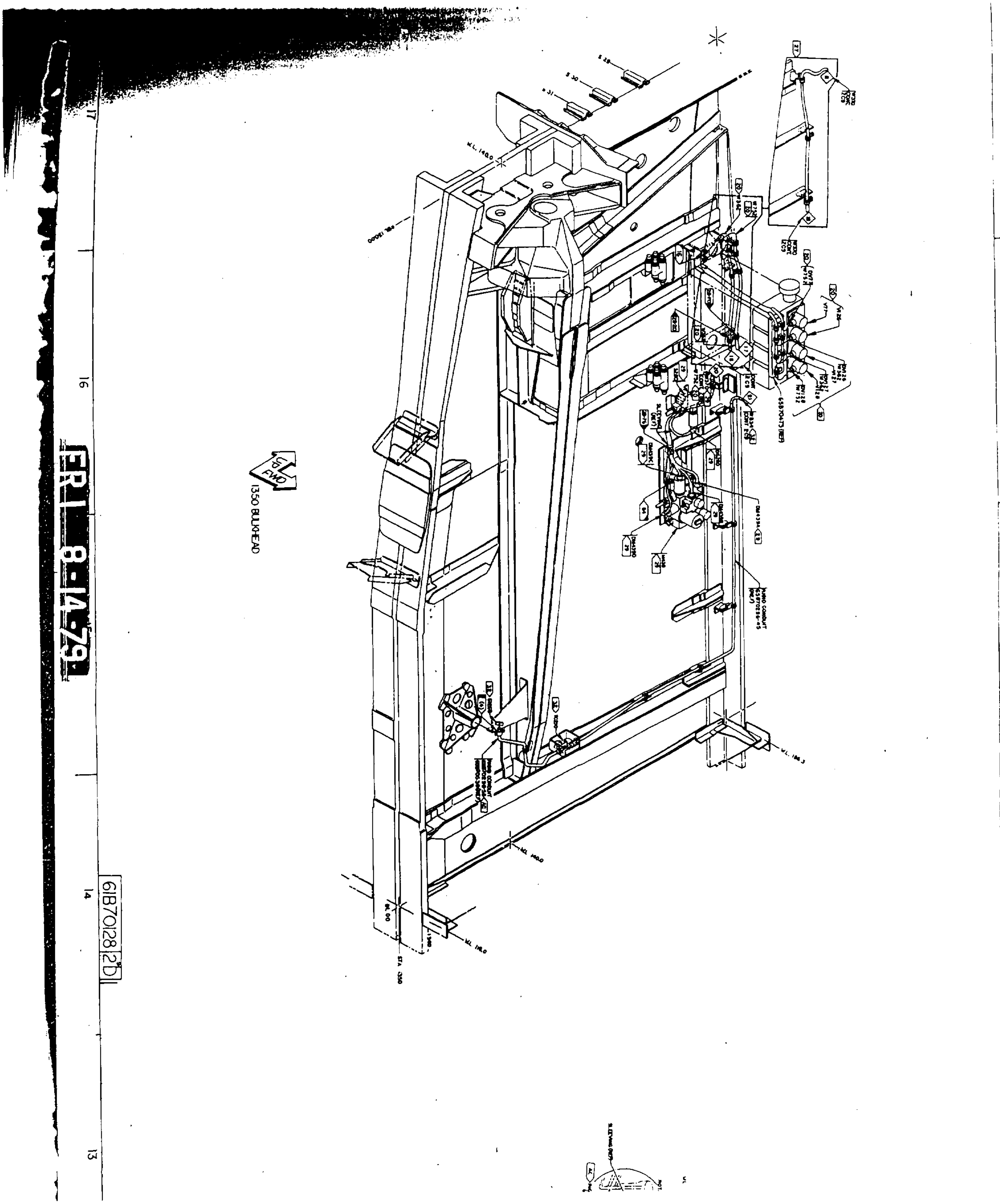
Not Valid After 05 07 199
Frame: 1 of

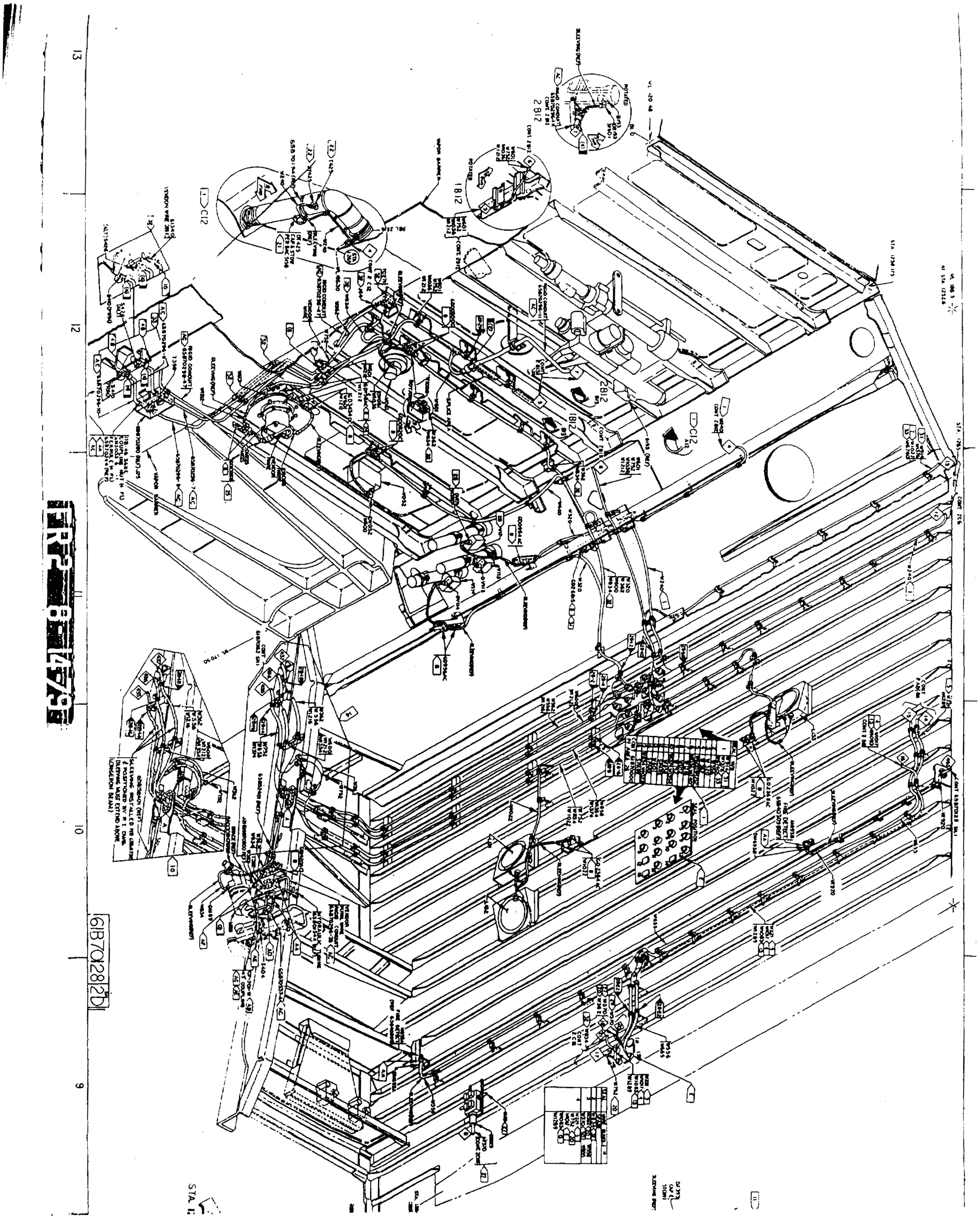
Commercial Data

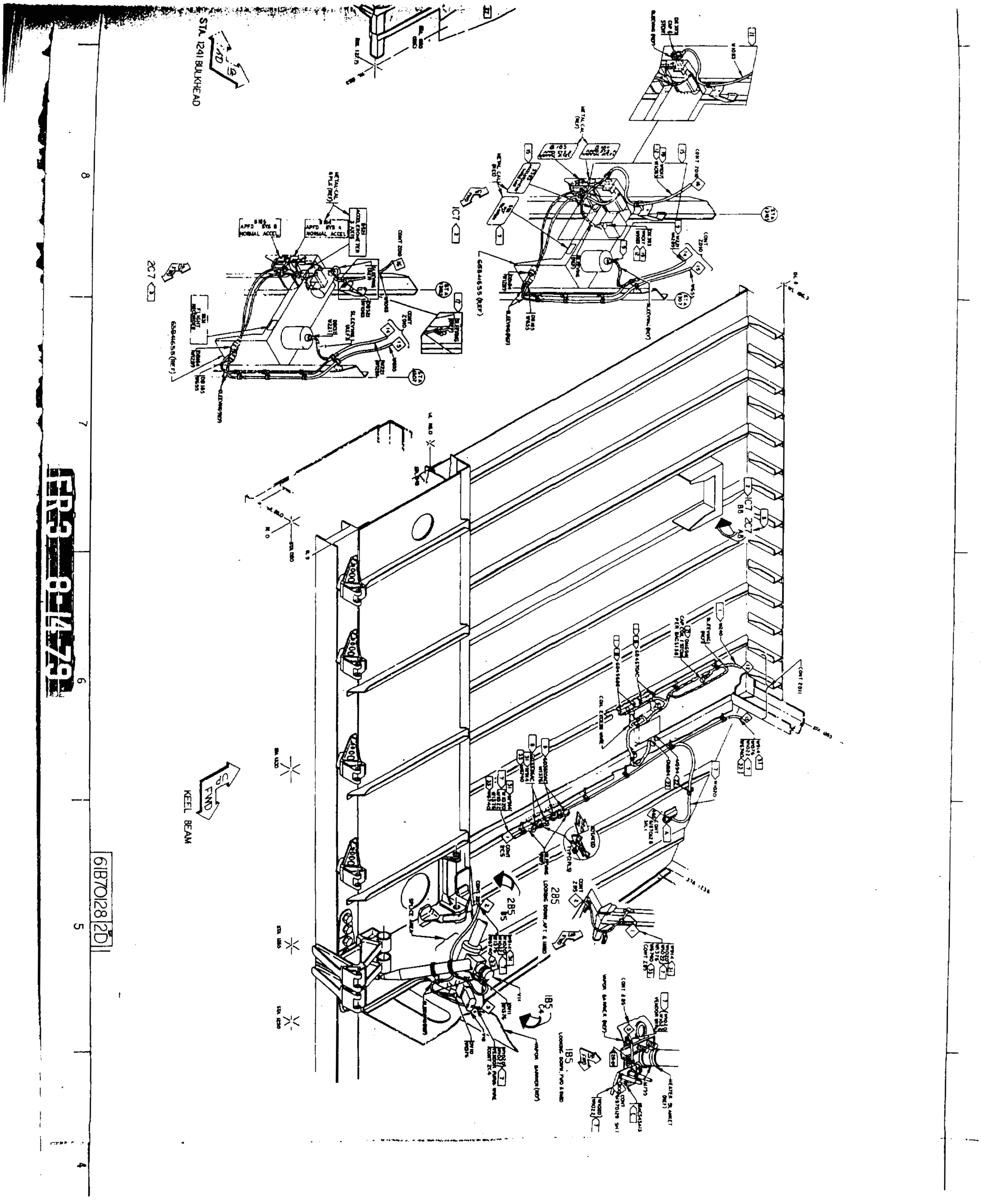

61B70128
1D
FWD
3A2

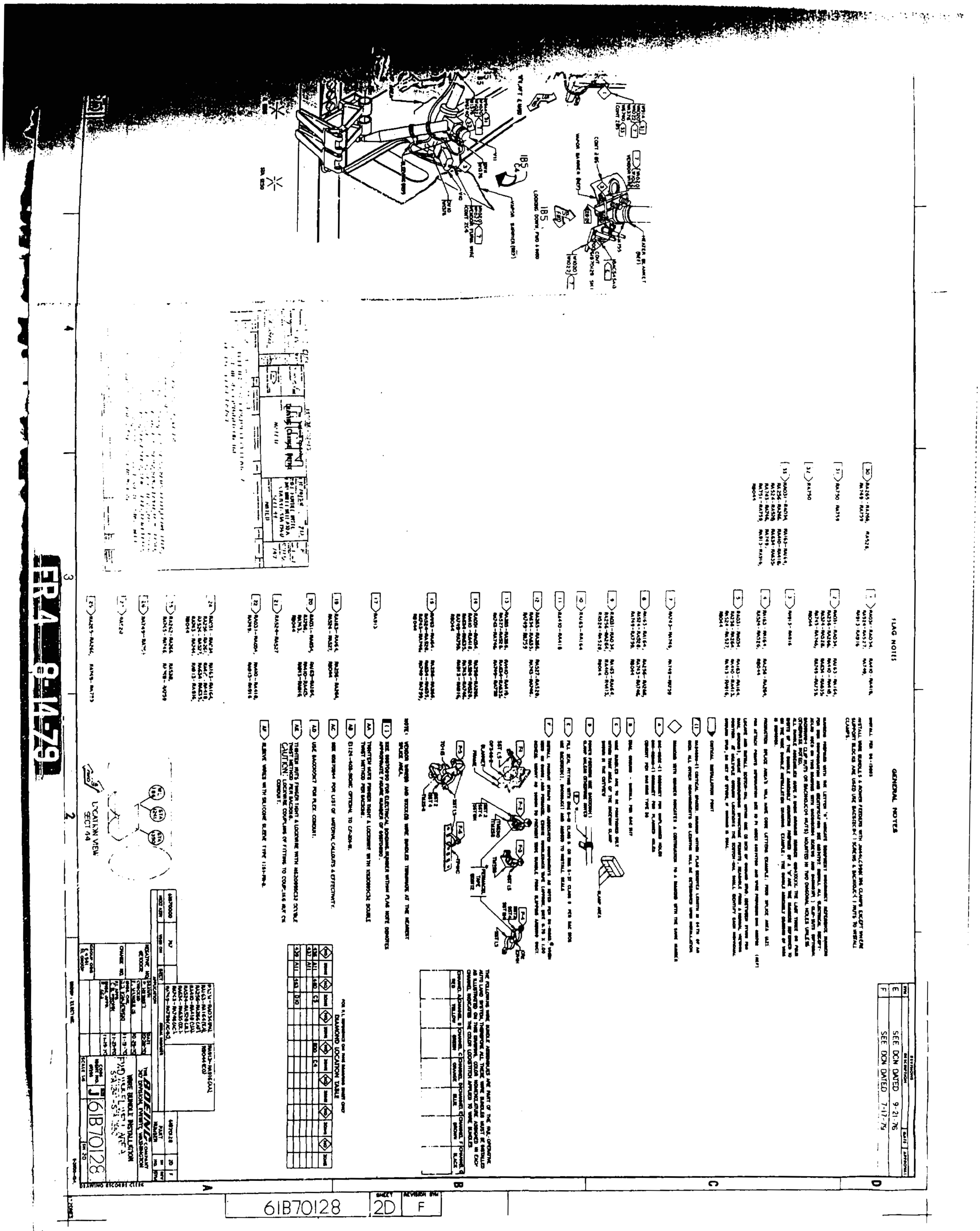

FR 3 8-14-79
61B70128
KEEL BEAM
2A2
FWD
UP
B9

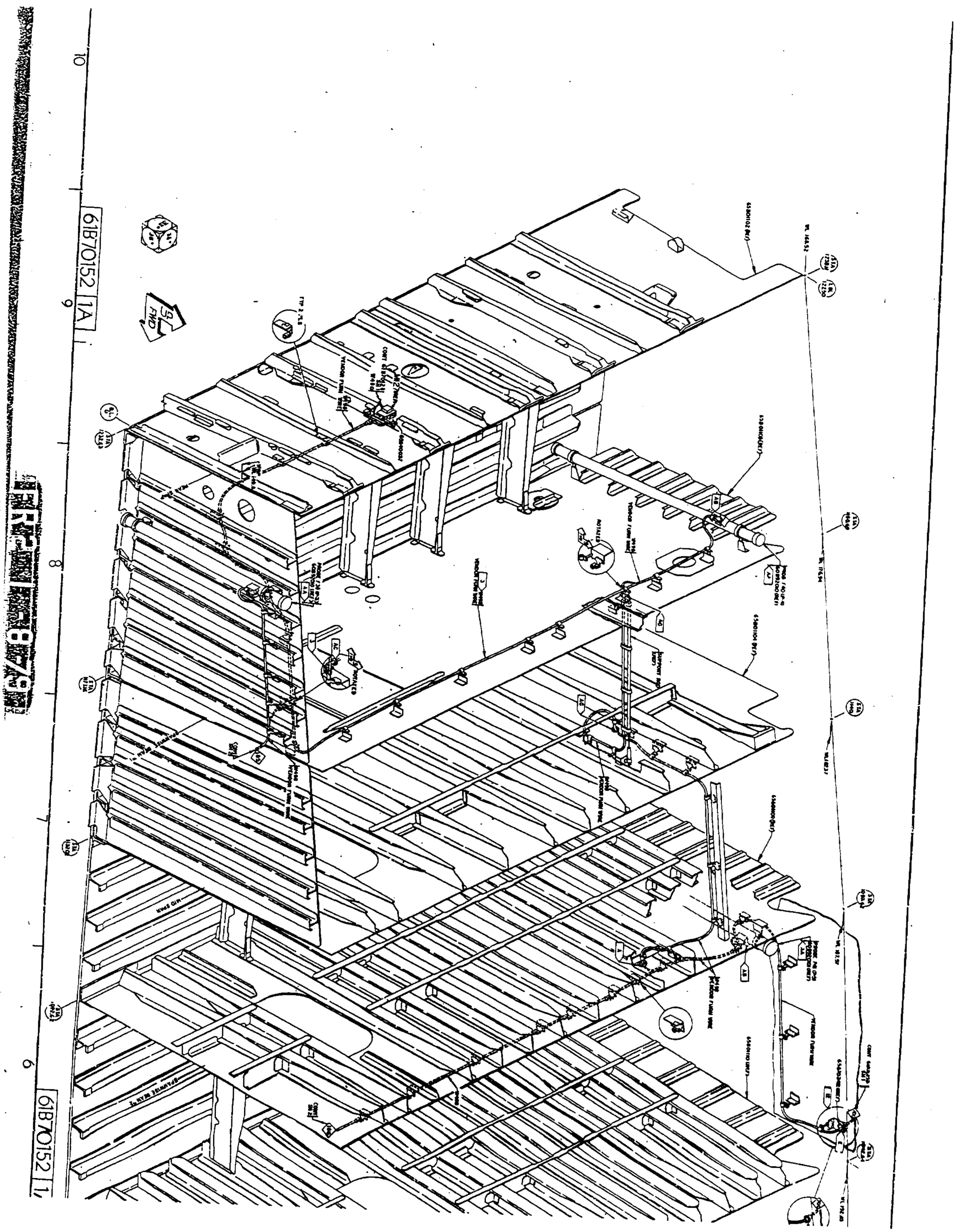

FLAGNOTES
GENERAL NOTES
SEE DCN DATED 7-10-79
61B70128
1D
F
FR 4 8-14-79


FRI 8-14-79
61B70128 2D
1350 BULKHEAD
UP
FWD
17
16
14
13




STA 1241 BULKHEAD
KEEL BEAM
FWD
61B70128 2D
FR3 8-14-79
APFD SYS B NORMAL ACCEL
APFD SYS A NORMAL ACCEL
ACCELEROMETER
LOOKING DOWN, AFT & INBD
LOOKING DOWN, FWD & INBD
1C7
2C7
2B5
1B5

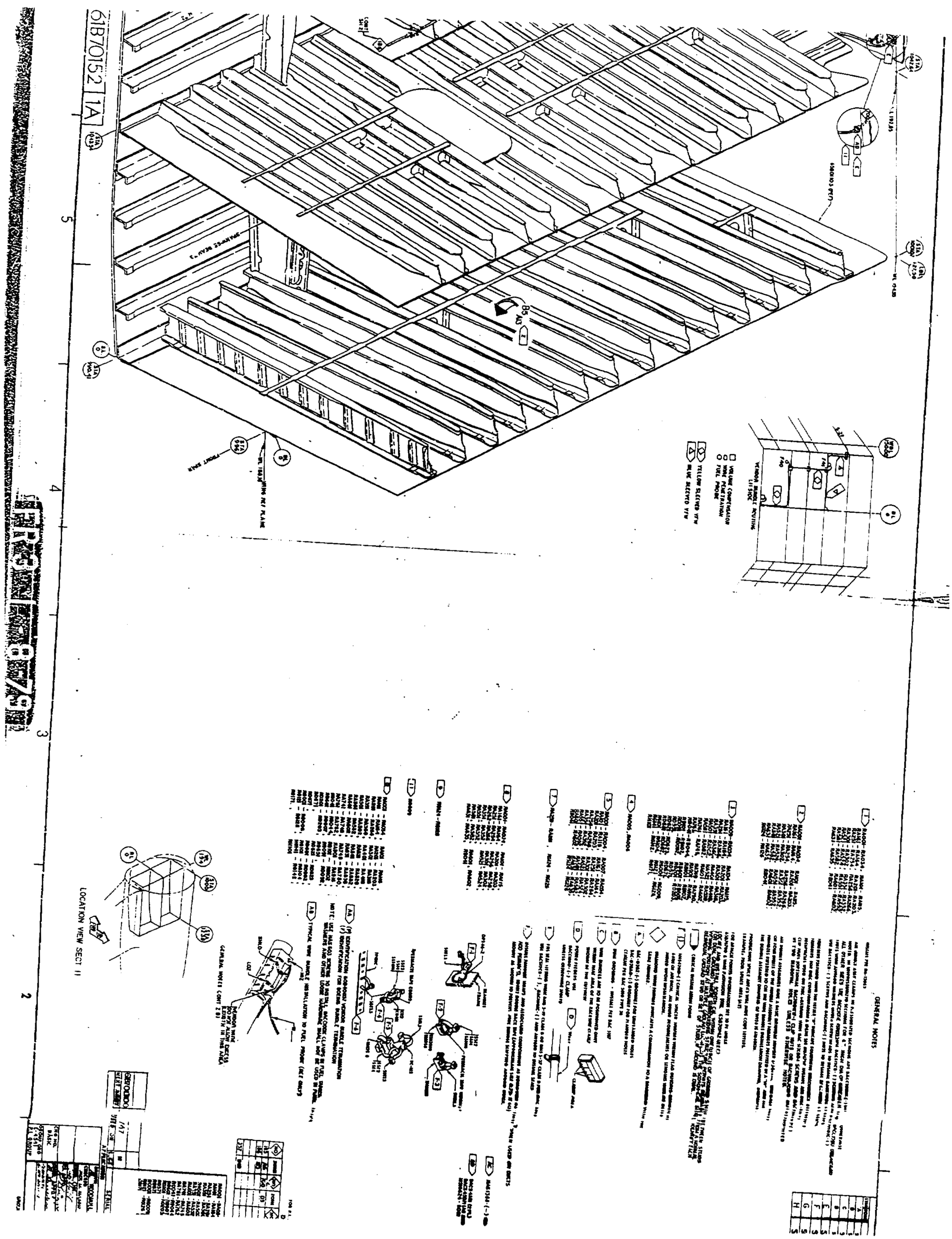

FLAG NOTES
GENERAL NOTES
SEE DCN DATED 9-21-76
SEE DCN DATED 7-17-79
DIAMOND LOCATION TABLE
LOCATION VIEW
SECT 44
THE BOEING COMPANY
747 DIVISION, EVERETT, WASHINGTON
WIRE BUNDLE INSTALLATION
61B70128
2D
F
FR 4 8-14-79

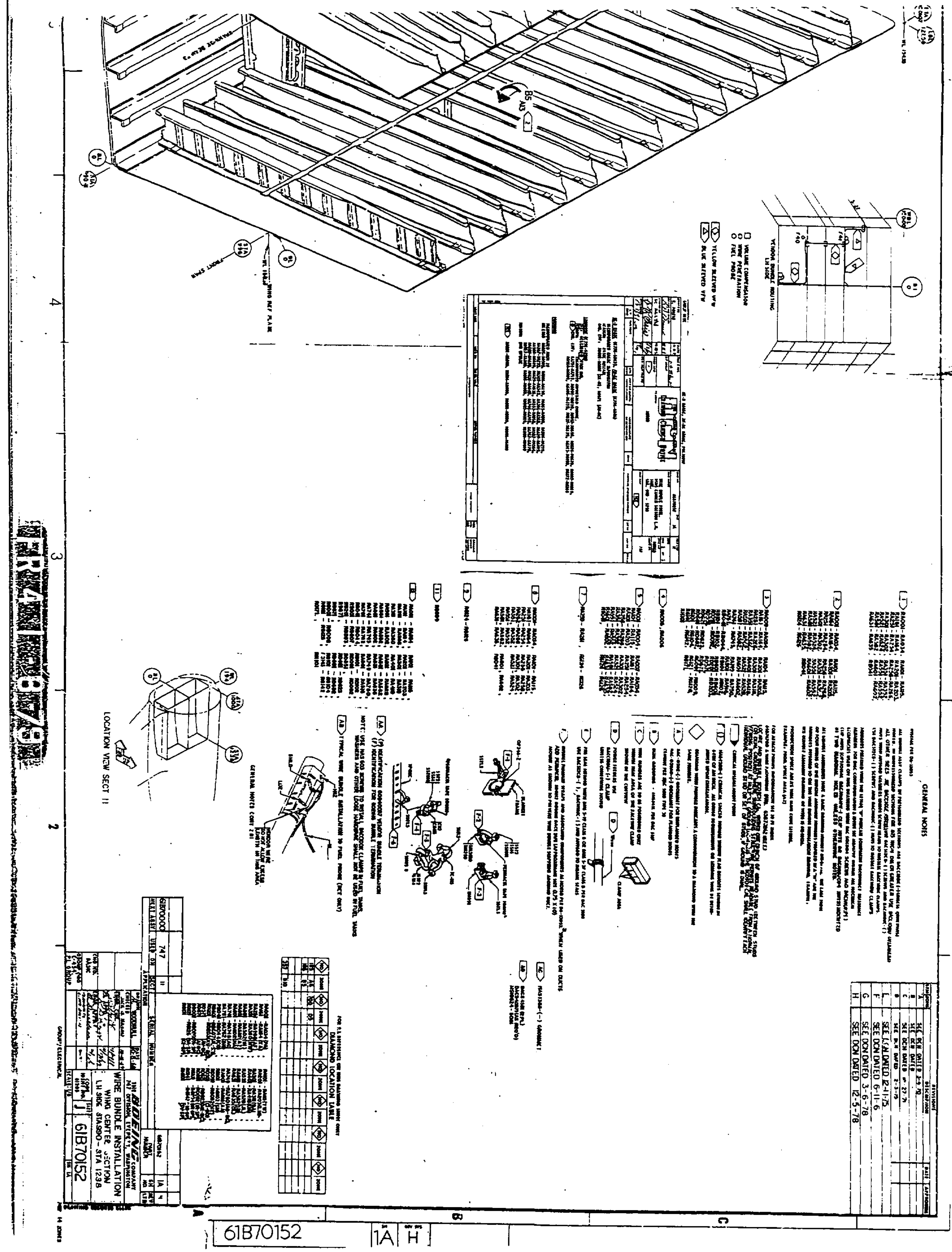


Order: 46766
DWG: 61B70152

Boeing Proprietary
SH: 0001A REV: H

Not Valid After 05 25 1998
Frame: 2 of 4


61B70152
1A
GENERAL NOTES
LOCATION VIEW SECT II
FRONT SPAR


61B70152
1A
H