DOCKET NO. **SA- 516**

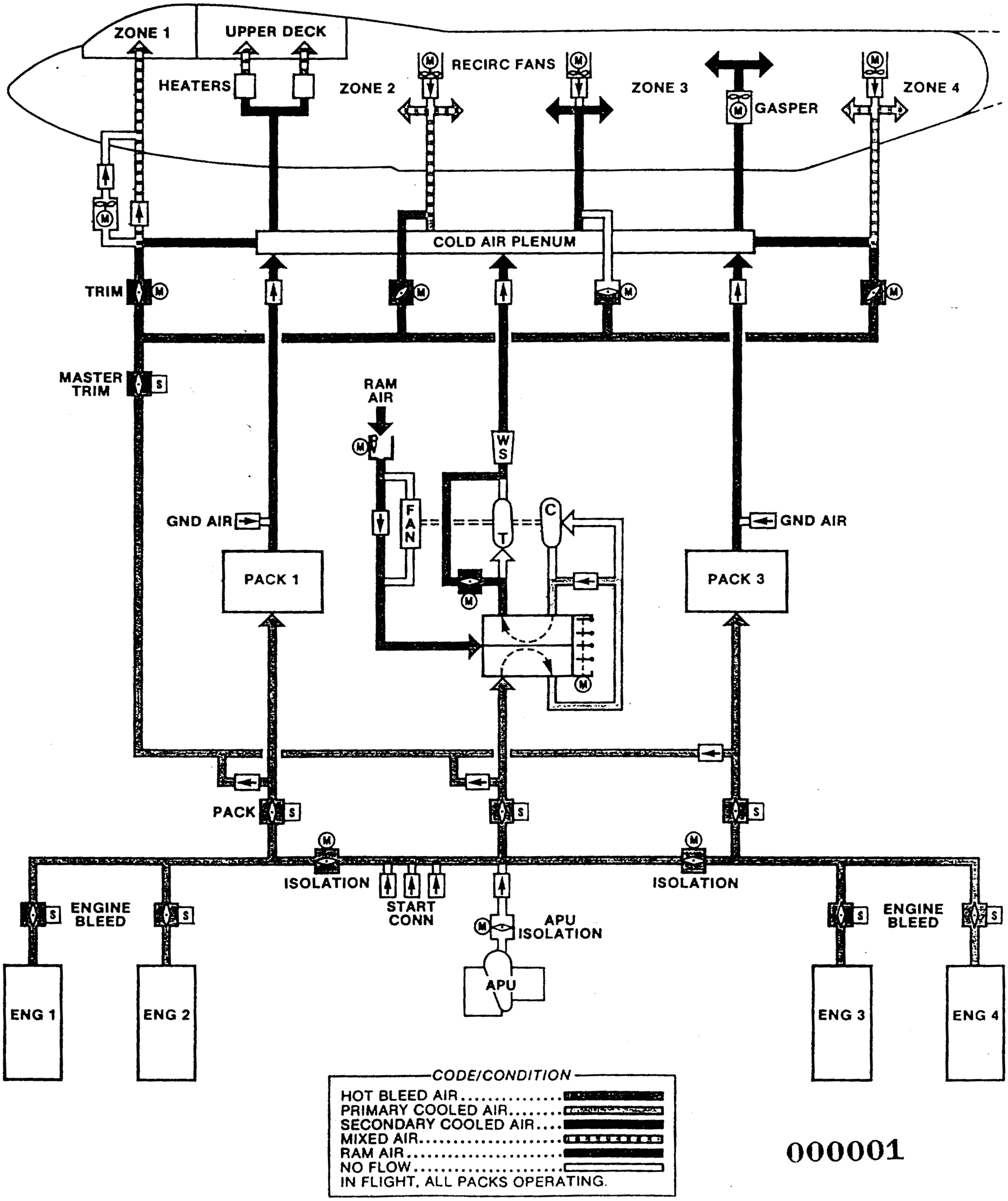
EXHIBIT NO. **9C**

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C

ATTACHMENTS TO THE SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

SYSTEMS FARTHAL
ATA 21-00-00

AIR CONDITIONING SYSTEM SUMMARY

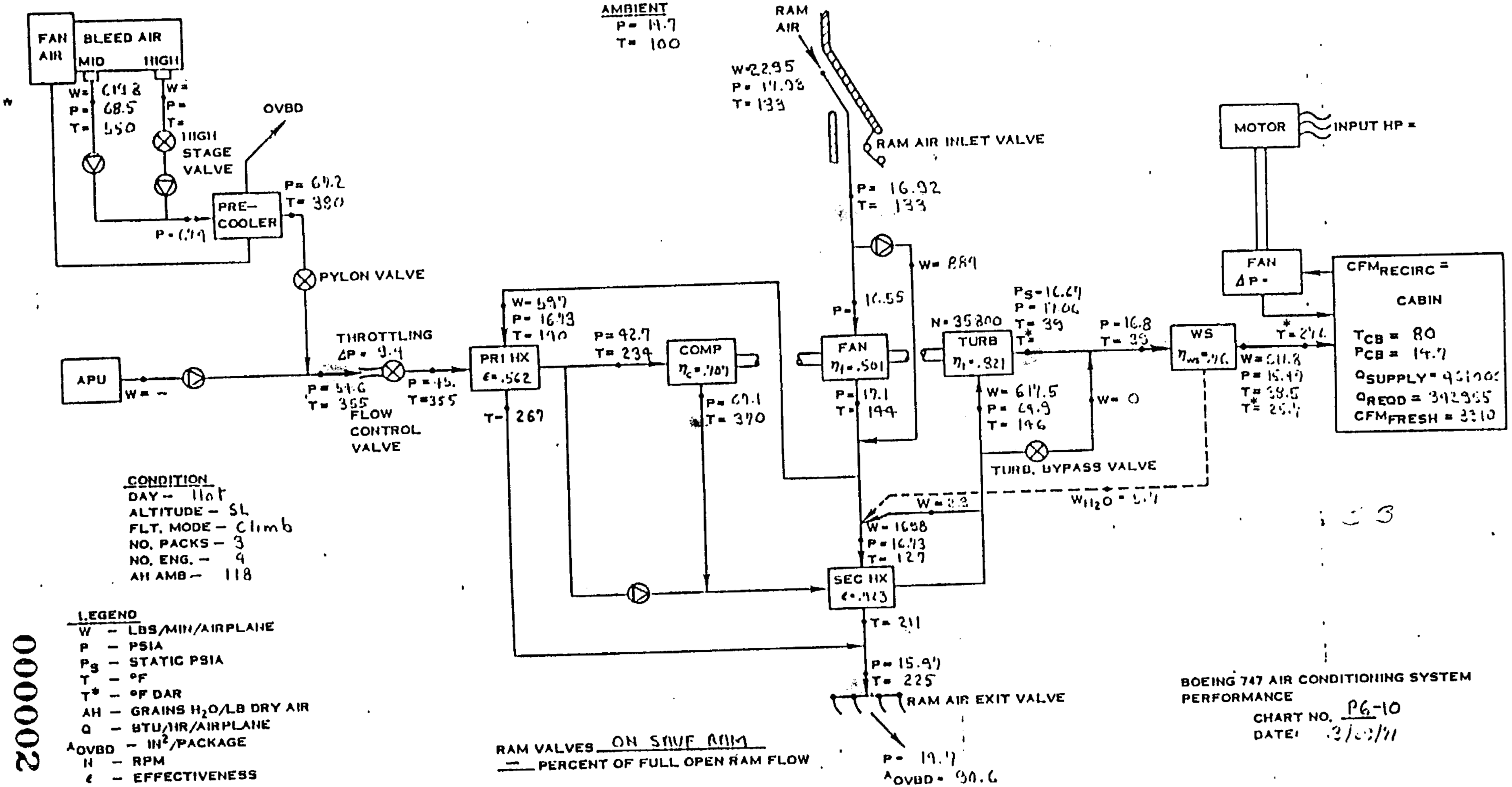


000001

ATA 21-00-00

Pack temps & pressure data
from

Hamilton Standard



CONDITION
DAY – Hot
ALTITUDE – SL
FLT. MODE – Climb
NO. PACKS – 3
NO. ENG. – 4
AH AMB – 118

LEGEND
W – LBS/MIN/AIRPLANE
P – PSIA
P_S – STATIC PSIA
T – °F
T^* – °F DAR
AH – GRAINS H_2O/LB DRY AIR
Q – BTU/HR/AIRPLANE
A_{OVBD} – IN^2/PACKAGE
N – RPM
ε – EFFECTIVENESS
η – EFFICIENCY
⊳ – CHECK VALVE

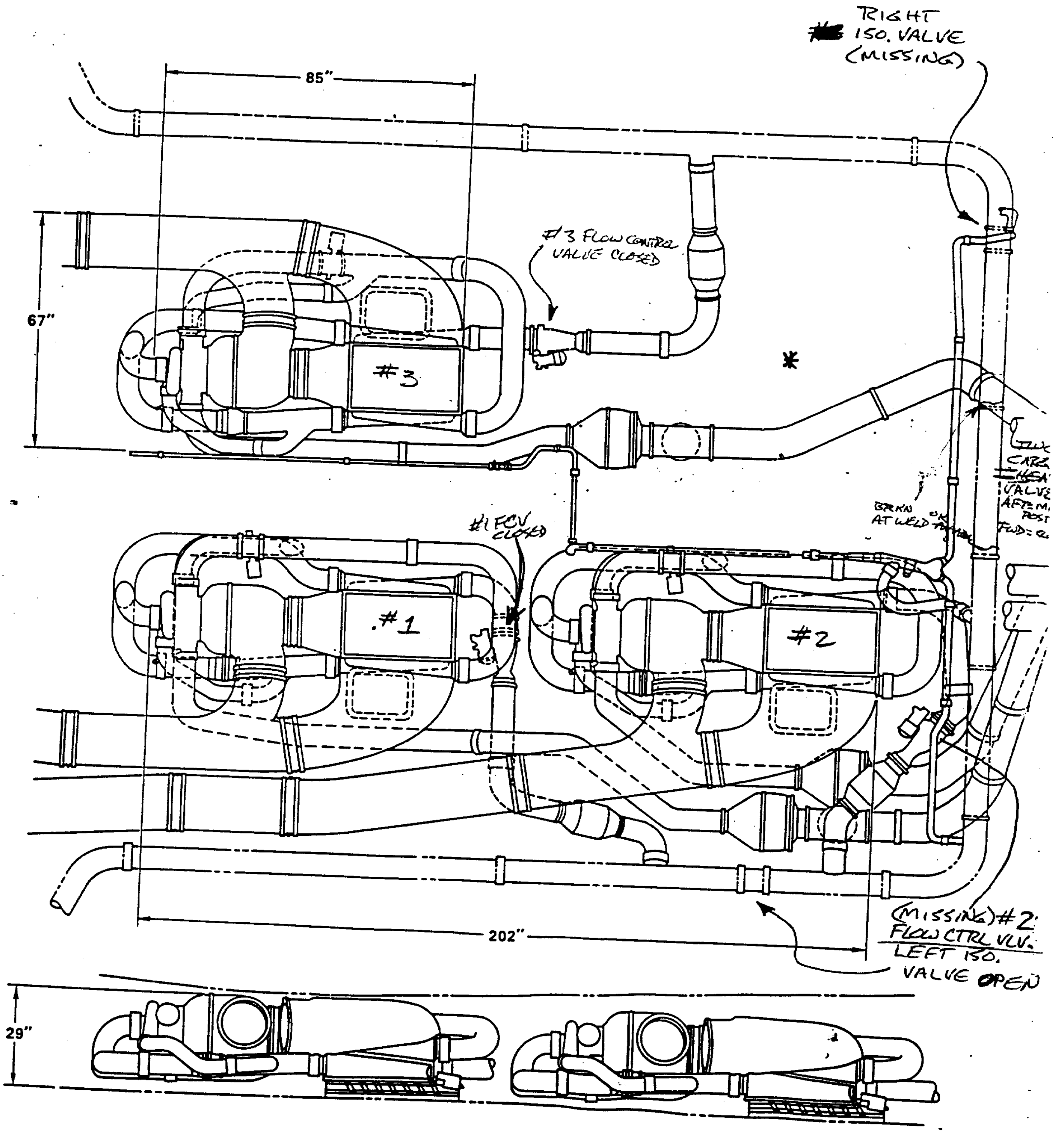
% value Rev J

RAM VALVES ON SAVE RAM
— PERCENT OF FULL OPEN RAM FLOW

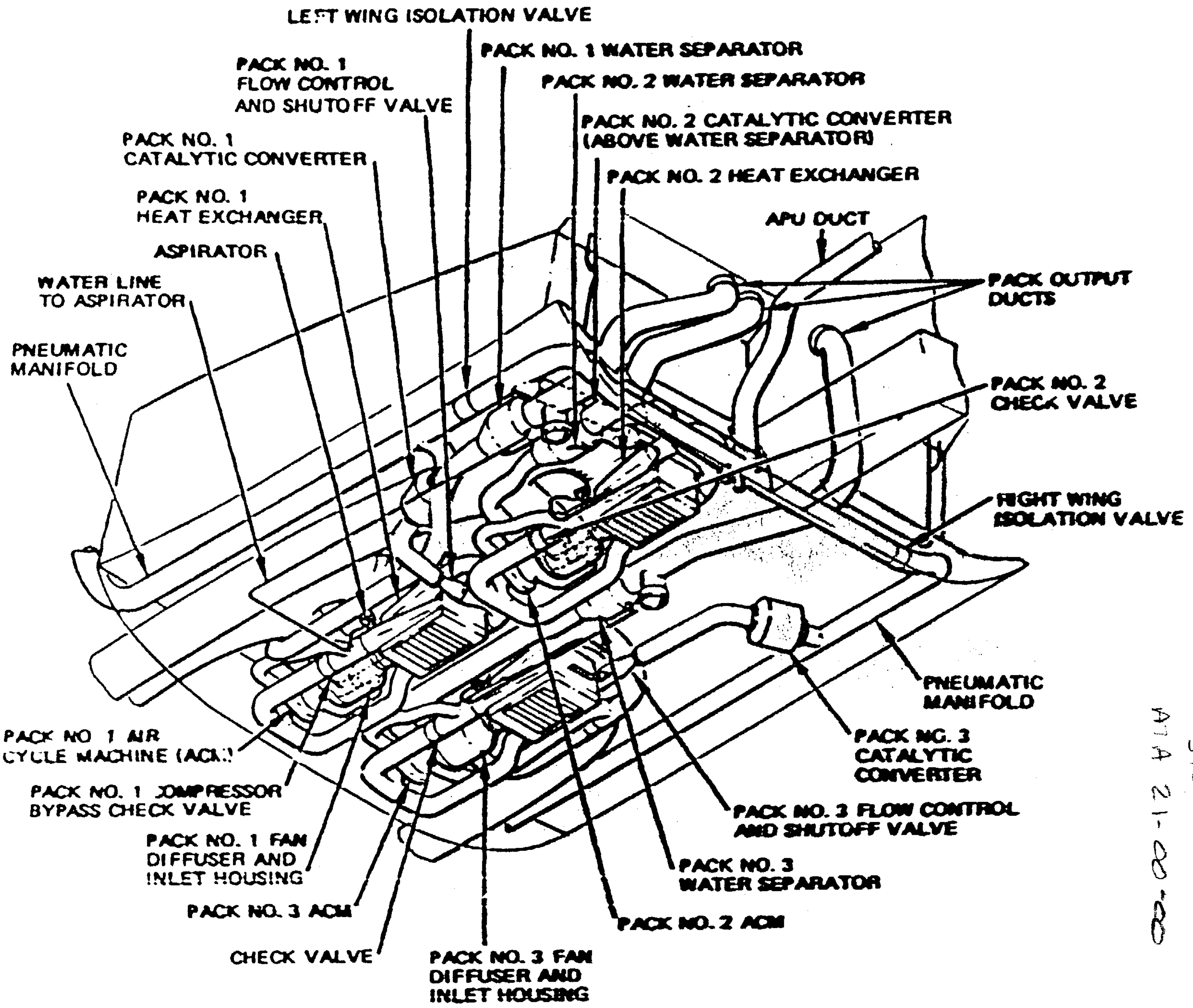
BOEING 747 AIR CONDITIONING SYSTEM PERFORMANCE
CHART NO. P6-10
DATE: 3/23/71

SYSTEMS FACTUAL
ATA 21-[illegible]

747 PACK INSTALLATION



SYSTEMS FACTUAL
ATA 21-00-00



SYSTEMS FACTUAL
24-00-00

CAUSES OF AIRCRAFT ELECTRICAL FAILURES

Donald Galler, George Slenski

December 20, 1990

ABSTRACT

In 1989, the Materials Laboratory, Wright Research and Development Center, Wright-Patterson Air Force Base awarded a Phase I SBIR contract to Failure Analysis Associates, to investigate the feasibility of developing a handbook for the evaluation of electrical and electronic components during aircraft accident investigation. The work was conducted under contract F33615-89-C-5647 and completed in January, 1990. As part of the work under that contract, a survey of data on failures of aircraft electronic and electrical components was conducted to identify problematic components. The motivation for the work was to prioritize future work on the development of accident investigation techniques for aircraft electrical components.

Three sources of data were used in the survey. The primary source was the Airforce Mishap Database, which is maintained by the Directorate of Aerospace Safety at Norton Air Force Base. Published data from the Air Force Avionics Integrity Program (AVIP) and Hughes Aircraft were also reviewed. Statistical data from these

three sources are presented in the paper. Photographs showing damaged components are also included in the paper.

Two major conclusions of the work are: (1) problems with interconnections are major contributors to aircraft electrical equipment failures and; (2) environmental factors, especially corrosion are significant contributors to connector problems.

AIR FORCE MISHAP DATABASE

The Air Force mishap database is a collection of aircraft mishap reports for all aircraft in service in the U.S. Air Force. Mishap reports are filed by pilots for any conditions which affect the safety of the aircraft. Specific conditions which require a pilot to file a report depend on the type of aircraft. In almost all cases some repair activity is performed to address the mishap.

There are four classes of mishaps in the Norton database. Classes A, B and C generally represent in-flight conditions that result in some damage to the aircraft. The fourth class includes potential mishaps. These may be the result of unusual conditions observed during maintenance or pre-flight checks. The designations refer to the dollar value and extent of the damage. Class A is the most severe. Individual reports indicate which system of the aircraft was involved and, in some cases, a component that was repaired or replaced.

Data was requested from Norton Air Force Base on all mishaps related to the electrical system and wiring of the aircraft. The report was generated Nov. 9, 1989 and included all mishap classes, for all aircraft from 1986 to the date of request. The report included a description of 652 mishaps which were caused by electrical failures related to instruments, wiring and electronic components. Failure records included 18 different component types on 30 different aircraft. A sample of the reports was selected and a total of 326 reports were evaluated in detail.

The results of the review are presented in Table 1 by aircraft and type of component. The totals for each component are combined and listed in Table 2. Adjusted totals in Table 2 exclude any reports that: (1) could be attributed to operator error; (2) did not identify the component or; (3) listed the constant speed drive as the source of the problem. Although the constant speed drive is generally viewed as part of the electric power system, its operation is primarily mechanical. Percentages based on the adjusted totals by component are listed in the right hand column of Table 2.

The data of Table 2 have been grouped according to basic system functions and combined percentages for each of the basic functions have been computed as shown in Table 3. The results are represented in Fig. 1. The Norton data shows that switches, connectors and conductors are the three leading causes of failures, contributing 20, 18 and 17% of all electrical failures on aircraft, respectively. The interconnection function, consisting of wiring and connectors, results in 35% of all electrical failures reviewed.

The absence of electronic components from the data shown in Fig. 1 may be due to the level of detail used in the repair or the accident investigation. It is expected that more active and passive electronic components are actually failure causes than are indicated. One reason for this is that the materials used in printed wiring boards and electronic components are not likely to survive post-impact damage. This damage may prevent the components from being identified as failure causes even if they did play a causal role in the mishap.

AVIONICS INTEGRITY PROGRAM DATA

A paper describing the Avionics Integrity Program (AVIP) [2] includes a summary of electrical failure causes on aircraft. The data is shown in Fig. 2. The paper suggests that connectors account for about 40% of maintenance repairs on aircraft electrical equipment. The formation of surface films that cause connectors to be non-conductive is identified as a major problem. Interconnections on circuit boards (the traces, plated through holes, sockets) and electronic components on circuit boards are also identified as major contributors to failure.

HUGHES AIRCRAFT FACTORY DATA

A study based on repair records for printed wiring boards (PWBs) at Hughes Aircraft [3] includes data on four types of PWBs of different ages and complexity levels. The study was based on part replacement data from factory test and quality control activities, not field failures. Over 58,000 repair records were used as the initial source of data for the study. The goal of the study was to rank components in terms of their replacement frequency rather than their failure rate. The results of the study are shown in Fig. 3. The reported composite replacement frequency ranking (from highest to lowest) was: ICs; transistors; hybrid circuits, capacitors and resistors; diodes.

LABORATORY ANALYSIS EXAMPLES

The inspection of electronic hardware at an accident site and laboratory analysis of selected components can be critical in ascertaining the cause of an aircraft accident. The Wright Laboratory Materials Directorate has conducted numerous accident investigations where electronic systems are suspected to have contributed to an aircraft mishap. A typical case is where an electrical fault is suspected to have initiated a fuel or hydraulic fluid fire. An example of wiring involved in an aircraft fuel fire is shown in Figure 4. The post impact conditions destroyed the organic insulation and melted the aluminum conductor. Another section of wiring from this mishap exhibited evidence of arcing between copper wiring and the aluminum airframe as shown in Figures 5 and 6. Elemental x-ray analysis confirmed that aluminum had been transferred to the copper wire. There were also no hydrocarbons found in the arc site. The presence of hydrocarbons or soot would have indicated the arcing occurred in the post-accident phase. Inspection of other aircraft revealed chafing damage to the wiring in the area suspected of arcing in the mishap aircraft. The wiring failure shown in Figure 7 caused the partial loss of an aircraft flight control system. Electrical arcing of adjacent wiring shown in Figure 8 disrupted the flight control computer and caused uncommanded aircraft maneuvers. The aircraft landed safely, however, this failure may not have been identified if the aircraft had impacted into the ground. Aircraft impact and fires typically associated with accidents can severely damage PWBs and semiconductors. The PWBs in Figures 9 and 10 are typical of electronic hardware removed from an accident. The majority of materials used in PWBs and semiconductors are damaged at temperatures above 300°C making any analysis extremely difficult. Specialized techniques are available for extracting data from damaged semiconductors. Fortunately, a component will rarely cause an aircraft mishap since critical systems use redundancy to preclude the possibility of a single point failure. After a mishap, electronic systems should always be analyzed to rule out the possibility that a single point failure seriously degraded a critical aircraft system.

SUMMARY OF ACCIDENT INVESTIGATION TECHNIQUES

The various failure analysis techniques for electronic components were reviewed and are compiled in Table 4. The table lists conditions most likely to be of interest and the failure analysis techniques that would be used in an analysis. In many cases additional research is needed to differentiate pre- and post- accident conditions.

CONCLUSIONS

1. The majority of aircraft mishaps involving electronics are related to interconnection problems. Interconnection problems are primarily due to wiring and connector failures. Chafing, which results in electrical arcing of wiring and corrosion, which results in the electrical breakdown in connectors appear to be the dominate failure mechanisms.

2. Connectors and semiconductors are the types of components primarily responsible for PWB level aircraft equipment failures.

3. A handbook for conducting aircraft accident investigations involving electronic components is feasible. A follow-on program would develop new failure analysis techniques where required and develop guidelines for conducting aircraft accident investigations. The most important challenge will be to develop techniques that can discriminate between pre- and post-accident conditions.

REFERENCES

1. Report from Norton Air Force Mishap Database. 1986 to Nov. 9, 1989. Report No. 11041.
2. AVIP Air Force Thrust for Reliability. J.C. Halpin. Aeronautical Systems Division, Wright-Patterson Air Force Base. 1985 Proceedings of the Annual Technical Meeting, Institute of Environmental Sciences.
3. Culprits Causing Avionic Equipment Failures. K.L. Wong, et al. 1987 Proceedings of the Annual Reliability and Maintainability Symposium. Summary of work done under F33615-84-C-3410.

Table 1. Mishap Data from Norton Air Force Base

COMPONENT	AIRCRAFT TYPE : GROUP I															TOTAL
	A-7	A-10	A-37	B-1	B-52	FB-111	C-5	C-10	C-12	C-21	C-23	C-130	C-131	C-135	C-141	
BATTERY					1				1	1						3
CAPACITOR				1												1
CKT BREAKER					2				1			1			1	5
CONDUCTOR		5	1	1	1			1	1			3		1	2	16
CONNECTOR	1	2	1		1	1			1	3				3	1	14
CS DRIVE				2												2
EM. POW. UNIT		1														1
AC GENERATOR	1			1					1			10			1	14
DC GENERATOR	2	1											1			4
INSTRUMENT												1				1
LIGHT				1								2		2	1	6
MOTOR		1										4		1		6
RELAY		1					1		3						1	6
RESISTOR						1										1
SWITCH		2	1		2		1				1			1	1	9
TRANSFORMER																0
OTHER										1		9	1	2		13
TOTAL	4	13	3	6	7	2	2	1	8	5	1	30	2	10	8	102

COMPONENT	AIRCRAFT TYPE : GROUP II															TOTAL
	F-4	F-5	F-15	F-16	F-111	H-1	H-3	H-53	O-2	T-33	T-37	T-38	T-39	T-41	OV-10	
BATTERY				8								1				9
CAPACITOR				1												1
CKT BREAKER	5		2									1				8
CONDUCTOR	10	1	3	11	1		1				1	2		1	2	33
CONNECTOR	10		1	12	1	1		3		1	2	4			2	37
CS DRIVE	2			1	1											4
EM. POW. UNIT				7												7
AC GENERATOR	3		1	6	1							2				13
DC GENERATOR								1		2	1	1				5
INSTRUMENT	3		1		1		1									6
LIGHT				3								1				4
MOTOR					1											1
RELAY		1	3	6	1		3					1				15
RESISTOR				1												1
SWITCH	7	1	8	9	3	1					2	26				57
TRANSFORMER					2						1	2				5
OTHER	4			9	1	1			1			1	1			18
TOTAL	44	3	19	74	13	3	5	4	1	3	7	42	1	1	4	224

Table 2. Summary of Data From Norton AFB by Component

COMPONENT	GROUP I	GROUP II	TOTAL	ADJUSTED TOTAL	PERCENT
SWITCH	9	57	66	56	20
CONNECTOR	14	37	51	51	18
CONDUCTOR	16	33	49	49	17
AC GENERATOR	14	13	27	27	10
RELAY	6	15	21	21	8
OTHER	13	18	31		
CKT BREAKER	5	8	13	13	5
BATTERY	3	9	12	12	4
LIGHT	6	4	10	10	4
GENERATOR-DC	4	5	9	9	3
EM. POW. UNIT	1	7	8	8	3
INSTRUMENT	1	6	7	7	2
MOTOR	6	1	7	7	2
CS DRIVE	2	4	6		
TRANSFORMER	0	5	5	5	2
CAPACITOR	1	1	2	2	1
RESISTOR	1	1	2	2	1
TOTAL	102	224	326	279	100

Table 3. Summary of Data from Norton Air Force Base
(by Function Category)

FUNCTION CATEGORY	NUMBER OF INCIDENTS	CATEGORY TOTALS	CATEGORY PERCENTAGES
INTERCONNECTIONS			
CONNECTORS	51		
CONDUCTORS	49	100	36
INSTRUMENTS			
SWITCHES	56		
INSTRUMENTS	7		
LIGHTS	10	73	26
POWER SYSTEM			
AC GENERATOR	27		
DC GENERATOR	9		
EMER. POWER UNIT	8		
BATTERIES	12		
CIRCUIT BREAKERS	13	69	25
ELECTROMECHANICA			
RELAYS	21		
MOTORS	7	28	10
PASSIVE COMPONENT			
RESISTORS	2		
CAPACITORS	2		
TRANSFORMERS	5	9	3
TOTAL	279	279	100

Figure 1. Summary of Electrically Related Aircraft Incidents[1]

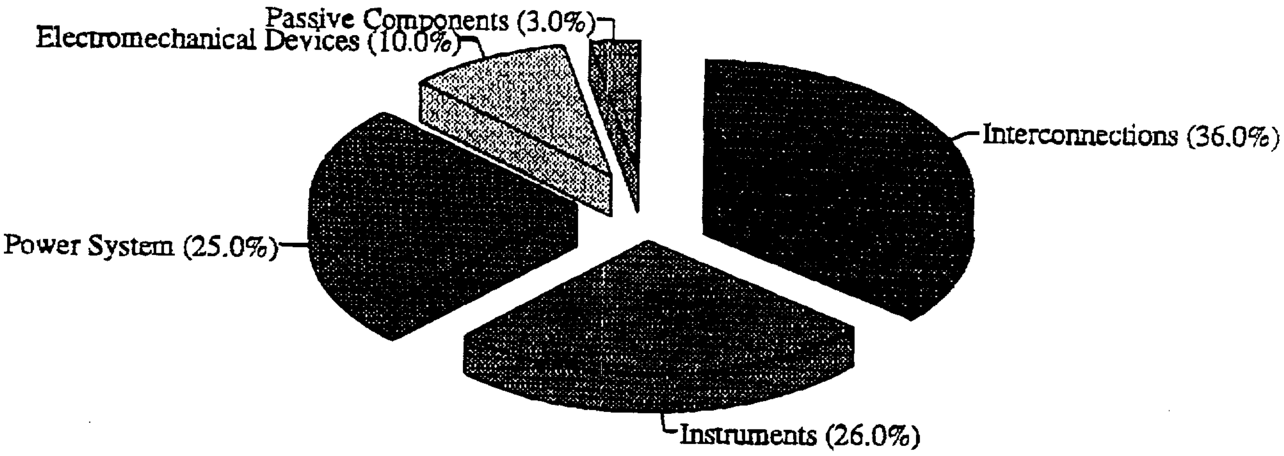


Figure 2. Causes of Aircraft Equipment Failures[2]

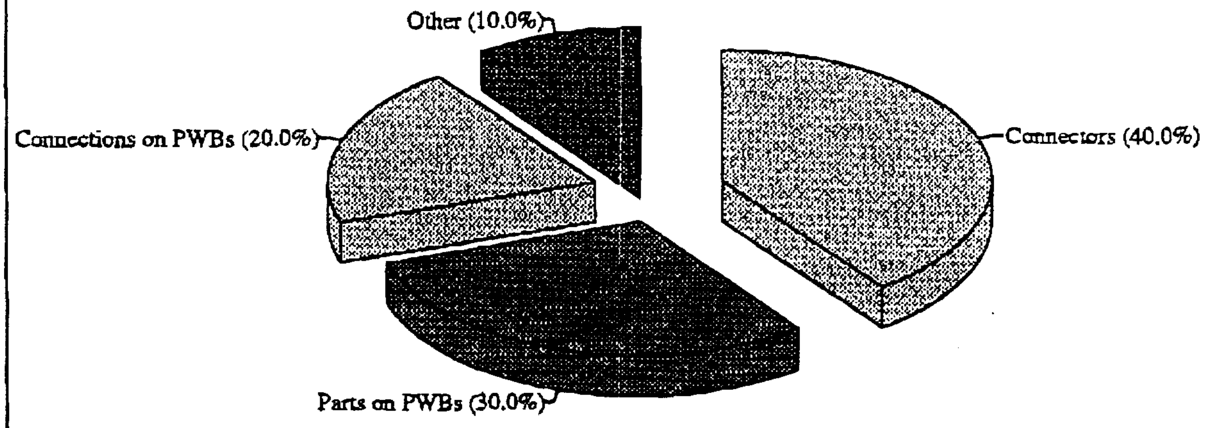


Figure 3. Printed Wiring Board Part Replacement Data[3]

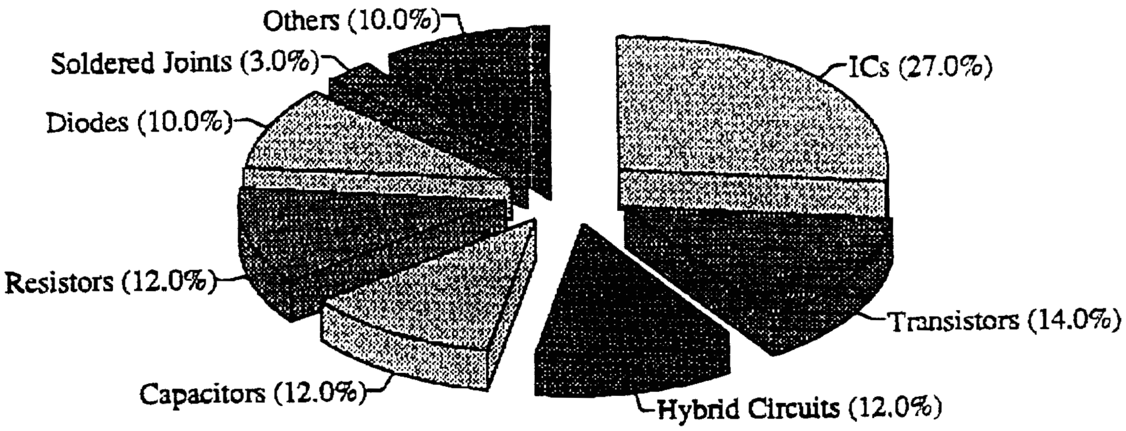


Figure 4. Example of electrical wiring involved in an aircraft accident. The organic insulation was degraded and the aluminum conductors where melted as a result of a post accident fire.

Figure 5. In this aircraft accident the copper wiring near a fuel cell had chafed and shorted to the aluminum structure.

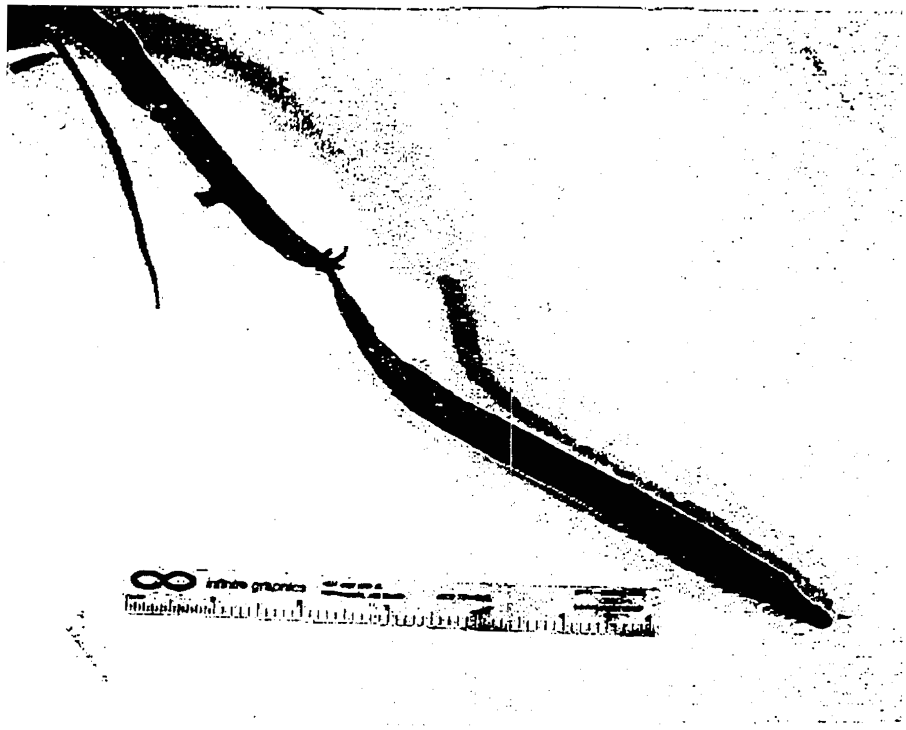


Figure 6. This is a close-up of the wiring in 5 Figure. The two melt areas on the copper wiring (middle and bottom) contained aluminum and confirmed that electrical arcing had taken place.

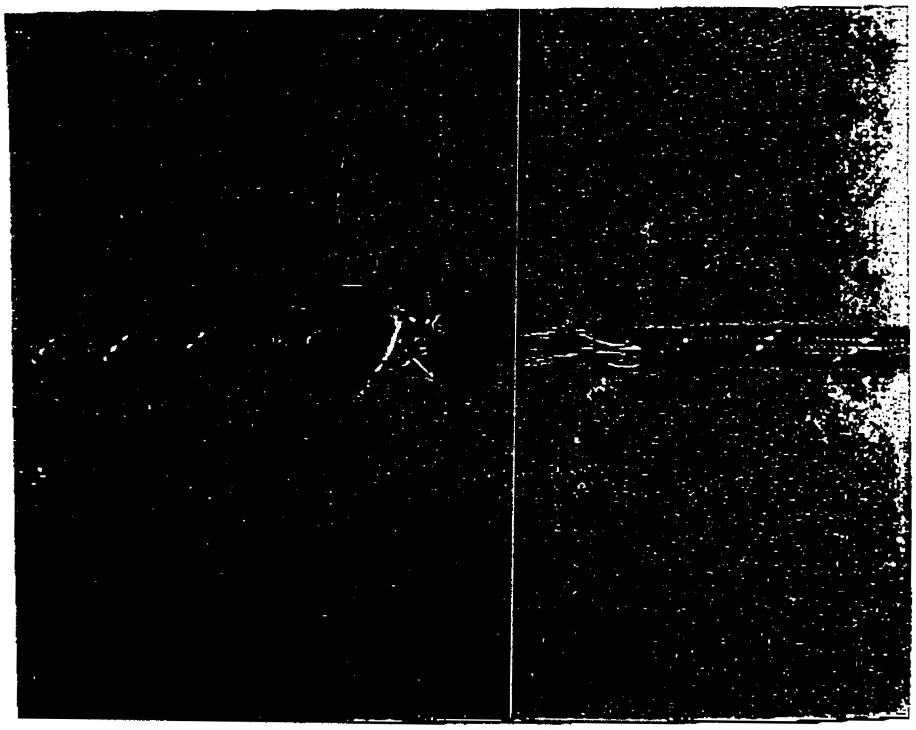


Figure 7. In this case a wire bundle was severed after chafing initiated an electrical arc. The high temperatures produced during sustained arcing damaged adjacent flight control wiring.

Figure 8. Photograph showing the wiring adjacent to the exhibit in Figure 7. Damage to the adjacent wiring disrupted the flight control computer.

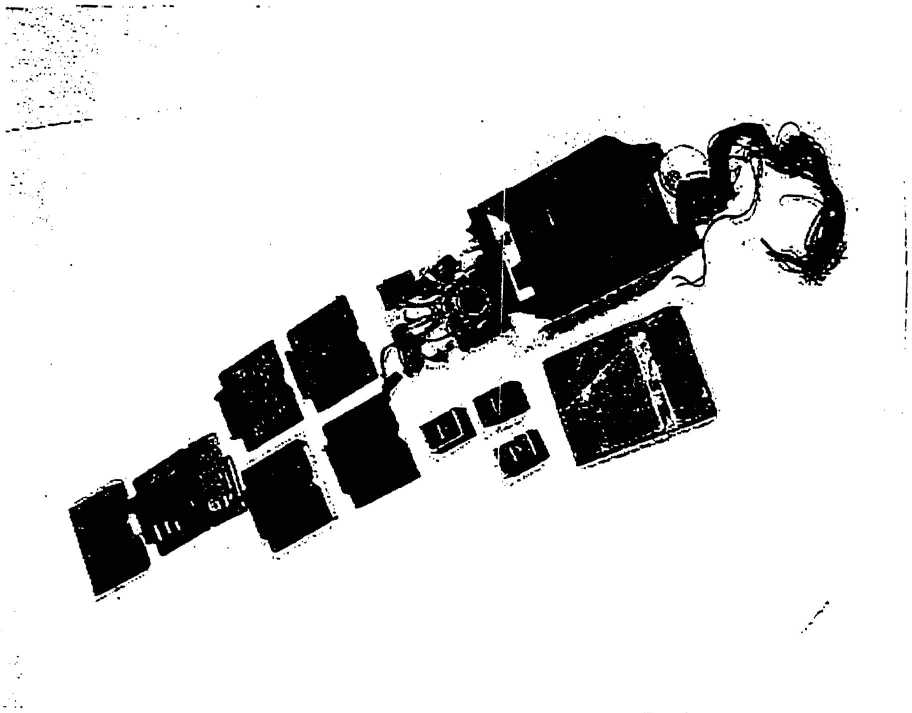


Figure 9. Printed wiring boards removed from an aircraft accident. Note the extensive heat damage to the hardware.

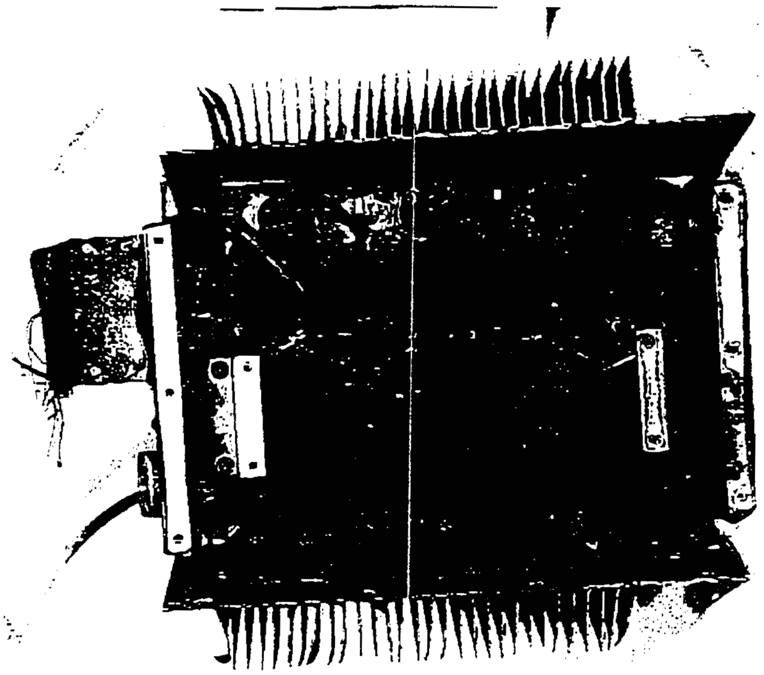


Figure 10. Close-up showing the physical and thermal damage exhibited by electronic hardware involved in an accident.

Final paper 6 Jan 93

SYSTEMS
FACTUAL
24-00-00

International Conference for the Promotion of Advanced Fire Resistant Aircraft Interior Materials, Atlantic City, NJ, 10 Feb 93

DEVELOPMENT AND ANALYSIS OF INSULATION CONSTRUCTIONS FOR AEROSPACE WIRING APPLICATIONS

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ABSTRACT

The Wright Laboratory Materials Directorate at WPAFB, Ohio recently completed a research and development program under contract F33615-89-C-5605 with the McDonnell Douglas Aerospace Company, St Louis, Missouri. Program objectives were to develop wire insulation performance requirements, evaluate candidate insulations, and prepare preliminary specification sheets on the most promising candidates. Aircraft wiring continues to be a high maintenance item and a major contributor to electrically-related aircraft mishaps. Mishap data on aircraft show that chafing of insulation is the most common mode of wire failure. Improved wiring constructions are expected to increase aircraft performance and decrease costs by reducing maintenance actions. In the laboratory program, new insulation constructions were identified that had overall improved performance in evaluation tests when compared to currently available MIL-W-81381 and MIL-W-22759 wiring. These insulations are principally aromatic polyimide and cross-linked ethylene tetrafluoroethylene (ETFE), respectively. Candidate insulations identified in preliminary specification sheets were principally fluoropolymers with a polyimide inner layer. Examples of insulation properties evaluated included flammability, high temperature mechanical and electrical performance, fluid immersion, and susceptibility to arc propagation under applied power chafing conditions. Potential next generation wire insulation materials will also be reviewed.

INTRODUCTION

The increased emphasis and reliance on electronic systems for modern aircraft has resulted in wiring becoming a critical safety of flight system. Aircraft now routinely use fly-by-wire systems with minimal or no mechanical backup systems. McDonnell Douglas Aerospace Company has a very active program in developing new insulation and connection systems and providing technical support to aerospace systems under development and in production. A recent study initiated by the Materials Directorate reported 34% of all electrically-related aircraft mishaps were related to interconnection failures involving wiring and connectors (Galler and Slenski, 1991). The Materials Directorate System Support Division conducts failure analysis investigations in support of Air Force accident boards, aircraft program offices, and depot operations. In this capacity wiring failures have been found to initiate hydraulic and fuel fires via electrical arcing or cause malfunctions in flight control systems and in other critical areas. At high operating temperatures some insulations can soften and are susceptible to chafing damage that normally would not occur at room temperatures. Examples where wire chafing led to arcing, a fire, and an aircraft mishap are shown in Figures 1 and 2. In both cases, the insulations were pure fluoropolymer constructions and had chafed against a metallic structure. Loss of electrical connections can also lead to severe degradation of aircraft performance. An example of this failure mode is shown in Figures 3 and 4. This is an example of an arc propagation failure in a primarily polyimide wire or MIL-W-81381 construction. In this case, polyimide was carbonized by high temperatures of an electrical arc produced by a metallic structure intimately contacting an exposed conductor carrying electrical power. Polyimide does not melt, but degrades into carbon at temperatures in excess of 650°C, which is much lower than the temperature of an electrical arc. In Figure 4, wiring adjacent to the initial chafe site was degraded by the high arc temperatures. The damaged insulation sustained additional arcing which led to over 30% of the wiring being severed. The arc propagation event can take place before the thermal circuit breakers interrupt current flow. This scenario requires several independent conditions which include an exposed conductor, sufficient current and voltage, and intimate contact between a conductor and metallic structure. Fortunately, this is one reason why arc propagation events are rare. The damage, however, can be severe enough that even a rare failure should be a concern in new and existing aircraft designs. Reported instances of arc propagation and maintenance difficulties with currently available wiring led the Materials Directorate to initiate an in-house program and then a contractual effort to develop new wire insulation constructions. Program goals were to have similar weight, volume and mechanical properties to MIL-W-81381 construction, have increased flexibility, yet not be susceptible to arc propagation failures. The new insulation constructions would also need to be manufacturable by more than one source and be available at a cost comparable to insulations currently used on aircraft.

DEVELOPMENT OF A PROGRAM FOR NEW WIRE INSULATIONS

The AF Materials Directorate, McDonnell Douglas Aerospace Company and other aerospace organizations actively evaluated arc propagation and other characteristics of many insulation candidates as potential replacements for MIL-W-81381 during the mid 1980's. Testing revealed that an insulation construction consisting of various combinations of polyimide tape and polytetrafluoroethylene (PTFE) layers would significantly improve arc propagation resistance (Cahill, 1987). These hybrid constructions combine the desirable properties of polyimide and fluoropolymer materials. The introduction of a high temperature fluoropolymer interrupts the carbon path formed by thermally degraded polyimide during the arcing process. Arc propagation is just one of many wire characteristics that must be considered when selecting wiring for an aircraft. In 1988 a program was conceived by the Materials Directorate that would provide a comprehensive evaluation of selected new insulation constructions. The ground rules were to evaluate commercially available materials that could be available within two years as a wire insulation product from multiple sources. In addition, an industry-supported wire performance test method document being developed by the SAE AE-8D Wire and Cable Subcommittee, AS 4373, would also be used as a testing guideline. McDonnell Douglas was awarded the two year wire development contract, F33615-89-C-5605, in late 1988. Work began in early 1989, and a final report was published by the government in mid 1991. The program was organized by tasks which included the following: establishment of wire performance requirements, selection of ten insulation constructions for evaluation, a highly focused screening evaluation of the most critical wire insulation characteristics, additional performance testing to provide comprehensive data on the top four insulations, an assembly and handling evaluation on selected insulations, and preliminary specification sheets on the most promising insulation candidates (Soloman, 1991). All testing included the two baseline aerospace wiring constructions MIL-W-81381/11,/7,/9 and MIL-W-22759/43,/44,/33.

WIRE PERFORMANCE REQUIREMENTS

Initially, the test program identified minimum wire performance requirements in the areas of assembly and handling, combat damage, thermal analysis, electrical, environmental, mechanical, marking, and wire volume and weight. Forty-three tests were identified and ranked or weighted on a scale of one to five, with five being the most critical. Weighting was based on probability of a failure, field frequency of a failure, and seriousness of failure. The most critical tests were selected to initially screen insulation candidates. Overall ranking of insulation candidates included a weighting factor based on the identified performance requirements. Weighting factors were determined by a survey of three aerospace companies and several government organizations. In all cases minimum performance requirements had to be exceeded in order for a new insulation construction to remain in the evaluation.

INSULATION CONSTRUCTIONS SELECTED

Insulation candidates were submitted by insulation manufacturers and material suppliers. Ten candidates were initially selected from a field of twenty-two proposed constructions. Nine of the ten candidates consisted of various polyimide tape and fluoropolymer layers as shown in Table 1 (Soloman, 1991). Test specimens consisted of 22 gauge and 26 gauge airframe and hook-up wiring.

SCREENING TESTING RESULTS

Screening tests shown in Table 2 were selected from the most important or heavily weighted wiring characteristics identified in the wire performance requirements (Soloman, 1991). Testing was conducted on the ten insulation candidates and the two baseline constructions. The most important tests were part of the verification of properties evaluation. Wire specimens were aged for 1000 hours at 200°C and then subjected to the selected screening tests. Thermally aging the wire specimens provided an indication of long term wiring field performance, since a 10,000 hour design life at 200°C will ultimately be required of any new insulation. Statistical analysis was used to rank insulations in each test and give an overall ranking. The best performing insulation construction was given a score of 0.0. Scores for other insulation constructions were determined by dividing the numerical difference between the best performer and selected insulation by the unbiased standard deviation. A weighted factor determined in the performance requirements evaluation was multiplied by the candidates' calculated score. For the screening evaluation, weighting ranged from 3 to 5.5. Screening test ranking of the candidates is given in Table 3 (Soloman, 1991). The ranking includes all construction types evaluated.

Selection of the top four candidates for further testing was based on overall screening test ranking and availability of a second manufacturing source. Based on these criteria the candidates selected for additional evaluation testing were Filotex, Thermatics, NEMA #3, and Tensolite. The Gore candidate was not continued in the program due to it's single source availability. MIL-W-81381 and MIL-W-22759 baseline constructions ranked fifth and tenth, respectively. MIL-W-81381 failed to meet minimum performance requirements in the dry arc propagation test.

FULL PERFORMANCE EVALUATION

A total of twenty-eight tests were conducted on the insulation candidates selected from the screening evaluation. Performance tests and their weighting are given in Table 4. Combined screening and performance evaluation results are given in Table 5 (Soloman, 1991). Data in Table 5 differs slightly from the referenced technical report due to the fact that several minor errors in the statistical analysis have been corrected. Candidate ranking was not affected by the corrections. The statistical approach used in the screening evaluation was also employed in the performance evaluation. Top performers were the Filotex and Tensolite constructions. The Filotex construction tested in the performance evaluation employed a fluorinated ethylene propylene (FEP) top coat, as opposed to the original PTFE top coat. The two top performing candidates and MIL-W-22759 were subjected to assembly and handling tests. Bundles were constructed and installed in an aircraft. During this evaluation characteristics such as insulation stripping, wire potting, splicing, handling, layout, damage susceptibility, and reparability were assessed. Overall the Filotex construction was a slightly better performer compared to the Tensolite and MIL-W-22759 constructions.

DISCUSSION

Hybrid wire constructions exhibited higher overall performance than the baseline constructions evaluated. Hybrids gave a more balanced range of insulation properties. As an example, wet arc tracking results for the top three candidates and baseline constructions are given in Figure 5 (Soloman, 1991). Hybrid candidates performed as well or better than MIL-W-22759, which is usually considered to be a non-arc tracking insulation. MIL-W-81381 readily arc tracks in this test. Abrasion test results, which give an indication of chafe susceptibility are given in Figure 6 (Soloman, 1991). Several hybrids performed at a level equal to or above MIL-W-81381. One of the most desirable characteristics of MIL-W-81381 type wiring is its ability to retain its excellent mechanical properties over a wide temperature range. As can be seen by the abrasion data pure fluoropolymer constructions rapidly lose their mechanical properties at high temperatures. A common complaint from maintenance personnel is the stiffness and springback of MIL-W-81381. Springback results for hybrids and baseline constructions are given in Figure 7 (Soloman, 1991). Hybrids fall between a very stiff insulation (MIL-W-81381) and a very flexible insulation (MIL-W-22759). While the appropriateness of a test method for smoke quantity determination can be debated, the results in Figure 8 at least show comparisons between insulation constructions (Soloman, 1991). Hybrids are comparable to MIL-W-81381, an insulation highly desirable for manned areas due to minimal smoke generation when the material is thermally degraded.

CONCLUSIONS

Since completing the insulation program in 1991, hybrid insulations have continued to gain popularity as an aerospace wiring. Major aircraft companies have selected constructions similar to the Tensolite and Filotex candidates. Several military programs are in the process of selecting hybrid constructions for aircraft use. Hybrid insulations are also being evaluated for space applications. Wire insulation processors continue to improve hybrid designs and have several products that are commercially available. Overall, hybrids can provide improved performance over currently available aerospace wire insulations. Hybrid insulations retain mechanical properties over a wide temperature range, are arc propagation resistant, provide reasonable flexibility for installation and maintenance, and can be manufactured at a cost comparable to existing aerospace wire insulations.

ACKNOWLEDGMENTS

The authors would like to gratefully acknowledge the program management and technical support provided by Mr. Ron Soloman and the technical support of Mr. Steve Domalewski that made the overall new insulation evaluation program possible. We would also like to acknowledge the time and material provided by the many companies and agencies that participated in the new insulation development program. These organizations include Barcel Wire and Cable, Brand-Rex Cable Systems Division, Champlain Cable Corp., E.I. DuPont De Nemours and Company, Filotex, W.L. Gore and Associates, Independent Cable Inc., Tensolite Company, Teledyne-Thermatics, Hudson International Conductors, Spectrum Technologies, Federal Aviation Agency, the SAE, Lockheed Aeronautical Systems Company, Grumman Aerospace Corporation, Douglas Aircraft Company, and the National Electronic Manufacturer's Association.

REFERENCES

Cahill, P., 1987, "An Evaluation of Aircraft Wet Wire Arc Tracking", Conference Proceedings Forth Aerospace Electrical Interconnect System Conference.

Galler, D. and Slenski G., 1991, "Causes of Aircraft Electrical Failures", National Aerospace and Electronics Conference.

Soloman, R., Woodford, L., and Domalewski, S., 1991, "New Insulation Constructions For Aerospace Wiring Applications", Vol. 1, Technical Report WL-TR-91-4066, Materials Directorate, Wright-Patterson Air Force Base, OH.

Woodford, L., 1991 "New Insulation Constructions For Aerospace Wiring Applications", Aerospace Electrical Interconnect System Conference.

Figure 1. Arcing site that ignited fuel and totally destroyed an aircraft.

Figure 2. In-flight fire initiated by wiring arcing to a hydraulic line.

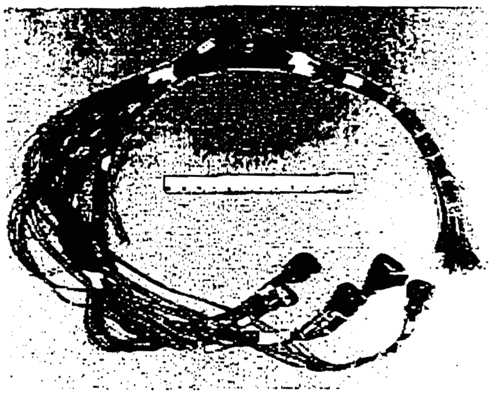


Figure 3. Example of a dry arc propagation failure in MIL-W-81381.

Figure 4. Close-up of Figure 3 showing carbonized insulation.

TABLE 1. SELECTED INSULATION CANDIDATES AND TWO BASELINE CONSTRUCTIONS.

CONSTRUCTION	DESCRIPTION
BARCEL #1	2919 polyimide(50%OL)/Unsintered PTFE
BRAND REX #1	XL-ETFE(50%OL)/616 polyimide/XL-EFTE(50%OL)
CHAMPLAIN #1	2919 polyimide(50%OL)/Extruded XL-ETFE
DUPONT #1	2 layers new polyimide-fluoropolymer (50%OL)/Fluoropolymer
FILOTEX	PTFE extrusion/616 polyimide/PTFE dispersion
GORE #3	PTFE(50%OL)/HSCR PTFE(50%OL)
THERMATICS #3	Modified PTFE(50%OL)/PTFE/polyimide/PTFE Tape/Modified PTFE
TENSOLITE #3	919 polyimide(50%OL)/PTFE(50%OL)
NEMA #2	PTFE(50%OL)/616 polyimide/PTFE(50%OL)
NEMA #3	616 polyimide/Extruded XL-ETFE
MIL-W-81381/7	616 polyimide(50%OL)/616 polyimide/polyimide topcoat
MIL-W-22759/43	Dual extrusion of ETFE

NEMA= National Electronic Manufacturers Association, FEP (fluoronated ethylene propylene)
029= 2.0 mil polyimide,0.5 mil
2919= 0.5 mil PTFE,1 mil polymide,0.5 mil polyimide,0.5 mil PTFE
616= 0.1 mil FEP,1 mil poltimide,0.1 mil FEP
919= 0.5 PTFE,1 mil polyimide,0.5 mil PTFE
PTFE=Polytetrafluoroethylene, ETFE=Ethylene tetrafluoroethylene
XL=Crosslinked, OL=Overlap, HSCR=High Strength Crush Resistant

TABLE 2. SCREENING TESTS AND WEIGHTING FACTORS.

SAE AS 4373 METHOD	TEST	WEIGHT FACTOR	SAE AS 4373 METHOD	TEST	WEIGHT FACTOR
901	Finished Diameter	4.2	(3)	Verification of Retained properties	5.5
(1)	Workmanship	3.0	701	Abrasion	5.5
301	Dry Arc Resistance	5.5	703	Dynamic Cut Through	4.5
(2)	Toxicity	5.0	(4)	Flex Life	5.5
708	Stiffness and Springback	4.2	707	Notch Propagation	5.0
801	Flammability	4.3	510	Voltage Withstand	5.5
601	Fluid Immersion	4.5	504	Insulation resistance	4.5
902	Finished Diameter	4.2	(5)	Examine Product	3.0

(1)- AS 4372, SAE Para. 3.1.4 (2)- Naval Engineering Standard 713, Issue 2
(3)- Specimens were aged for 1000 hrs at 200°C (4)- MDC B0482
(5)- SAE AS 4372 Para. 3.1.4

TABLE 3. SCREENING TEST RESULTS

RANKING	SCORE	INSULATION	RANKING	SCORE	INSULATION
1	6.52	FILOTEX	7	9.92	CHAMPLAIN #1
2	7.23	THERMATICS #3	8	9.94	BARCEL #1
3	8.59	NEMA #3	9	10.97	NEMA #2
4	9.05	GORE	10	11.18	M22759
5	9.22	M81381	11	13.96	BRAND REX #1
6	9.59	TENSOLITE #3	12	14.19	DUPONT #1

TABLE 4. PERFORMANCE TESTS AND WEIGHTING FACTORS.

SAE AS 4373 Method	TEST	Weight Factor	SAE AS 4373 Method	TEST	Weight Factor
(1)	BSI Dry Arc Test	5.5	701	Abrasion	5.2
501	Dielectric Constant	2.0	702	Cold Bend	3.3
502	Corona Inception	3.3	703	Dynamic Cut Through	4.8
506	Surface Resistance	2.2	704	Flex Life	4.7
507	Time/Current to Smoke	3.3	705	Insulation Impact Resistance	3.1
509	Wet Arc Tracking	3.2	706	Insulation Tensile Strength	3.2
511	Wire Fusing Time	3.2	707	Notch Propagation	5.0
602	Forced Hydrolysis	3.5	803	Smoke Quantity	4.3
603	Humidity Resistance	2.2	804	Thermal Index	4.0
604	Weight Loss/Outgassing	2.2	805	Thermal Shock	4.0
606	Weathering Resistance	3.5	712	Wire Surface Marking	3.8
607	Wicking	3.5	(3)	Crush Resistance	3.0
(2)	Wire to wire Rub	5.2	807	Verification of Retained Properties	5.5

(1)- British Standard Institute 90/76828 and 90/80606
(2)- Douglas Aircraft Company Procedure (3)- ASTM D3032, Section 20

TABLE 5. COMBINED SCREENING AND PERFORMANCE TEST RESULTS

RANKING WEIGHTED	SCORE WEIGHTED	SCORE UNWEIGHTED	INSULATION
1	8.21	8.41	FILOTEX
2	8.22	7.79	TENSOLITE
3	9.20	9.10	M81381
4	9.38	9.88	THERMATICS
5	10.51	10.46	NEMA #3
6	11.36	11.23	M22759

FIGURE 5. WET ARC TRACKING RESULTS

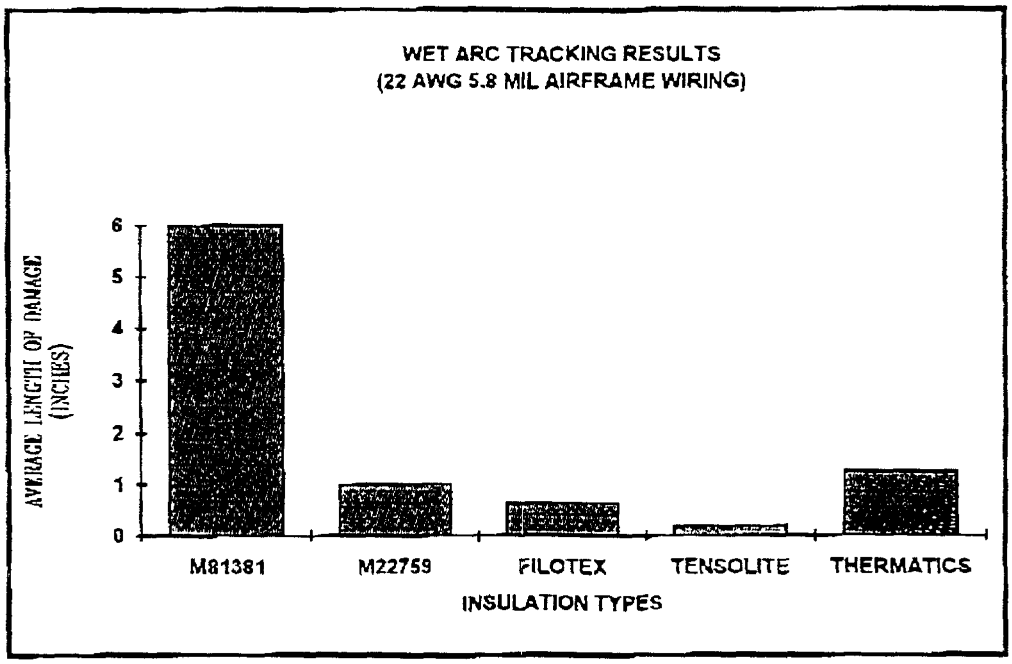


FIGURE 6. ABRASION TEST RESULTS

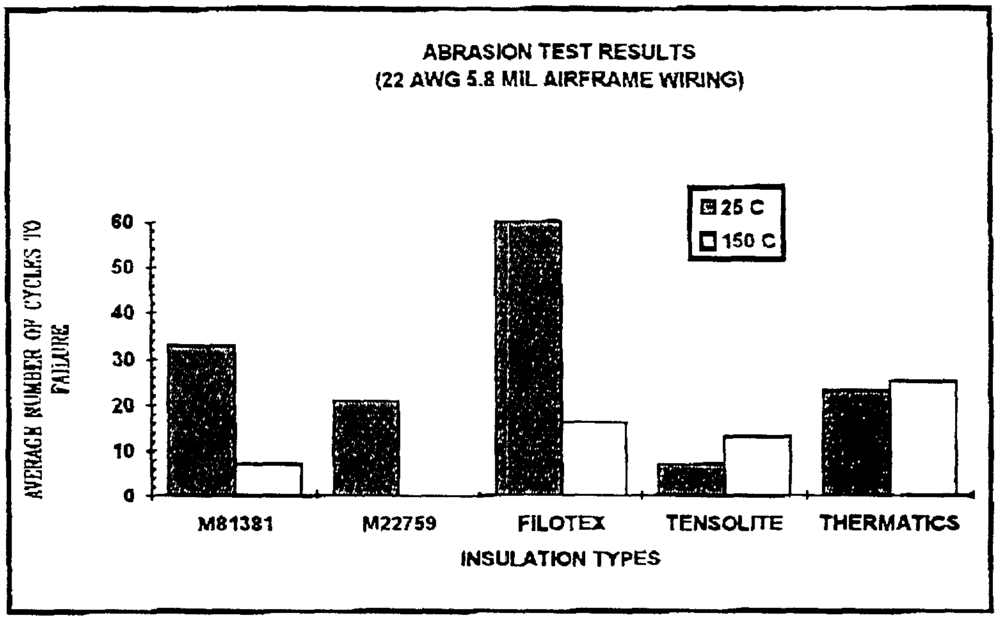


FIGURE 7. SPRINGBACK TEST RESULTS.

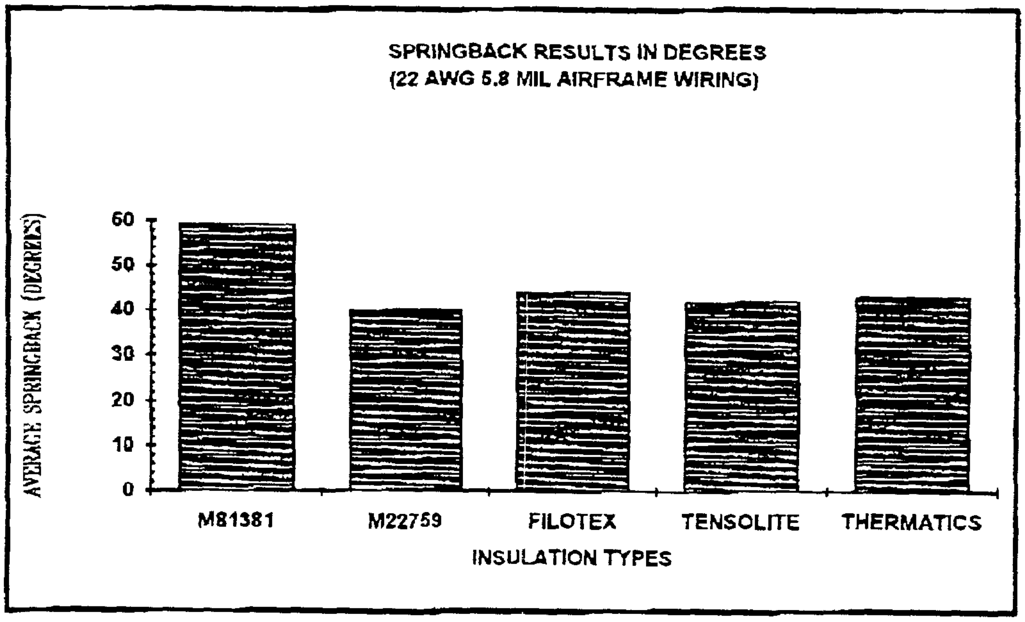
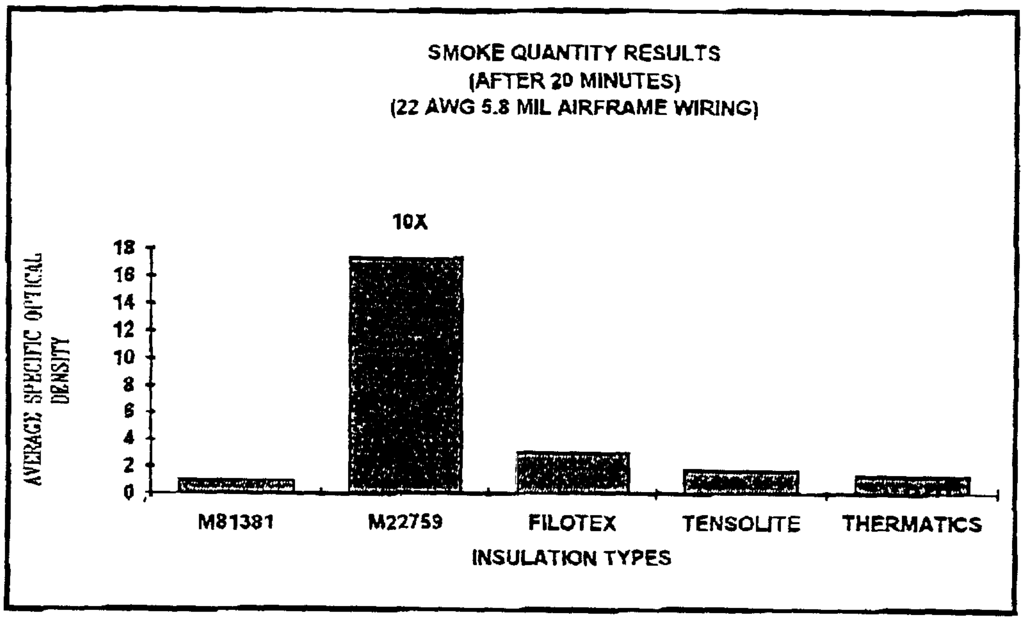


FIGURE 8. SMOKE QUANTITY TEST RESULTS.



SYSTEMS PRACTICE
24-00-00

BOEING 747
SERVICE BULLETIN
SUMMARY

BOEING COMMERCIAL AIRPLANES · POST OFFICE BOX 3707 SEATTLE, WASHINGTON 98124-2207

SUBJECT: ELECTRICAL POWER - MAIN 115 VOLT AC POWER DISTRIBUTION - WIRE INSPECTION AND PROTECTIVE SLEEVING INSTALLATION

ATA: 2451

NUMBER: 747-24-2118
DATE: February 9, 1989
REVISION 2: December 21, 1989

BACKGROUND

This modification will prevent chafing of wire bundles located behind the flight engineer's panel.

Two operators have reported instances where several circuit breakers tripped and smoke appeared from the back of the flight engineer's panel. Several wires were subsequently found to be severely burned and fused together as a result of chafing against the connector back shell.

Rerouting wire bundle and enclosing the wire bundles in Teflon sleeving will prevent chafing conditions which could result in several systems becoming inoperative.

ACTION

At a convenient maintenance interval where manpower and facilities are available, inspect for chafed wires behind the flight engineer's panel. If no chafing is found, enclose wire bundle with Teflon sleeving and reroute. If chafing is found, repair wire bundle, enclose in Teflon sleeving and reroute.

EFFECTIVITY

All 747 airplanes line position 1 through 540

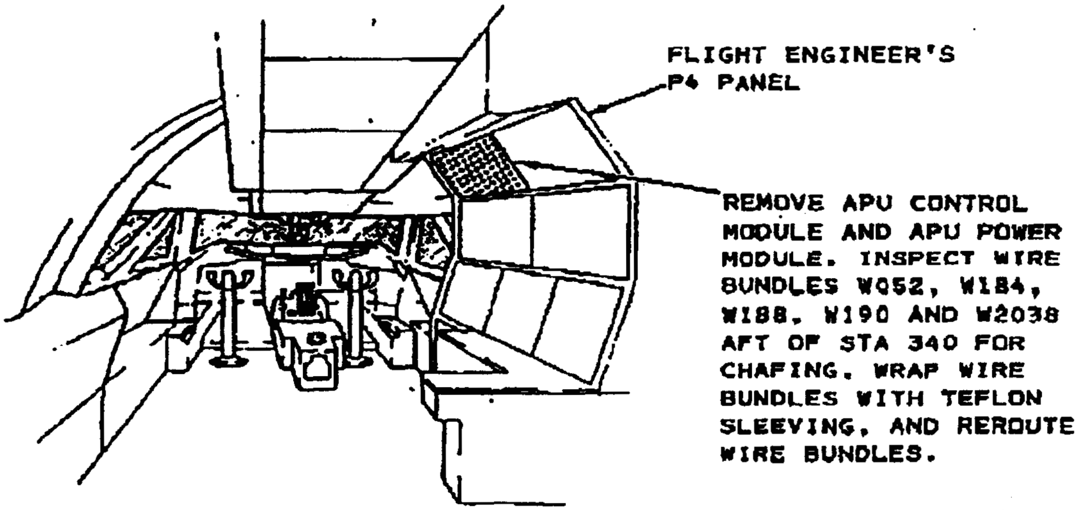
MANPOWER

Total Man-hours - 6 per Airplane

Elapsed Time - 6 Hours

MATERIAL INFORMATION

Operator furnished parts



AD-FAN C/F-FAA AD 94-05-07
SYSTEMS FACT. ATA 24-00-00

COPIES:

DEPT.	M. O.	INST'L DWG.	F.A.B. DWG.
PRD. CTL.	6		
TOOLING			
BOEING			
LOCKHEED			

TWA
MODIFICATION ORDER

XXXXXX
XXXXXX
M. O. NUMBER 71T80
DATE 4-8-94
A.T.A. 24-50
PAGE 1 OF 13 PAGE

CHARGE TO APPROVED MASTER MODIFICATION ORDER NO. ______ THIS PAGE REPLACES PAGE DATED ______

TITLE
CHECK WIRE BUNDLES ABOVE P6 PANEL - 747 AIRCRAFT

AIRCRAFT AFFECTED / ENGINE AFFECTED 17104, 17105, 17107, 17108, 17109, 17110, 17116, 17119, 17133, 17134, 17303, 17305

TOTAL QUANTITY	AIRCRAFT	ENGINES	UNITS	MODULE 1	2	3	4	5	6	7	8
MODIFIED	12										
INSPECTED											

☐ SCHEDULE REPAIR
☐ SHOP OVERHAUL
☐ PRE-SERVICE
☒ CHECK "C"
☒ BASE OVERHAUL
☐ UNSCHEDULED REPAIR
☐ OTHER
☐ LAYOVER

CLASSIFICATION: MAJOR ☐ MINOR ☒
FAA APVL REQ'D ☐ YES ☒ NO
☒ COPY TO F.A.A.
F.A.A. LIAISON (TWA)
F.A.A. REPRESENTATIVE

	DATE	REQ'D
ENGINEER K.S. Craycraft	3/31/94	
MANAGER-ENGINEERING A.W. Lujin	3/31/94	
DIR./PROJ. COORD.-ENGINEERING	4-4-94	
S. V.P.-ENGINEERING NR		
CONTROLLER		
SR. V.P.-MAINT. & ENGINEERING		

TWA COST SUMMARY (SEE COST PAGES FOR DETAILS

TOTAL DIRECT COSTS		TOTAL RELATED COSTS		TOTAL COST
$ 2,886.00	+	-0-	=$	2,886.00

FINANCE USE ONLY

TOTAL OBSOLESCENCE
$

OVERHEAD	TOTAL COSTS	COST PER UNIT
	2,886.00	240.50

			CODE	REVIEWED BY/DATE	COST CTR	ACCOUNT
☑ EXPENSE	☐ CAPITAL	☐ BILLABLE	12	4-7-94 Vickie Loganbill	711	1426-2

CONTRACT CUSTOMER None WEIGHT AND BALANCE DATA None FLIGHT OPERATIONS INFO None

A. REFERENCE:
1. FAA A.D. 94-05-07 (Amendment 39-8845)
2. Boeing Service Bulletin number 747-24A2186, Revision 1.

B. DESCRIPTION:
This M.O. directs the accomplishment of the Boeing Service Bulletin 747-24A2186, Revision 1 which directs a check of the clearance between the wire bundles above the P6 Panel and provides protection to the bundles if less than .25 inch clearance exists between the bundles.

C. JUSTIFICATION: (Priority 1) Airworthiness Directive
A 747-300 operator experienced a failure of the wire bundles above the P6 panel that resulted in smoke in the cockpit, sounds of electrical arcing and circuit breakers popping. The FAA issued AD 92-27-12 that requires a check of these wire bundles on all 747 aircraft by January 23, 1993 and repeated at intervals not to exceed 120 days. The FAA issued A.D. 94-05-07 that supersedes A.D. 92-27-12 and requires that Boeing Service Bulletin 747-24A2186 Revision 1 be accomplished within 4,000 hours of April 4, 1994. Accomplishment of this M.O. will, within 4,000 hours, assure compliance with A.D. 94-05-07.

D. RELATED INFORMATION:
M47-AD-V6 currently accomplishes the required checks on the wire bundles and must be continued until the accomplishment of this M.O.

FOR REVISED PAGES ONLY: TYPED KEF DATE 4-8-94 PAGE 2

AIRCRAFT FLEET ______ NO. COPIES PRODUCTION CONTROL ______ THIS PAGE REPLACES PAGE DATED ______

SUBJECT
CHECK WIRE BUNDLES ABOVE P6 PANEL - 747 AIRCRAFT

M.O. NO.
71T80

K.S. Craycraft
ENGINEER

A.W. Lujin
MANAGER

AFFECTED AIRCRAFT:

NOTE: THIS FORM WILL ONLY BE INFREQUENTLY REVISED. SO REFER TO AS&P 7-10-07 WHICH IS THE OFFICIAL LISTING OF AIRCRAFT TO BE COVERED BY MO'S AND INCLUDES AIRCRAFT LEASED TO OTHERS AS WELL AS PARKED AIRCRAFT.

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ACFT NBR____________ **STATION**____________ **DATE**________

FOR REVISED PAGES ONLY:
AIRCRAFT FLEET ______
NO. OF COPIES PRODUCTION CONTROL:
M.O. ____ FAB.DWG. ____ INSTL.DWG. ____

TYPED KEF DATE 4-8-94 PAGE 3
THIS PAGE REPLACES PAGE DATED________

TITLE
CHECK WIRE BUNDLES ABOVE P6 PANEL - 747 AIRCRAFT

M.O. NO.
71T80

ENGINEER K.S. CRAYCRAFT MANAGER A.W. LUJIN

E. MODIFICATION INSTRUCTIONS:

MECH

Refer to the attached Boeing Service Bulletin.

B. Reason

An aborted take-off was reported by an operator because of smoke in the flight compartment. Circuit breakers opened and electrical arcing was heard during the take-off roll. The operator reported that 42 wires were damaged and 6 power feeder cables were burned and cut. These wires are in 5 different wire bundles.

The damaged wires are located above the P6 panel around STA 400, WL 385, and RBL 25. This is an area where two wire bundles cross over the other three wire bundles. It was concluded that the wire bundles rubbed against each other at the crossover point and damaged the wires.

This change gives inspection, repair, and wire installation instructions to prevent abrasion of wires around the P6 panel. This can prevent damage to the airplane.

Revision 1 is sent to clarify the location of the area above the P6 panel that needs inspection. It also clarifies the materials that the operators can use.

The location of the area that needs inspection is changed from STA 400, WL 385, RBL 25 to STA 400, WL 385, RBL 25. The illustration is changed to show the location of the area that needs inspection relative to the access panel for the fire detection module.

Sleeve 1151-FRB and tapes that meet or exceed the specification MIL-I-42852 are added in the material information section. Installation instruction for sleeve 1151-FRB is given in the figure.

C. Description

INSPECTION AND REPAIR - Inspect the wires above the P6 panel around STA 400, WL 385, and RBL 25. This is the area where wire bundles W418, W1100, and W1362 cross over wire bundles W998 and W718. Repair or replace damaged wires.

NOTES:

- The inspection and repair described in the Boeing All Base Telegraphic Message M-7240-92-1100, dated April 14, 1992, is in compliance with the inspection and repair described in this service bulletin.
- The Boeing All Base Telegraphic Message M-7240-92-2918, dated December 30, 1992, described the inspection and repair and wire installation change in this service bulletin.

WIRE INSTALLATION CHANGE - Measure the clearance between wire bundle W718 and wire bundles W418, W1100, and W1362 at the crossover point. Measure the clearance between wire bundle W998 and wire bundles W418, W1100, and W1362 at the crossover point. No action is necessary if the clearance is 0.25 inch or greater. Do these changes if the clearance is less than 0.25 inch

- Wrap tape or sleeve around wire bundles W418, W1100, and W1362.
- Tie wire bundle W718 to wire bundles W418, W1100, and W1362 at the crossover point.
- Tie wire bundle W998 to wire bundles W418, W1100, and W1362 at the crossover point.

Revision 1 - no more work is necessary on airplanes changed by the initial release of this service bulletin.

II. MATERIAL INFORMATION

A. Parts Necessary For Each Airplane

Quantity	Part Number (Specification)	Name
8 feet	BMS 13-54 (a)	Lacing Tape
1 roll	Scotch 70 (one inch wide) (b)	Tape
	or	
1 roll	Tapes that meet or exceed the specification MIL-I-4685~~8~~ 2	Tape
	or	
1 foot	1151-FRB, (determine diameter at installation) (c)	Sleeve

(a) Refer to the material list at the end of the Boeing Material Specification (BMS) for supplier data. There is no specific grade, type, class, finish and color requirement.

(b) Minnesota Mining and Manufacturing Company (V26066)
Industrial Tape Division
3M Center
St Paul, Minnesota 55144-1000

(c) Bently Harris Manufacturing Company (V81851)
241 Welsh Pool Road
Lionville, Pennsylvania 19353

B. Parts Necessary to Change Spares

None

C. Special Tools and Equipment

No special tools or equipment are necessary to do the change in this service bulletin. Also, maintenance and overhaul tools in manuals shown in Paragraph I.J., References, can be necessary. Examine operator tool supply to make sure all necessary tools are available.

D. Existing Parts Accountability

None

M.O. 71T80
Page 9
Date 4-8-9

III. ACCOMPLISHMENT INSTRUCTIONS

NOTES:

1. The paragraphs identified with letters give the general work instructions and the necessary tests. The instructions identified with numbers on the figure give the recommended sequence of steps.

2. If an electrical circuit is disturbed, make sure that an operational test is done on each affected system. Use the applicable subject of the maintenance manual to do the test.

A. Remove the ceiling panels on the aft side of the P6 panel above the access panel for the fire detection module. If necessary, remove the ceiling panel forward of the p6 panel.

B. Remove electrical power from airplane circuits as specified in the 747 Maintenance Manual Subject 24-22-00.

C. Do the ~~inspection~~ CHECK and changes as shown in Figure 1.

D. Supply electrical power to the airplane circuits as specified in the 747 Maintenance Manual Subject 24-22-00.

E. Install the ceiling panels.

F. Put the airplane back in serviceable condition,

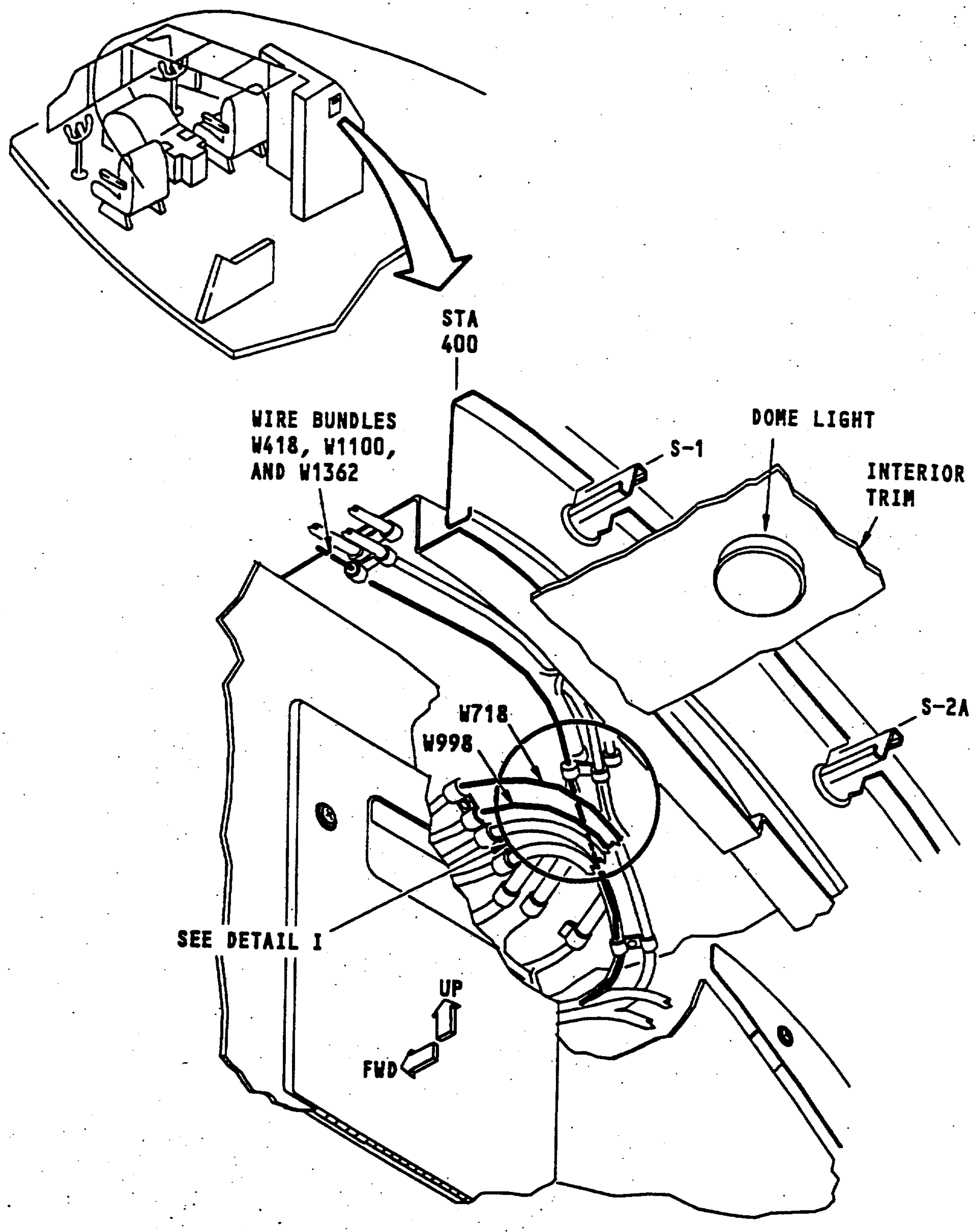
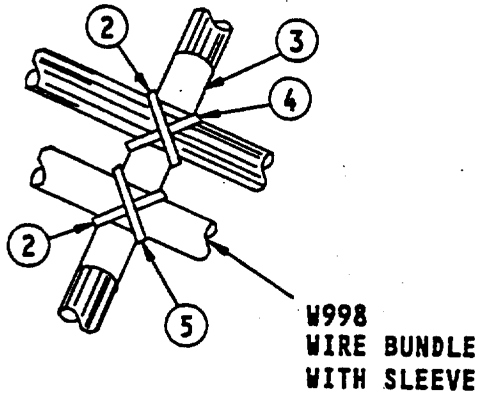
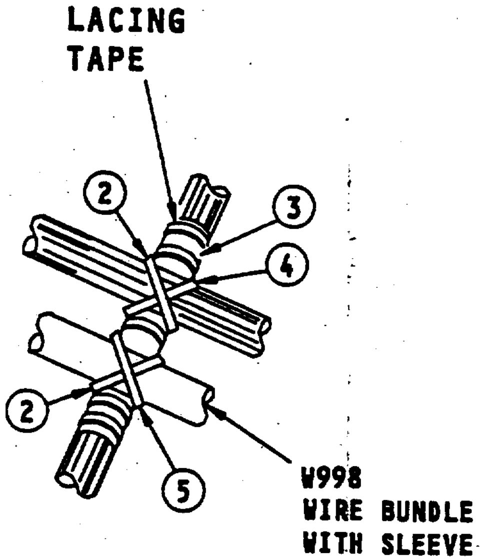


FIGURE 1. WIRE BUNDLE INSPECTION, REPAIR AND WIRE INSTALLATION CHANGE



TAPE SHOWN INSTALLED



SLEEVE SHOWN INSTALLED

DETAIL I

FIGURE 1. WIRE BUNDLE INSPECTION, REPAIR AND WIRE INSTALLATION CHANGE

NOTES:

A. The instruction numbers shown below agree with the numbers shown inside the circle symbols in the figure.

B. Do step 1 immediately when manpower, parts, and facilities are available.

C. The operators can do steps 2 through 5 at the same time as step 1 or during the next C check.

INSPECTION AND REPAIR (step 1)

1 ~~Inspect~~ CHECK the area where wire bundles W418, W1100, and W1362 cross over wire bundles W998 and W718. Replace or repair damaged wires as specified in the Boeing Standard Wiring Practices Manual, Chapter 20, Section 20-10-13. Use moisture resistant splice as needed.

WIRE INSTALLATION CHANGE (steps 2 through 5)

2 Measure the clearance between wire bundle W718 and wire bundles W418, W1100, and W1362 at the crossover point. Measure the clearance between wire bundle W998 and wire bundles W418, W1100, and W1362 at the crossover point. No action is necessary if the measured clearance is a 0.25 inch or more.

NOTE: Do steps 3 through 5 if the clearance measured in step 2 is less than 0.25 inch.

3 Wrap tape or sleeve around wire bundles W418, W1100, and W1362 at the crossover point.

NOTES:

- One wrap of tape with fifty percent overlap is sufficient.
- Cut the sleeve along its length before you wrap it around the wire bundles. The sleeve must have a fifty percent overlap. Use lacing tape BMS 13-54 to tie the sleeve to the wire bundle. Do not put the lacing tape at the crossover point.

4 Tie wire bundle W718 to wire bundles W418, W1100, and W1362 at the crossover point. Use two ties of lacing tape BMS 13-54 to tie the wire bundles together. Do not use plastic ties. The ties must grip securely so as to hold the bundles together without relative movement between the bundles, but not so tightly as to deform the wires or cables. Tie the wire bundles together as specified in the Boeing Standard Wiring Practices Manual, Chapter 20, Section 20-10-11.

5 Tie wire bundle W998 to wire bundles W418, W1100, and W1362 at the crossover point. Use two ties of lacing tape BMS 13-54 to tie the wire bundles together. Do not use plastic ties. The ties must grip securely so as to hold the bundles together without relative movement between the bundles, but not so tightly as to deform the wires or cables. Tie the wire bundles together as specified in the Boeing Standard Wiring Practices Manual, Chapter 20, Section 20-10-11.

FIGURE 1. WIRE BUNDLE INSPECTION, REPAIR AND WIRE INSTALLATION CHANGE

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

SYSTEMS FACTUAL
ATA 24-[illegible]

October 16, 1997
B-B600-16272-ASI

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

BOEING

Subject: TWA 800 - Wiring Short Circuits Reported to Boeing

Dear Mr. Swaim:

Recently you requested information regarding wire shorts, wire fires and wire types on 747 airplanes. The following information is provided in response to your request.

1. How many wiring short circuit events were reported to Boeing in 1996 ? If possible, locations and cause should be included, especially if due to FOD in the bundle.

Response: There was one reported wire insulation abrasion on the 747 in 1996. The operator reported that a burning smell was noted during cargo loading in the forward cargo compartment. Cargo loading system wiring was found damaged and shorted to ground below the cargo floor at station 650, below the aft right corner of a large ball mat. A wiring loom "P" clip was found broken enabling the wire to chafe against structure. A hole was found burned through the bottom angle of the cargo floor cross member, where the wiring clip attached, and charring was evident in the surrounding insulation blanket. Repairs were made.

2. How many wiring fires were reported in 1996. If possible, provide narratives for these.

Response: There were seven reported wiring fires on the 747 in 1996. A description of each event follows:

a. 747-200 reported on January 10, 1996

At seat 33K an electrical burning smell was noted. Investigation revealed a fluorescent lamp holder damaged/burned.

SYSTEMS FACTUAL
AA 24-00-00

b. 747-200 reported on January 10, 1996

At seat 33H-K electrical burning smell was noted, investigation revealed a fluorescent lamp holder damaged/burned.

c. 747-400 reported on February 9, 1996

The flight crew detected a burning smell and then noticed smoke in the flight deck of the airplane. The source was traced to window 1L. The smoke and heat increased in intensity so the window heat was turned off. Maintenance found the connection at the aft lower corner to window 1L burnt. The window was changed.

d. 747-100 reported on February 15, 1996

Cabin crew reported sparks coming from door 4 right electrical control panel on landing. Door 4 right PES/PSS control panel was removed. Flames came from wiring and PES/PSS switches. Flames were extinguished. Damage and fire contained inside control panel.

e. 747-400 reported on March 12, 1996

During flight an electrical burning smell was noted near seat 27G. The crew found the odor to be coming from the seat entertainment unit. The unit was shut down and the cables were disconnected from the seat entertainment unit. Maintenance investigation found the electrical cables to the seat were scorched. Prime cause was found to be the spring clip connector retainers were missing from 2 locations on the seat electronics box allowing vibration to affect the connections. The seat electronics unit and seat cables were replaced System checkout was good.

f. 747-200 reported on October 12, 1996

Wire bundle arcing and resultant fire at aft bulkhead of forward lower lobe cargo hold on a 747-200 freighter. This occurred with the airplane on the ground, during post C-check functional test.

Note: Portions of the damaged wire bundles were forwarded to Boeing for evaluation in determining the cause of the damage. The results of the analysis indicated the primary conductor(s) sustained mechanical or thermal damage prior to the application of electrical power.

g. 747-400 reported on November 1, 1997 (see response to question 1)

The operator reported that a burning smell was noted during cargo loading in the forward cargo compartment. Cargo loading system wiring was found damaged and shorted to ground below the cargo floor at station 650, below the aft right corner of a large ball mat. A wiring loom "P" clip was found broken enabling the wire to chafe against structure. A hole was found burned through the bottom angle of the cargo floor cross member, where the wiring clip attached, and charring was evident in the surrounding insulation blanket. Repairs were made.

3. What was the type of wiring (Poly-X, Kapton, hybrid, etc.) used in W824 and W834 bundles installed in airplanes with line numbers between 630-639?

Response: W824 used BMS 13-51 (Kapton) wire in 747 airplanes with line numbers between 630 and 639.

W834 used BMS 13-48 (ETFE) wire in 747 airplanes with line numbers between 630 and 639

If you have any questions, please do not hesitate to contact me at any time.

Very truly yours,

R. T. Howes 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

SYSTEMS FACTUAL
ATA 24-00-00

ANALYTICAL ENGINEERING REPORT

TO: D.M. Haselman M.S. 96-03
I.S. Ghoreishi M.S. 02-AK
CC:

Similar deposits found in N93119 P14 panel. R Swain

NO.: 9-5576-WP-97-394-R1
ITEM NO.: Chem 6304
DATE: October 31, 1997
MODEL: EQA

GROUP INDEX: 9-5576 - Analytical Engineering, Chemical/Physical

SUBJECT: Identification of Deposits on Wire Bundle.

BACKGROUND

A wire bundle (No. W118, connector number D1947J) removed from a P14 panel of 747 airplane RA104 (S/N 19670) was submitted for analysis of deposits observed on the surface of the wire insulation near the connector.

CONCLUSIONS

The deposits were identified as a complex mixture of organic and inorganic environmental debris. Based on the peaks observed in the 1200-1000 wavenumbers range of the infrared transmittance spectra and elements detected with the electron microprobe, the mixture likely contains silicates, sulfates and phosphates. Many sulfate and some phosphate compounds have an infrared peak or series of peaks in this wavenumber range. Dark-colored deposits on the wire insulation had a higher organic fraction compared to the light-colored deposits on the surface of the connector. The deposits contain water- soluble elements, suggesting that the material may have been deposited from water. The source of the water is unknown. No evidence of arcing or overheating on the wires or connector were observed.

EXPERIMENTATION AND RESULTS

The connector submitted for analysis is shown in Figure 1. A region with dark deposits on the wires is shown in Figure 2. Lighter colored deposits on the connector have the appearance of being deposited from a liquid, as shown in Figure 3. The dark deposits on the wires and the light deposits on the connector were analyzed using infrared microspectroscopy and electron microprobe.

The dark deposit lifted from the surface of one of the wires was found to be separable into an MEK-soluble fraction and an MEK-insoluble fraction. Infrared transmittance spectra of these materials are shown in Figure 4. The peaks in the 3000 to 2800 wavenumber range are associated with -C-H stretching, suggesting the presence of an organic material, possibly lubricant or corrosion inhibiting

SYSTEMS FACTUAL
ATA 24-00-00

compound. A representative infrared spectrum of the light deposit lifted from the surface of the connector is shown in Figure 5.

Representative electron microprobe elemental surveys of the deposits are shown in Figure 6. The following elements were detected in the dark deposit from the wires: carbon, silicon, sulfur, oxygen, potassium, with smaller quantities of calcium, aluminum, sodium, magnesium, titanium, magnesium and iron. The light deposit on the connector was found to contain carbon, sodium, silicon, phosphorus, sulfur, oxygen and smaller quantities of aluminum, calcium, cadmium, potassium and iron.

The infrared spectra of the two deposits are similar, suggesting that the deposits contain some of the same compounds with the exception of the components giving rise to color, which are different. Based on the peaks observed in the 1200-1000 wavenumbers range of the infrared transmittance spectrum and elements detected with the electron microprobe, the mixture likely contains silicates, sulfates and phosphates. Many sulfates and some phosphate compounds have an infrared peak or series of peaks in this wavenumber range. The dark deposit contains more organic material compared to the light deposit based on the relative quantity of carbon detected and the size of the organic infrared peaks. Most of the elements detected are water-soluble. The suggests that at least some portion of these contaminants were deposited from a liquid phase. The source of water is unknown.

Prepared by Catherine A. Barron
C.A. Barron
M/S 73-09, 237-8073

Approved by
W. L. Plagemann
M/S 73-09, 234-3025

Electron microprobe by J. Wessel.

Information About Electrical Arcs.

24-00-00
OSHA - Electrical Safety
Guidelines

Electrical burns are the result of the electric current flowing through the tissues or bones. Tissue damage is caused by the heat generated by the current flow through the body. Electrical burns are one of the most serious injuries you can receive and should be given immediate attention. Since the most severe burning is likely to be on the inside, what may appear at first to be a small surface wound could, in fact, be an indication of severe internal burns. Arc and contact burns will be discussed in the next section.

ARC

Arc burns make up a substantial portion of the injuries from electrical malfunction.The electric arc between metals can be up to 35,000 degrees F which is about four times hotter than the surface of the sun. Workers several feet from the source of the arc can receive severe or fatal burns. Since most electrical safety guidelines recommend safe working distances based on shock considerations, workers can be following these guidelines and still be at risk from arc.

Electric arcs can occur due to poor electrical contact or failed insulation. Electrical arcing is caused by the passage of substantial amounts of current through the vaporized terminal material - usually metal or carbon. Since the heat of the arc is dependent on the short circuit current available at the arcing point, arcs generated on 480 V systems can be just as dangerous as those generated at 13,000 volts.

BLAST

The third source of possible hazard is the blast associated with an electric arc..This blast comes from the pressure developed by the near instantaneous heating of the air surrounding the arc and from the expansion of the metal as it is vaporized. (Copper expands by a factor in excess of 65,000 times in boiling). These pressures can be great enough to hurl people, switchgear, and cabinets considerable distances. Another hazard associated with the blast, is the hurling of molten metal droplets which can cause contact burning and associated damage.

A possible beneficial side effect of the blast, is that it could hurl a nearby person away from the arc, thereby, reducing the effect of arc burns.

Ghoreishi, Issa S ← Mr. Ghoreishi is a Boeing wire specialist & DER.
R. Swaim

To: Whitney, Marvin
Subject: FW: TW 800 Ships Wiring

Dennis,
Following are my response to Bob Swaim questions dated June 2, 1997:

Q1- Is Wiring identified with a "42A" the BMS 1342 Revision A, insulated with the Poly-X Coating?

A1- Wiring identified as a 42A is BMS 13-42 Revision A, "Wire Electric, Alkine-Imide Insulated, Copper and Copper Alloy, 600 V (RMS) 302F (150C)" , is known as Poly-X type insulated wire.

Q2- Please Identify how the wiring is coded. For example, We have wiring with W42A/8/1-16-06090?

A2- This is the wire manufacturer's identification of the wire. This is the breakdown of this identification. W (Wire), 42 (BMS 13-42), A (Revision of the Specification), 8 (Type 8, wire or cable - 10 mil (NOM) Insulation, Tinned Copper Conductor)), 1 (Class 1, A single insulated conductor)), 16 (16 Guage), 06090 (Wire MFG Cage Code, in this case this number is for Raychem Company)

Q3- Was Poly-X wire used on RA164 (TWA 800).

A3- The Poly-X wire was used as a general purpose wire on the RA164 (TWA 800) aircraft.

Q4- Was Poly-X wire used in the center wing fuel tank (CWT Fuel Quantity Indication System (FQIS) wiring between the flight engineer panel and the CWT?

A4- Wire known as Poly-X was not used between the P4 panel (Panel-Flight Engineer Instrument) and the center tank connector DM127. The FQIS wire between the P4 panel (Panel-Flight Engineer Instrument) and and the center tank connector DM127 is 10-60875-2 type wire. The FQIS wire with in the center fuel tank is 10-60875-4 type wire.

Q5- Was Poly-X wire used in any of the wiring runs adjacent to CWT FQIS and was Poly-X used for any of the fuel pumps?

A5- Wire known as Poly-X was used in wire runs adjacent to CWT FQIS wire. Please refer to the wires types list adjacent to CWT FQIS which was provided on February 4, 1997. Poly-X wire was used for the fuel pump wiring.

Q6- What Problems the Poly-X wiring had in service? What is the effect of the fatigue, chemical attack, cold/heat exposure on the Poly-X wire.

A6- Wire known as Poly-X had three in-service problems:
-Abrasion of the insulation in bundles installed in high vibration areas.
(This problem was corrected by Boeing Service Bulletin No. 747-71-2105, Dated July 19, 1974)
-Random flaking of the topcoat.
-Insulation radial cracks in tight bend radii.

Radial cracking phenomena of the Poly-X wire was associated mainly with mechanical stress. Bend radius is the largest contributor to mechanical stress in an installed wire or cable. Presence of moisture in conjunction with mechanical stress is also a contributor.

Thanks;
Issa S. Ghoreishi
Ph. 266-4098, M/S 02-AK
Pg. 541-9055

SYSTEMS FACTUAL

OBTAINED FROM MAT[illegible]
PROCESS [illegible]
HISTORICAL [illegible]

A 24-00-00

1. SCOPE

a. This specification covers crosslinked alkane-imide polymer insulated copper and copper alloy wire and cable. This specification requires qualification of products.

b. RATING

The wire of this specification is rated for the following conditions.

(1) When operating potentials do not exceed 600 volts (RMS).

(2) Where any combinations of ambient temperature and conductor current, for either intermittent or continuous service, does not produce a stabilized conductor temperature in excess of 302 F (150 C).

2. REFERENCES

Except where a specific issue is indicated, the noted issue of the following references shall be considered a part of this specification to the extent specified herein.

2.1 SPECIFICATIONS

2.1.1 FEDERAL

a.	TT-S-735, Type III	Standard Test Fluids; Hydrocarbon, March 1964
b.	UU-T-450B	Tissue, Facial, 24 Sept. 1963
c.	CCC-T-191b	Textile Test Methods, 15 May 1951
d.	C-F-206C	Felt Sheet, Cloth, Felt, Wool, Pressed, 30 July 1968

2.1.2 MILITARY

a.	MIL-C-7078B	Cable Electric Aerospace Vehicle General Specification for, 17 March, 1964
b.	MIL-T-5438	Tester; Abrasion, Electrical Cable, 19 Dec. 1949
c.	MIL-H-5606B	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance, 26 June 1963
d.	MIL-A-6091C	Alcohol, Ethyl, Specially Denatured, 9 Feb. 1968 •
e.	MIL-L-7808E	Lubricating Oil, AircraftTurbine Engine, Synthetic Base, 13 March 1963
f.	MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, 1 March 1965
g.	MIL-D-26937A	Detergent, Synthetic, Anionic (Alkyl Benzene Sulfonate), 15 April 1963

000051

(Poly-X used in N93119) RSwain

BY F. G. Hovrend CK'D J. P. Stock ENG [illegible]	Q.C. [illegible] MAT'L J. H. Rachl	WIRE: ELECTRIC, ALKANE-IMIDE INSULATED, COPPER AND COPPER ALLOY, 600V (RMS) 302F(150C) **BOEING MATERIAL SPECIFICATION**	**BMS 13-42A** PAGE 1 OF 54

ORIGINAL ISSUE 7-30-69 (CAG)

CODE IDENT. NO. 81205

REVISED 4-13-70

R

5.2.1.3 **Conductor Elongation and Tensile Strength**

5.2.1.3.1 Elongation

The individual strands of the conductor or the whole conductor removed from finished wire shall have the following minimum elongation when measured in accordance with 8.5.

Soft annealed copper	10 percent
High-strength copper alloy	6 percent

5.2.1.3.2 Tensile Strength (High-Strength Copper Alloy Only)

When high-strength copper alloy is specified, the individual strands of the conductor or the whole conductor removed from finished wire shall have a minimum tensile strength of 58,000 psi when measured in accordance with 8.5.

5.2.1.4 **Conductor Diameter**

The diameter of the conductor shall be as specified in Table II.

5.2.1.5 **Insulation**

The insulation shall be constructed so that it can be readily removed by mechanical wire-stripping devices.

5.2.1.5.1 Primary Insulation

The primary insulation of one or more layers shall be crosslinked extruded alkane-imide polymer. When more than one layer is employed a coating of modified imide polymer may be used between the layers. The alkane-imide polymer shall be an off-white color readily distinguishable from the basic brown color of the imide coating.

5.2.1.5.2 Coating

A coating of modified imide polymer shall be applied over the insulation. This coating shall be continuous and free from cracks, splits, blisters, and other defects when examined without aid of magnification.

5.2.1.5.3 Insulation Elongation and Tensile Strength

The primary insulation and the coating shall have an elongation of 50 percent (minimum) when tested per 8.14 and shall have a tensile strength of 7500 PSI (minimum) for wire sizes 30 through 10 and 5000 PSI (minimum) for wire sizes 8 through 4/0 when tested per 8.14.

5.2.2 FINISHED CABLE CONSTRUCTION

The construction of finished cable shall be as specified in the individual Type and Class construction details. In multi-conductor cables the insulated wires as determined by the class designation shall be spirally laid to provide as concentric a cable as possible. The lay of the individual wires shall be not less than eight or more than sixteen times the major diameter of the cable. The direction of lay shall be left-hand. Fillers will not be allowed.

5.2.2.1 **Shield Construction and Coverage**

The shield shall be a closely woven braid and shall comply with the following:

a. The individual shield strand size shall be as follows:

  (1) Size 38 strands shall be used over wire or cable having a major diameter of 0.300 inch or less.

  (2) Size 36 strands shall be used over wire or cable having a major diameter greater than 0.300 inch and less than 0.400 inch.

  (3) Size 34 strands shall be used over wire or cable having a major diameter of 0.400 inch or over.

MATERIAL CLASSIFICATION	SUPPLIER	WIRE SIZE	QUALIFICATION REFERENCE
TYPE I All Classes 1	RAYCHEM CORPORATION 300 CONSTITUTION DRIVE MENLO PARK, CALIFORNIA	24 thru 12	747 Materiel Group Letter E-5519-3-563 March 23, 1970
TYPE V All Classes 2		30 thru 20	
TYPE VIII All Classes		24 thru 0000	
TYPE IX All Classes		30 thru 20	
TYPE X All Classes 3		24 thru 12	
TYPE XI All Classes 4		30 thru 20	

1 Suppliers approved for Type I wire are approved for Type III and Type IV cable, all classes, in the sizes listed for Type I.

2 Suppliers approved for Type V wire are approved for Type VI and Type VII cable, all classes, in the sizes listed for Type V.

3 Suppliers approved for Type X wire are approved for Type XII cable, all classes, in the sizes listed for Type X.

4 Suppliers approved for Type XI wire are approved for Type XIII cable, all classes, in the sizes listed for Type XI.

ORIGINAL ISSUE 4-13-70
REV.

BY F. G. Howard
ENG A. P. Stork

BOEING MATERIAL SPECIFICATION
QUALIFIED PRODUCTS LIST

BMS 13-42A

[illegible]
24-5000

THE ASSISTANT SECRETARY OF THE NAVY
Research Development and Acquisition
1000 Navy Pentagon
Washington DC 20350-1000

AUG 26 1997

The Honorable Jim Greenwood
House of Representatives
Washington, DC 20515

Dear Mr. Greenwood:

It is my understanding that your constituent, Mr. Ed Block, has expressed concern regarding wiring in the F-14 aircraft and has requested information from the Navy via your office. I trust you have recognized from the detailed response of Rear Admiral Jeff Cook, the Program Executive Officer for Tactical Aircraft Programs, dated June 2, 1997, that the Navy has aggressively rectified this F-14 issue and remains committed to enhancing the safe operation of all our warfighting systems.

In the early 1980's the F-14 wiring reliability was of major concern. Kapton wiring, initially identified as a remedy for the problems of Poly-X in critical aircraft areas, also developed similar reliability problems. Spec 55 wiring, first incorporated into new production aircraft in 1980 and completely retrofitted into critical harnesses of existing F-14's by 1989, has proven to be a reliable solution. The Navy's technical and safety organizations are satisfied that early F-14 wiring problems have been fully resolved for nearly a decade.

I appreciate Mr. Block's concern, but firmly believe we have taken the necessary steps to ensure that the F-14 fleet does not have a wiring safety issue. As always, if I can be of further assistance, please let me know.

Sincerely,
and very Respectfully

John W. Douglass

ATA 24-50-00

DEPARTMENT OF THE NAVY
PROGRAM EXECUTIVE OFFICER
TACTICAL AIRCRAFT PROGRAM
1421 JEFFERSON DAVIS HWY
ARLINGTON VA 22243

IN REPLY REFER TO
2 June 1997

The Honorable James C. Greenwood
House of Representatives
Washington, DC 20515-3805

Dear Mr. Greenwood:

Thank you for the opportunity to respond to Mr. Ed Block's recollection of the April 10, 1997 meeting. However, we understood that the groundrules established at the beginning of this meeting were that no official minutes were to be recorded. Therefore, we were disappointed to learn that portions of Mr. Block's notes had become available to the media. Consequently, I believe it is important that you have the Navy's position on this issue as it relates to the F-14 aircraft.

Three types of wiring have been used in the F-14, MIL-W-81044/16-19 (Poly-X), MIL-W-81381 (Kapton) and MIL-W-22759/32-/35 and /41-/46 (Spec 55). Poly-X wiring, based on a polyimide type material, was the original wiring used in F-14 production. In 1976, Raychem discontinued manufacturing Poly-X and the Navy began phasing in Kapton wiring into aircraft production. Spec 55 wiring was developed by Raychem in 1977 but a 1978 study comparing Kapton and Spec 55, indicated that these wires were approximately equivalent but that Kapton was lighter. Based on this study, a decision was made to continue phasing Kapton wiring into production, while using up Poly-X on hand.

During the mid to late 1970's, the Navy experienced significant maintainability problems and a reduction in combat readiness due to Poly-X wiring. Poly-X wiring was found to be deficient in the operating environment of the F-14. Specifically, high humidity and high pH based aircraft cleaning solutions caused the wire insulation to crack which increased the potential for electrical failures. Because of these problems, Poly-X was prohibited from being used in certain critical harnesses in Severe Wind and Moisture Problem (SWAMP) areas. By the time Poly-X was completely phased out of production aircraft, 337 F-14 aircraft had been produced.

In 1979, the Navy proposed an extensive retrofit program to completely replace Poly-X wiring with Kapton wiring in 323 (out of the first 337) aircraft. Total cost estimate was $354M; but this was never appropriated by Congress. (The $354M figure was referred to by Mr. Block during the April 10, 1997 meeting.) Instead, a wiring modification program costing $26M was implemented from 1982 through 1989, which involved replacing Poly-X and Kapton wiring with Spec 55 in critical SWAMP areas as well as the incorporation of anti-chafe protection and water intrusion prevention.

SYSTEMS PACKAGE
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The rewire with Spec 55 was required due to continuing maintainability and durability problems with Poly-X and the emergence of similar problems with Kapton in SWAMP areas. This decision was reinforced by two studies conducted in 1981 that indicated that both wire types, based on polyimide materials, had similar properties and were not the optimum choice for use in naval aircraft because the wire insulation was susceptible to stress, chaffing and breakdown. The different chemical composition of Spec 55 wiring coating solved many of the problems inherent with Poly-X and Kapton wiring. Based on these studies, the Naval Air Systems Command issued policy guidance in 1981, stating that Spec 55 was the preferred wiring for use in naval aircraft for all rework and repair actions.

During the April 10, 1997 meeting, the Navy stated that there are no F-14 aircraft currently flying with Poly-X wiring. That statement, which was based on limited data we were able to gather shortly before the meeting, was incorrect. In fact, there are currently 45 active aircraft with some Poly-X. However, these aircraft have received the Spec 55 update to critical wiring harnesses. Of the remaining 337 aircraft that were originally produced with Poly-X wiring, 91 were placed in storage at Davis-Monthan Air Force Base because their useful fatigue life had expired or because they were considered excess inventory and represent war reserve. These aircraft were **not** placed in storage due to problems with Poly-X wiring as alleged by Mr. Block.

There are currently 295 F-14 aircraft actively flying today. Of these, 45 contain some amount of Poly-X wiring, 161 contain a mix of Kapton and Spec 55 wiring and 89 are completely Spec 55 wired. All aircraft have Spec 55 in critical wiring harnesses. As stated during the April 10, 1997 meeting, the F-14 has not experienced a wiring safety issue.

In summary, there is no documented wiring safety issue in the F-14. No grounding bulletins have ever been issued due to wiring problems. The Navy identified a maintainability problem with both Poly-X and Kapton wiring in certain critical harnesses in F-14 aircraft. This was corrected by switching to Spec 55 wiring in production and retrofitting critical harnesses in previously manufactured aircraft through a wiring improvement program.

The Navy recommends that this issue be closed from an F-14 perspective.

I hope this information will be useful to you. If I may be of further assistance, please let me know.

Sincerely,

J A Cook

J. A. COOK
Rear Admiral, U. S. Navy

Encl #D
1

DEPARTMENT OF THE NAVY
NAVAL AIR SYSTEMS COMMAND
NAVAL AIR SYSTEMS COMMAND HEADQUARTERS
WASHINGTON, DC 20361

IN REPLY REFER TO
AIR-411:DRE
Ser: 085
01 OCT 1982

SYSTEMS
FACTUAL
ATA [illegible]

From: Commander, Naval Air Systems Command
To: National Electrical Manufacturers Association (NEMA)
2101 L Street, NW, Suite 300
Washington, DC 20037

Subj: Summary of Findings of the Military Aircraft Subcommittee Investigation on MIL-W-81381

Encl: (1) Part (1) Committee 7HP: Location West Coast
Part (2) Committee 7HP: Location East Coast

Dear Jack,

I have read the results of your committee's investigation and wish to thank you and the wire manufacturers for your efforts in bringing more light on the subject of aircraft wire problems associated with MIL-W-81381. Enclosure (1) contains comments addressed to your report. As you know, the problems with poly-X wire are well known to headquarters and its use has been curtailed. On the other hand, we truly expected the committee to concentrate on MIL-W-81381 in conjunction with our experience with it and not spend quite so much time on poly-X.

It is known at Headquarters which aircraft, by serial number has MIL-W-81381 and which does not. Our remarks concerning this wire pertain particularly and specifically to those aircraft that have it installed. Also, your inspection team missed opportunities to inspect Kapton wire aircraft when they did not go to NAS Whidbey where all of the EA-6B's are based or to NAS Cecil Field where the East Coast S-3A's are based.

While your committee made no recommendations concerning the use of MIL-W-81381, I am sure you would agree that in order to maximize the utility of MIL-W-81381 already in use, the Navy should:

a. upgrade training
b. ensure proper tool distribution
c. enforce strict compliance with MIL-W-5088
d. Keep aircraft cleaning solvents at lowest PH level
e. Continue to replace MIL-W-81381 in S-3 wingfold areas and other S-3 trouble areas
f. continue review of F-4 SLEP aircraft and make changes as necessary
g. continue monitoring the performance of MIL-W-81381

In summary your inspection definitely highlighted wire problems endemic to the fleet. You can see why the Navy and the military require aircraft wire which is maintenance free and clearly, as your report shows, MIL-W-81381 is not.

Donald R. Eaton
By Direction

SYSTEMS FACTUAL
ATA 24-50-00

U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

MAY 21 1997

The Honorable James C. Greenwood
House of Representatives
Washington, DC 20515

Dear Congressman Greenwood:

Thank you for your letter of April 30 on behalf of Mr. Ed Block regarding our recent meeting. I appreciate the opportunity to have met with you and Mr. Block.

Mr. Block's views on civil aviation wiring, as presented at our April 10 meeting are not new to the Federal Aviation Administration (FAA). We have exchanged correspondence with Mr. Block on these same issues.

I do not agree with most items in the minutes prepared by Mr. Block and believe that the conclusions are solely his. Although there was insufficient time at the April 10 meeting to discuss the issues of aging wiring and Mr. Block's recommendations, I believe my comments clearly indicated a disagreement with most of the issues he presented. That disagreement, and my expressed reasons, have been omitted from the minutes.

The White House Commission, headed by Vice President Gore, has made specific recommendations regarding aging wiring in civil aircraft. In response to those recommendations, the FAA is planning to study the issues associated with aging wiring, conduct any research necessary, and take appropriate action based on the study recommendations. Our study will consider the issues raised by Mr. Block and others, as well as all service experience to date with all types of wiring.

If you need further assistance, please contact A. Bradley Mims, Assistant Administrator for Government and Industry Affairs, at (202) 267-3277.

Sincerely,

Thomas E. McSweeny

Thomas E. McSweeny
Director, Aircraft Certification
Service

Enclosure
Transmitted Correspondence

[illegible] FACTUAL

MA 24-00-00

NASA/MSFC TWA800 8/27/97 CABLE#4 SAMPLE A

N93119 Wire strand with balled end. Wire was mixed with (tied to) W480 CWT FQ15 bundle as examined at Marshall Space Flight Center.

SYSTEMS FACTUAL
ATA 24-00-00

MICROFILMED 5-29-84

THE **BOEING** COMPANY

REV LTR

CODE IDENT. NO. 81205

NUMBER T-29646

TITLE: ELECTRIC BONDING REQUIREMENTS AS DETERMINED BY THE IGNITION CAPABILITIES OF HEATED FILAMENTS AND POINT-CONTACTS (U)

FOR LIMITATIONS IMPOSED ON THE USE OF THE INFORMATION CONTAINED IN THIS DOCUMENT AND ON THE DISTRIBUTION OF THIS DOCUMENT, SEE LIMITATIONS SHEET.

MODEL ALL
CONTRACT
ISSUE NO.
ISSUED TO: R.R. Willoughby

Bill' File Copy

PREPARED BY T.R. Wilson 2-9-67
T. R. Wilson
SUPERVISED BY 2/13/67
G. V. Oswald
APPROVED BY 2/17/67
D. W. Exner
APPROVED BY 2/22/67
R. E. Pedersen

SHEET 1

SYSTEMS FACTUAL
ATA 24-00-00.

commonly employ fuel pumps and other motors which are internally grounded. The class of motor represented by Figure 2 is unique, in that inrush currents which often are in the 500 to 1000 ampere region must pass to ground (structure) through the case ground circuit. The latter consists of the ground lead (Rg) in parallel with the case-ground (Rb). Ground lead Rg is normally an insulated wire of the same size as the positive-side line conductor. In the typical installation it may range from one to several feet in length. Assuming size 8 or 10 wire, the resistance of this circuit would commonly lie between 2 and 10 milliohms.

As an example, let us assume that in a given instance, Rg is 0.005 ohm, and Rb is the identical value. The effective resistance of two equal resistors in parallel is 1/2 that of either, giving a net of 0.0025 ohm. If the inrush current of the motor in this instance is 700 amperes, then the IR drop across the ground-path is:

$$700\ (0.0025) = 1.75 \text{ volt}$$

It should be noted that should a ground-fault occur within the motor at Pt. A, then Figure 2 would resemble Figure 1, except that the current flowing between the housing and structure would divide between Rb and Rg. In Figure 1, Rg does not pass appreciable current during a ground-fault.

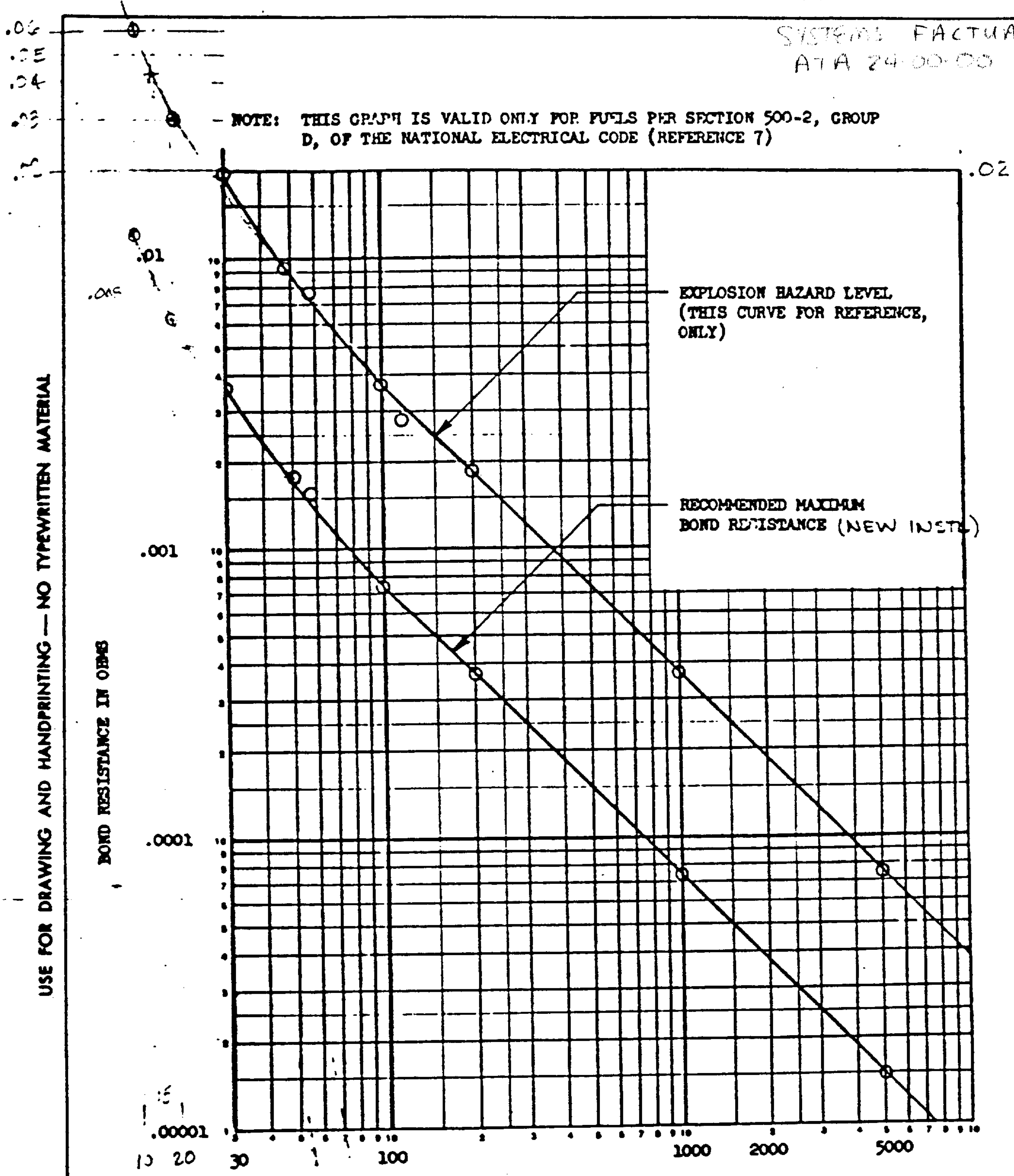
With the configurations illustrated by Figure 1 or Figure 2, the voltage, Eb, developed across the ground circuit may cause ignition of combustible mixtures in either of two ways, as follows:

1. A localized hot-spot may occur in the ground-path represented by Rb, if the resistance of this ground should be largely concentrated in a small point having low current-carrying capacity. Such a point can be so severely heated that incandescence, or expulsion of molten and vaporized metal results. Laboratory tests have shown this type of action can be a potent ignition source.

2. A foreign, extraneous metallic object (debris) may have lodged in such a manner as to form a parallel path (Rx), across the joint. This path could also involve safety wire installed on screws which bridge the joint, thus forming a built-in filament. The point-contacts associated with metallic debris or the cut ends of safety wire may be heated to incandescence by the flow of current, (Ix on Figures 1 or 2).

SYSTEMS FACTUAL
ATA 24-00-00

NOTE: THIS GRAPH IS VALID ONLY FOR FUELS PER SECTION 500-2, GROUP D, OF THE NATIONAL ELECTRICAL CODE (REFERENCE 7)



BOND RESISTANCE IN RELATION TO AVAILABLE FAULT CURRENT

FIGURE 7

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL

SYSTEMS
24-00-00

WHERE ARC MARKS WERE FOUND ON UPPER DECK FRAMES

Wire Bundles Routed in Ribs 420 and 480
Between Stringers S2A and S2A.

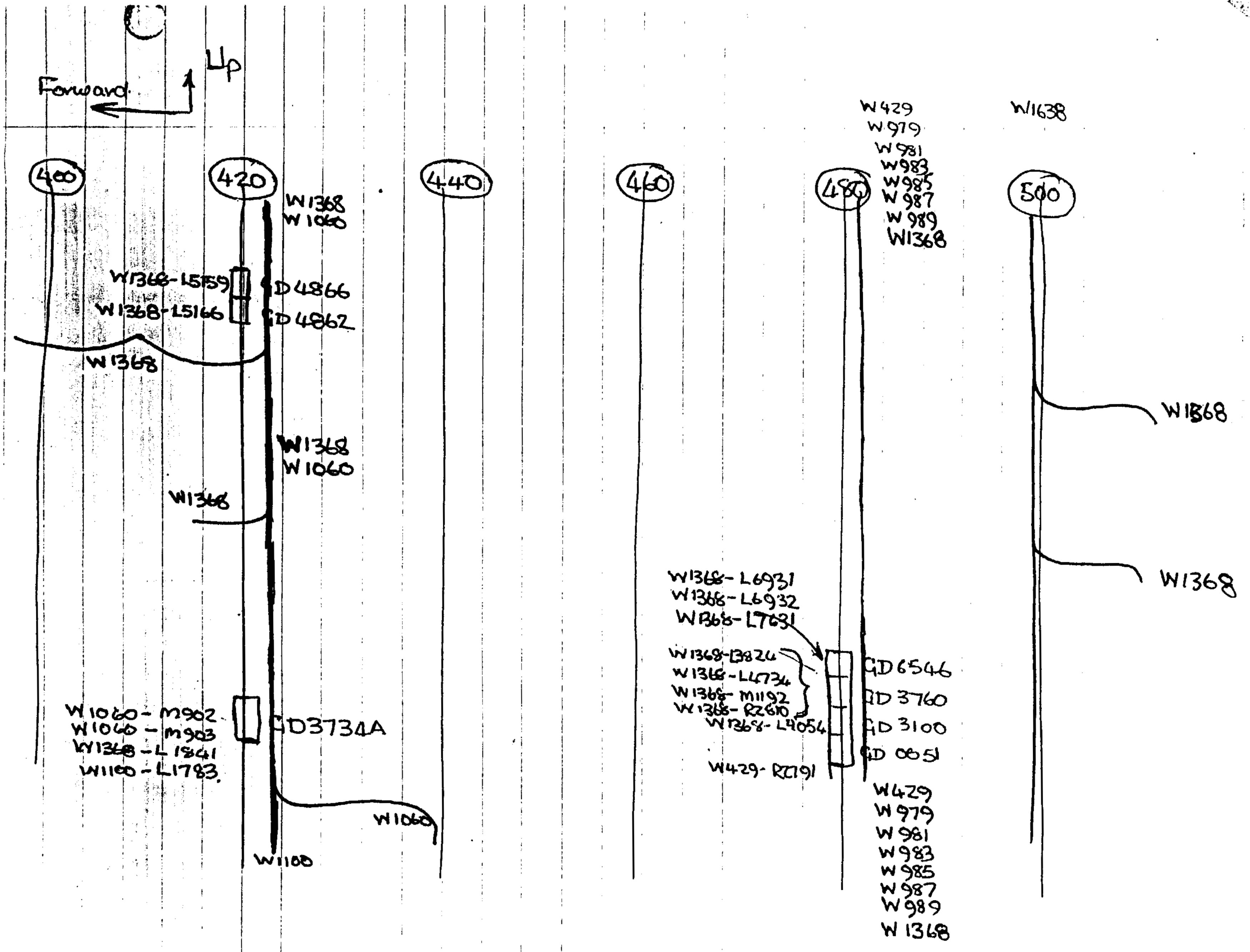
References. PI Drawing 61B70102.-Sheet 0002. Frame 1
PI Drawing 61B70102 - Sheet 0002 Frame 2.
Electrical Schematic: 33-51-12 Pages 1 and 2.
Emergency Lights - Upper Deck.

Wire Bundle W1368 - is the primary wire bundle for the emergency lighting in the upper deck and is installed in by Rib 420 and 480. It appears to wander all over the place.

Wire Bundles, W797 through W989 are AIDS wire bundles from the Flight Deck to the E11-3 radio rack.

Note 1: All the wires in Wire Bundle W1368 are either AWG20 or AWG22. There are no large gage wires in this bundle.
The wires in the AIDS bundles are AWG24 or AWG22.

Note 2. Emergency Light Power Units are installed in the same location as the wire bundles



W1368 = Emergency Lighting Upper Deck

W1060 = Emergency Lighting Attendants Panel.

W979 – 989 = AIDS wires from Flight Deck to E11-3

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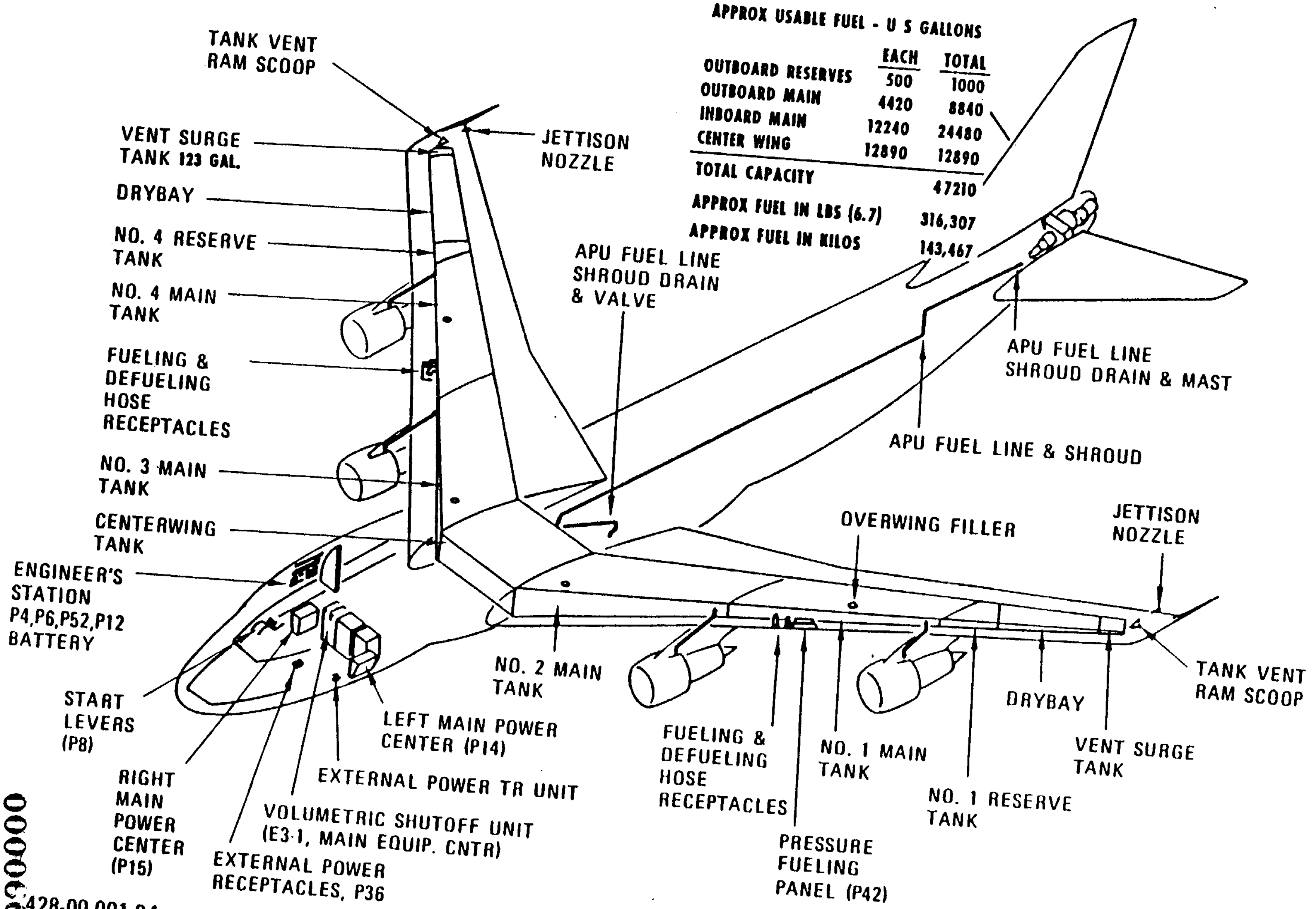
28-00-00



APPROX USABLE FUEL - U S GALLONS

	EACH	TOTAL
OUTBOARD RESERVES	500	1000
OUTBOARD MAIN	4420	8840
INBOARD MAIN	12240	24480
CENTER WING	12890	12890
TOTAL CAPACITY		47210
APPROX FUEL IN LBS (6.7)		316,307
APPROX FUEL IN KILOS		143,467

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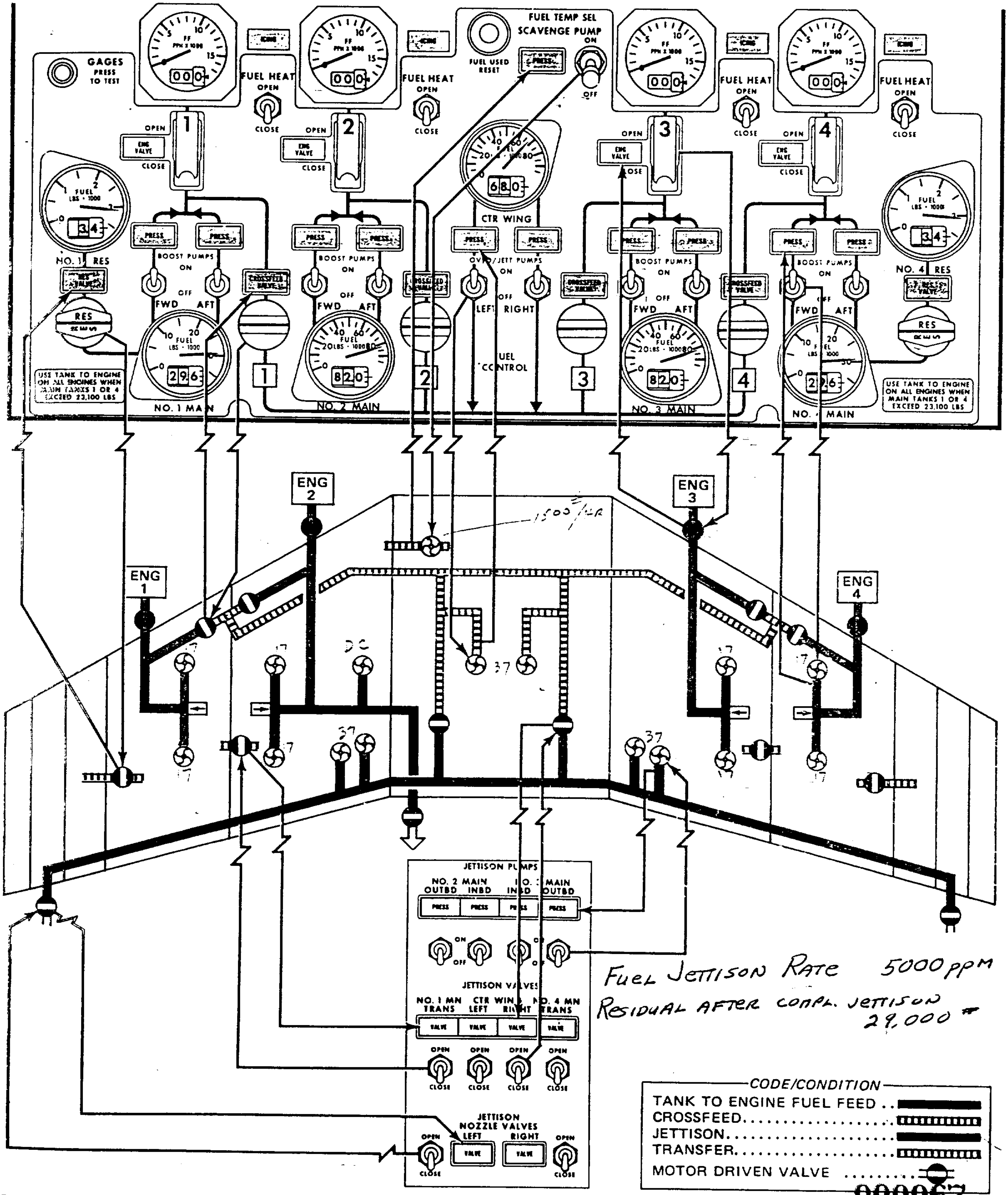
428-00-001-04
JUN 1976

FUEL SYSTEM ARRANGEMENT

FUEL CONTROLS



Fuel Jettison Rate 5000 ppm
Residual after compl. jettison 29,000 #

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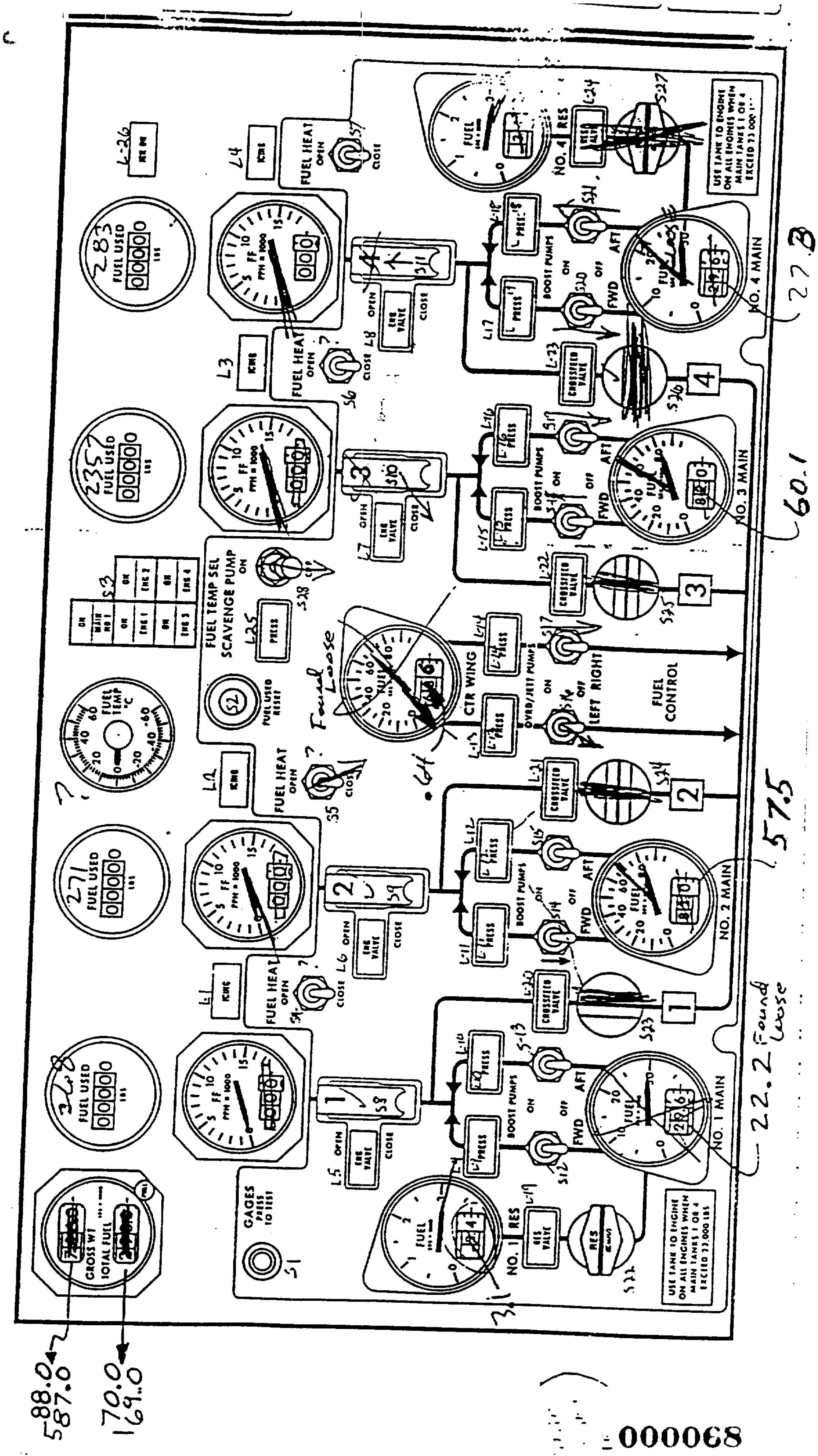

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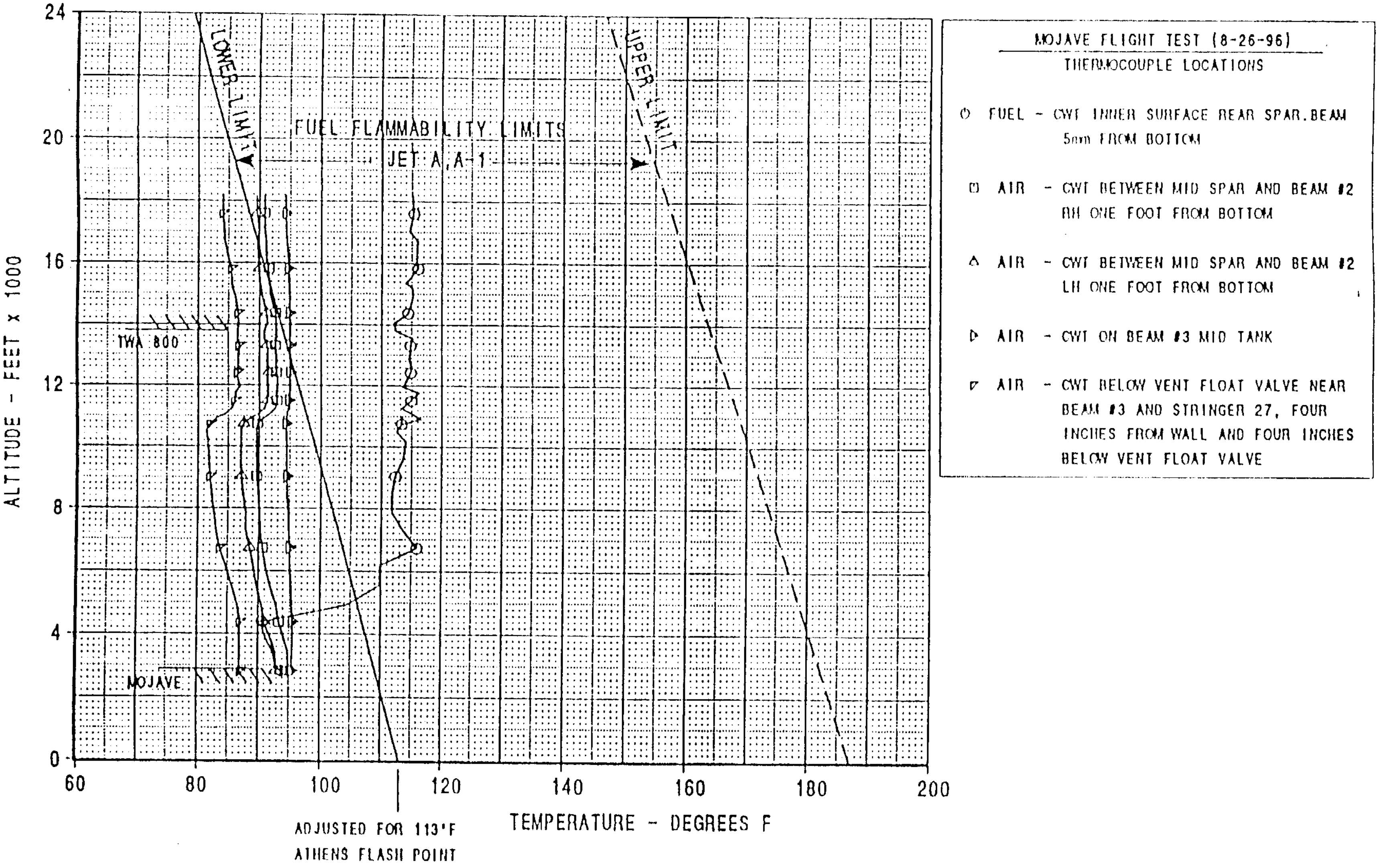
747-100 Center Wing Tank Temperature Test



BOEING

Commercial
Airplane
Group

747
Service Bulletin

Number: 747-28-2205 NSC 01
Date: September 25, 1997

ATA System: 2811

Notice of Status Change

SYSTEMS FACTUAL
28-00-00

SUBJECT: FUEL-FUEL TANKS-CENTER FUEL TANK INSPECTION

This notice is applicable to Service Bulletin 747-28-2205, dated June 27, 1997.

DESCRIPTION:

This notice of status change is sent to the operators to clarify the items that follow:

1. Paragraph three in the Summary Background and on page 8, paragraph I.B. Reason. The word "absent," is inappropriate. There is no reason to suspect that bonding jumpers are missing.

2. On page 13, NOTE: 3.b.1). The word "necessary" should be "recommended". Although the pistol grip probes offer a significant advantage, other Avtron probes can be used.

3. On page 13, NOTE: 3.d. The following should have been included: "Make sure the meter is in the correct range. It is possible to get a misleading measurement if the wrong range is selected."

4. On page 17, paragraph 7.f.1) and on page 19, paragraph 8.f.1). The requirements to use the AVTRON model T477W, should have stated that any standard ohmmeter can be used.

5. On pages 17 and 18. Subparagraph d. is inappropriate and should be removed.

6. On page 19, paragraph .8.e.2). The sentence, "See Figure 9.", should say, "See Figure 10."

7. On page 37. Forward Isolation Valve Illustration

One of the three bonding meter measurements shown, points to the upper support bracket. Change the location of the meter to point to the lower support bracket. Also the resistance value should be changed from 10.0 milliohms to 1.00 milliohms.

The bonding jumper wire is shown incorrectly. The wire appears to go from the support bracket to the valve body. There is no bonding jumper wire to the valve body. The bonding jumper should be shown between the support bracket and the support bracket mounting plate.

8. On page 81, STEP 2 NOTES. The words, "of the pump" are not appropriate. STEP 2 applies to the pressure switch also.

The next revision to the service bulletin will include the data in this Notice of Status Change.

BOEING

Commercial
Airplane
Group

747
Service Bulletin

Number: **747-28-2205**
Date: June 27, 1997

ATA System: 2811

Summary

SYSTEMS FACTUAL
ATA 28-00-00

SUBJECT: FUEL - FUEL TANKS - CENTER WING FUEL TANK INSPECTION

THE BOEING COMMERCIAL AIRPLANE GROUP RECOMMENDS THAT EACH OPERATOR EXAMINE THIS SERVICE BULLETIN IMMEDIATELY.

BACKGROUND

This inspection will make sure that the wiring, tubing and component installations inside the center wing fuel tank are in satisfactory condition and electrically bonded to the airplane structure.

This inspection should identify any conditions of in-service deterioration and make sure that such conditions are repaired.

Examples of such conditions are non-conforming wire connections and clearances, improper mounting of components, including interference, absent or loose bonding jumpers, deteriorated fay surface bonds and corrosion at wire terminals and connectors.

Refer to Boeing Message M-7240-97-0805 dated 22 May 97 for additional information.

As part of a service bulletin validation program, this inspection was completed on airplanes RT610 and RD255 before the release of this service bulletin.

ACTION

Open the center wing fuel tank for inspection.

Examine for damage all of the wiring, tubing and component installations inside the center wing fuel tank.

Examine for damage the fuel system wiring and component installations outside the center wing fuel tank.

Remove and examine the APU boost pump and the scavenge pump, if installed.

Measure the bonding resistance of fuel system tubing and components, and report the findings.

Repair any non-normal installations.

COMPLIANCE

Boeing recommends that this inspection be accomplished at the next convenient maintenance interval, not to exceed two years after the date of this service bulletin.

EFFECTIVITY

All 747 airplanes line positions 0001 through 1124.

INDUSTRY SUPPORT INFORMATION

Boeing warranty remedies are available for airplanes in warranty as of June 24, 1997. Please refer to Paragraph I.F., Industry Support Information.

MANPOWER

Total Man-hours - 32 for each airplane
Elapsed Time - 8 Hours

MATERIAL INFORMATION

None

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B. Reason

This inspection will make sure that the wiring, tubing and component installations inside the center wing fuel tank are in satisfactory condition and electrically bonded to the airplane structure.

This inspection should identify any conditions of in-service deterioration and make sure that such conditions are repaired.

Examples of such conditions are non-conforming wire connections and clearances, improper mounting of components, including interference, absent or loose bonding jumpers, deteriorated fay surface bonds and corrosion at wire terminals and connectors.

Refer to Boeing Message M-7240-97-0805 dated 22 May 97 for additional information.

As part of a service bulletin validation program, this inspection was completed on airplanes RT610 and RD255 before the release of this service bulletin.

C. Description

The center wing fuel tank is opened and examined for evidence of damage or deterioration of wiring, tubing and component installations.

Fuel system components outside the center wing fuel tank are examined for evidence of damage or deterioration.

The APU boost pump and the scavenge pump, if installed, are removed and examined.

Bonding resistance measurement data is recorded and the findings reported, as instructed, on the figure pages.

Any non-conforming installations are repaired.

Please make a copy of the figure pages 2 through 13 of this service bulletin, that apply to the airplane inspected, and send to the address below. Include the airplane variable number and hours/cycles.

PLEASE SEND A REPORT OF YOUR INSPECTION AFTER EACH AIRPLANE INSPECTION IS COMPLETE.

SEND TO: BOEING COMMERCIAL AIRPLANE GROUP
ATTENTION: MANAGER, AIRLINE SUPPORT

D. Compliance

Boeing recommends that this inspection be accomplished at the next convenient maintenance interval, not to exceed two years after the date of this service bulletin.

E. Approval

This service bulletin was examined by the Federal Aviation Administration (FAA). The changes specified in this service bulletin comply with the applicable Federal Aviation Regulations (FAR) and are FAA approved. This service bulletin and the FAA approval were based on the airplane in its original Boeing delivery configuration or as modified by other FAA approved Boeing changes.

If an airplane has a non-Boeing modification or repair that affects a component or system also affected by this service bulletin, the operator is responsible for obtaining appropriate regulatory agency approval before incorporating this service bulletin.

SYSTEMS FACTUAL
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III. ACCOMPLISHMENT INSTRUCTIONS

NOTES:

1. The paragraphs identified with a letter give the general work instructions and the necessary tests. The instructions identified with numbers on the figures give the recommended sequence of steps.

2. Obey all of the warnings and cautions given in the specified manual sections.

3. Bonding Meter Measurement Information - General

    a. Measure and record the electrical bond resistance between the component and primary structure electrical ground as shown in the figures.

    b. Types of meters necessary to complete this inspection:

        1) Bonding Meter

        Use the Avtron Model T477W Bonding Meter to take the bonding resistance measurements required in this service bulletin. Refer to BSWP 20-20-00. Also, it is necessary to use the Pistol Grip Probes, Avtron Part No. C22161.

        2) Megohmmeter

        Use a standard megohmmeter like the General Radio 1644A, or equivalent to take Scavenge Pump and APU Pump insulation resistance measurements off the airplane.

    c. The center wing tank structural webs that follow are to be considered as primary structure electrical ground. See Figure 1.

        - Front, Mid and Rear Spar
        - Spanwise Beams No. 1, 2 and 3
        - Right and Left Side Body Rib (tank ends)
        - Butt Line zero Partial Rib
        - Upper and Lower Skin Panels

    d. The bonding resistance measurement should not exceed the value indicated on the figure. All Avtron Meter display ranges are calibrated in milliohms. The limit values shown in the figure, above the meter symbol, is in milliohms. Record your resistance measurement, in milliohms as displayed by the meter, in the space provided. See Figure 1.

    e. Make sure that the probe tips penetrate the surface coating (Yellow Zinc Chromate or anodize) to assure reliable values. Refinish bared or scratched areas. Refer to SRM 51-20-01.

    f. If measured resistance exceeds the limit shown in the figure, then repair the bonding and grounding jumper installation at both ends or the fay surface bond path. Refer to BSWPM 20-20-00 and applicable AMM subjects. Write down the resistance measurement before and after the repair.

4. Examine all the bonding jumper installations on all components, including all valves, pumps and tubes. Refer to BSWPM 20-20-00.

5. Make sure each tube section is bonded. The figures attempt to show the most common configurations. Make sure each section of tubing is measured and the value recorded.

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ATR 28·00 [illegible]

A. **Center Wing Tank Internal Dry Bay Inspection** (On airplanes with a dry forward bay)

Open the Center Wing Tank (CWT) dry bay. Refer to AMM 28-11-00/201 and 28-11-01/401.

1. Examine for evidence of fuel leaks from the wet bay.
2. If the Water Injection System is installed, examine all the components. See Figure 13.
3. If the Water Injection System was installed, but has been deactivated, make sure the wiring has been removed or capped and stowed at both ends. Refer to BSWPM Chapter 20.

   NOTE: Boeing recommends that the wiring be removed from the dry bay completely. The wiring at the pressure seal should either be removed and a new pressure seal installed or the wiring at the seal should be capped and stowed on both sides of the seal with a maximum length of four (4) inches on either side.

4. Examine the 1.5 in. diameter drain holes.
5. Examine the tubing to the exit port.

B. **Center Wing Tank Internal Wet Bay Inspection**

Open the center wing fuel tank for inspection. Refer to AMM 28-11-00/201 and 28-11-01/401.

1. Examine the Fuel System Pressure Manifolds and Components. See Figure 2.
2. Examine the Refuel Distribution Manifolds. See Figure 3.
3. On airplanes with the Secondary Refuel Valve Shutoff System, examine the tubing and components. See Figure 4.
4. Examine the Vent System tubing and components. See Figure 5.
5. Examine the Scavenge System tubing and components.
   a. On airplanes with the Electric Pump Scavenge System, see Figure 6.
   b. On airplanes with the Hydromechanical Scavenge System, see Figure 7.
6. Examine the Override/Jettison Pump Priming tubing. See Figure 8.
7. Examine the APU Fuel Supply Tube. See Figure 9.
8. Examine the Fuel Quantity Indication System (FQIS) components and installations. See Figure 11.
   a. In-Tank Fuel Quantity Wire Harness Repair

      NOTE: if a non-normal FQIS wiring installation condition is found, then the procedures that follow should be used to make any repairs.

   b. **Retermination of Lo-Z (unshielded) Wiring**
      1) Cut off damaged terminal and trim conductor until all visible damage and/or corrosion has been eliminated.
      2) Prepare conductor for installation of terminal. Refer to BSWPM 20-30-11.

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3) Clean stripped conductor. Refer to BSWPM 20-60-01. Use solvent and a soft bristle brush. Refer to BSWPM 20-00-11.

4) Install and crimp a BACT12M4, or equivalent, terminal to the conductor. Use crimp tools as specified in BSWPM 20-30-11.

5) Brush coat all exposed surfaces of conductor with BMS 5-45 tank sealant or ProSeal 860 sealing compound. Inject enough sealant to fill the void between the insulating sleeve and the terminal body at the rear of the terminal. Take precautions to avoid contaminating terminal mating area with sealant.

c. Retermination of Hi-Z (shielded) Wiring

NOTE: Some Hi-Z wires use a solder sleeve to attach the shield pigtail to the shield. It is NOT permissible to repair these wires using solder sleeves, as the necessary heat sources are not allowed inside the fuel tank. Any repair to such wires must employ the procedure below using mechanically secured ferrules.

1) Cut off damaged terminal and trim conductor until all visible damage and/or corrosion has been eliminated.

2) Clean stripped conductor. Refer to BSWPM 20-60-01. Use solvent and a soft bristle brush. Refer to BSWPM 20-00-11.

3) Prepare center conductor and shield for installation of terminal. Refer to BSWPM 20-30-11 and for pigtail wire 20-10-15 paragraph 5C.

4) Assemble the inner ferrule, outer ferrule and pigtail wire and crimp. Use the crimp tools as specified in BSWPM 20-10-15. The inner and outer ferrules are identified in BSWPM 20-10-15, Table VI Shield Terminations for Boeing 10-60875 Cable .

5) Install and crimp a BACT12M130 or equivalent terminal to the pigtail wire.

6) Install and crimp a BACT12M4, or equivalent, terminal to the conductor. Use crimp tools as specified in BSWPM 20-30-11.

7) Brush coat all exposed surfaces of conductor with BMS 5-45 tank sealant or ProSeal 860 sealing compound. Inject enough sealant to fill the void between the insulating sleeve and the terminal body at the rear of the terminal. Take precautions to avoid contaminating terminal mating area with sealant.

d. Splicing of Lo-Z (unshielded) Wiring

1) Trim wire ends as necessary to remove any damage and/or corrosion.

2) Prepare conductor for installation of splice. Refer to BSWPM 20-30-12.

3) Clean stripped conductors. Refer to BSWPM 20-60-01. Use solvent and a soft bristle brush. Refer to BSWPM 20-00-11.

4) Install a 1.5 inch piece of 0.5 inch diameter RT876 sleeving or Teflon tubing over one wire end. This tube will be used to contain sealant applied in step 7.

5) Install and crimp wires to an NAS1387-4 splice. Refer to BSWPM 20-30-12.

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6) Brush coat all exposed metal surfaces with BMS 5-45 tank sealant or ProSeal 860 sealing compound.

7) Slide the sleeving or tubing installed in step 4 over the splice. Inject BMS 5-45 or ProSeal 860 into the sleeving. Make certain the space inside the sleeving is completely filled.

NOTE: Do not use heat to shrink the sleeving.

e. **Splicing of Hi-Z (shielded) Wiring**

1) Trim wire ends as necessary to remove any damage and/or corrosion.

2) Prepare each wire end for installation of one coaxial contact.

3) Clean stripped conductors. Refer to BSWPM 20-60-01. Use solvent and a soft bristle brush. Refer to BSWPM 20-00-11.

4) Install one male coaxial contact (Boeing P/N 10-60479-44 or Cinch P/N CN0941-15) onto one wire end.

5) Install one female coaxial contact (Boeing P/N 10-60479-41 or Cinch P/N CN0941-16) onto the remaining wire end.

6) Install a 1.5 inch piece of 0.5 inch diameter RT876 sleeving or Teflon tubing over one wire end. This sleeving will be used to contain sealant applied in step 9.

7) Mate the two coaxial contacts.

8) Brush coat all exposed metal surfaces with BMS 5-45 tank sealant or ProSeal 860 sealing compound.

9) Slide the sleeving or tubing installed in step 6 over the splice. Inject BMS 5-45 or ProSeal 860 into the sleeving. Make certain the space inside the sleeving is completely filled.

NOTE: Do not use heat to shrink the sleeving.

9. Examine the Structure and Sealant Installations. See Figure 12.

C. **Center Wing Tank External Inspection**

1. Examine the Override/Jettison Pumps. See Figure 2.
2. Examine the Refuel Valve Control Units. See Figure 2.
3. On airplanes with the Horizontal Stabilizer Tank (HST),
examine the Horizontal Stabilizer Tank Isolation Valve Actuators. See Figure 2.
4. Examine the Jettison Transfer Valves. See Figure 2.
5. On airplanes with a Fueling Isolation Valve,
examine the Fueling Isolation Valve Actuator. See Figure 2.

SYSTEMS FACTUAL
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6. On airplanes with the Horizontal Stabilizer Tank, examine the Secondary Refuel Valve Pressure Switches. See Figure 4.

7. On airplanes with the Electric Scavenge Pump System, examine the Scavenge Pump and Pressure Switch. See Figure 6.

   a. Remove the Scavenge Pump from the airplane. Refer to AMM 28-15-01/401.

   b. Examine the Scavenge Pump for:

      - Fuel leaks
      - Heat discoloration
      - Corrosion or damage.
      - The impeller for damage or excessive wear.
      - Interference between impeller and housing.
      - Foreign Object Damage, ingestion or impact.
      - Signs of bulges, bent flanges, broken screw, medium to heavy corrosion damage (as specified in the 747 Corrosion Prevention Manual Subject 20-40-00, Part I, General Information - Corrosion Removal Techniques, Paragraph 3.A), etc.

   c. Examine the Scavenge Pump electrical connector for:

      - Heat discoloration
      - Corrosion or damage.
      - Damaged contacts

      <u>NOTE:</u> Clean the cap after the inspection. Refer to BSWPM 20-60-01.

   d. If necessary, replace the Scavenge Pump.

      <u>NOTE:</u> Although the pumps are removed from the airplane for the tests that follow, they may still contain some residual fuel. Take precautions for proper drainage and ventilation.

   e. Do a Scavenge Pump Pressure Switch - case ground resistance measurement test.

      1) Use the AVTRON model T477W ohmmeter.
      2) Measure pin 4 resistance on the pressure switch connector. See Figure 6.

   f. Do a Scavenge Pump - case ground resistance measurement test.

      1) Use the AVTRON model T477W ohmmeter.
      2) Measure from pin 4 on the pump connector to the body of the pump. Maximum value should not exceed 10.0 ohms. This is a continuity check to support the insulation resistance test.

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g. Do a Scavenge Pump - insulation resistance measurement test.

   1) Use a standard megohmmeter like the General Radio 1644A, or equivalent.

   2) Set the megohmmeter in the range of 10 to 50 volts DC for the initial safety check of the pump.

   3) Measure the insulation resistance between pin 4 and each of pins 1, 2 and 3 on the pumps electrical connector. If any of the measurements are below 1 megohms, then the pump should be replaced.

   4) Set the megohmmeter to 500 VDC range.

   5) Measure the insulation resistance between pin 4 and each of pins 1, 2 and 3 on the pumps electrical connector. If any of the measurements are below 1 megohms, then the pump should be replaced.

h. Install the Scavenge Pump. Refer to AMM 28-15-01/401.

8. Examine the APU Fuel Boost Pump. See Figure 10.

a. Remove the APU Pump from the airplane. Refer to AMM 28-25-01/401.

b. Examine the APU pump for:

   - Fuel leaks
   - Heat discoloration
   - Corrosion or damage.
   - The impeller for damage or excessive wear.
   - Interference between impeller and housing.
   - Foreign Object Damage, ingestion or impact.
   - Signs of bulges, bent flanges, broken screw, medium to heavy corrosion damage (as specified in the 747 Corrosion Prevention Manual Subject 20-40-00, Part I, General Information - Corrosion Removal Techniques, Paragraph 3.A), etc.

c. Examine the APU pump electrical connector for:

   - Heat discoloration
   - Corrosion or damage.
   - Damaged contacts

   NOTE: Clean the cap after the inspection. Refer to BSWPM 20-60-01.

d. If necessary, replace the APU Pump.

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NOTE: Although the pump is removed from the airplane for the tests that follow, it may still contain some residual fuel. Take precautions for proper drainage and ventilation.

e. Do an APU Pump Pressure Switch - case ground resistance measurement test.

  1) Use the AVTRON model T477W ohmmeter.

  2) Measure pin 4 resistance on the pressure switch connector. See Figure 9.

f. Do an APU Pump - case ground resistance measurement test.

  1) Use the AVTRON model T477W ohmmeter.

  2) Measure from pin 3 on the pump connector to the body of the pump. Maximum value should not exceed 10.0 ohms. This is a continuity check to support the insulation resistance test.

g. Do an APU Pump - insulation resistance measurement test.

  1) Use a standard megohmmeter like the General Radio 1644A, or equivalent.

  2) Set the megohmmeter in the range of 10 to 50 volts DC for the initial safety check of the pump.

  3) Measure the insulation resistance between pin 3 and each of pins 1 and 2 on the pumps electrical connector. If any of the measurements are below 1 megohms, then the pump should be replaced.

  4) Set the megohmmeter to 500 VDC range.

  5) Measure the insulation resistance between pin 3 and each of pins 1 and 2 on the pumps electrical connector. If any of the measurements are below 1 megohms the pump should be replaced.

h. Install the APU Pump. Refer to AMM 28-25-01/401.

9. Examine the FQIS wiring. See Figure 11.

  a. Outside the center wing tank, examine all FQIS wiring for damage and proper clearance with all other components and structure.

    1) Examine the routing on the rear spar, where it penetrates to the inside of the tank.

    2) Examine the rear spar electrical disconnects for proper terminations.

    3) Examine the routing in the wheel well area, for damage and for proper clearance with all other components and structure.

D. Close the center wing fuel tank. Refer to AMM 28-11-00/201 and 28-11-01/401.

E. Return the airplane to serviceable condition.

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FIGURE TABLE OF CONTENTS

ATA 28-00-00

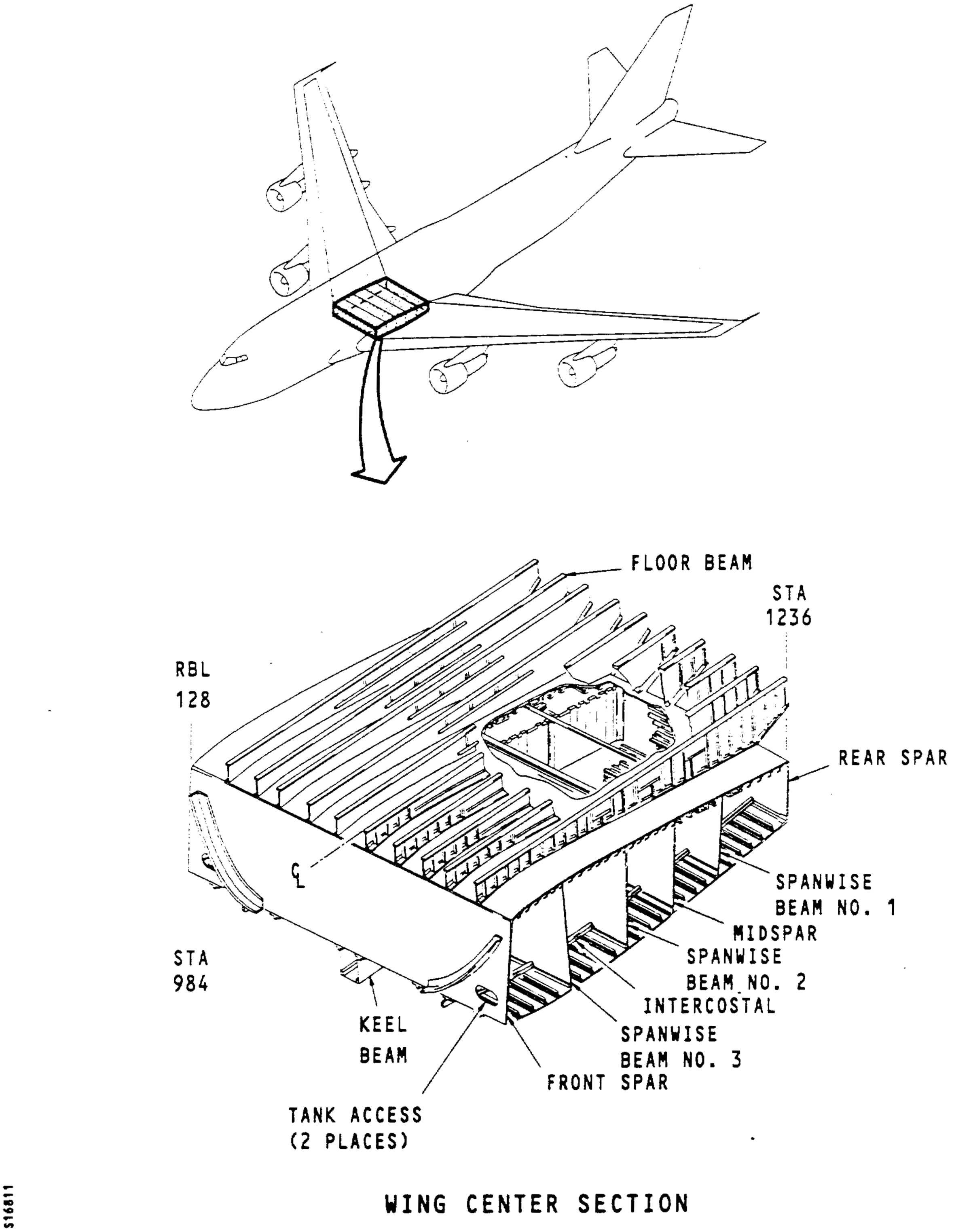

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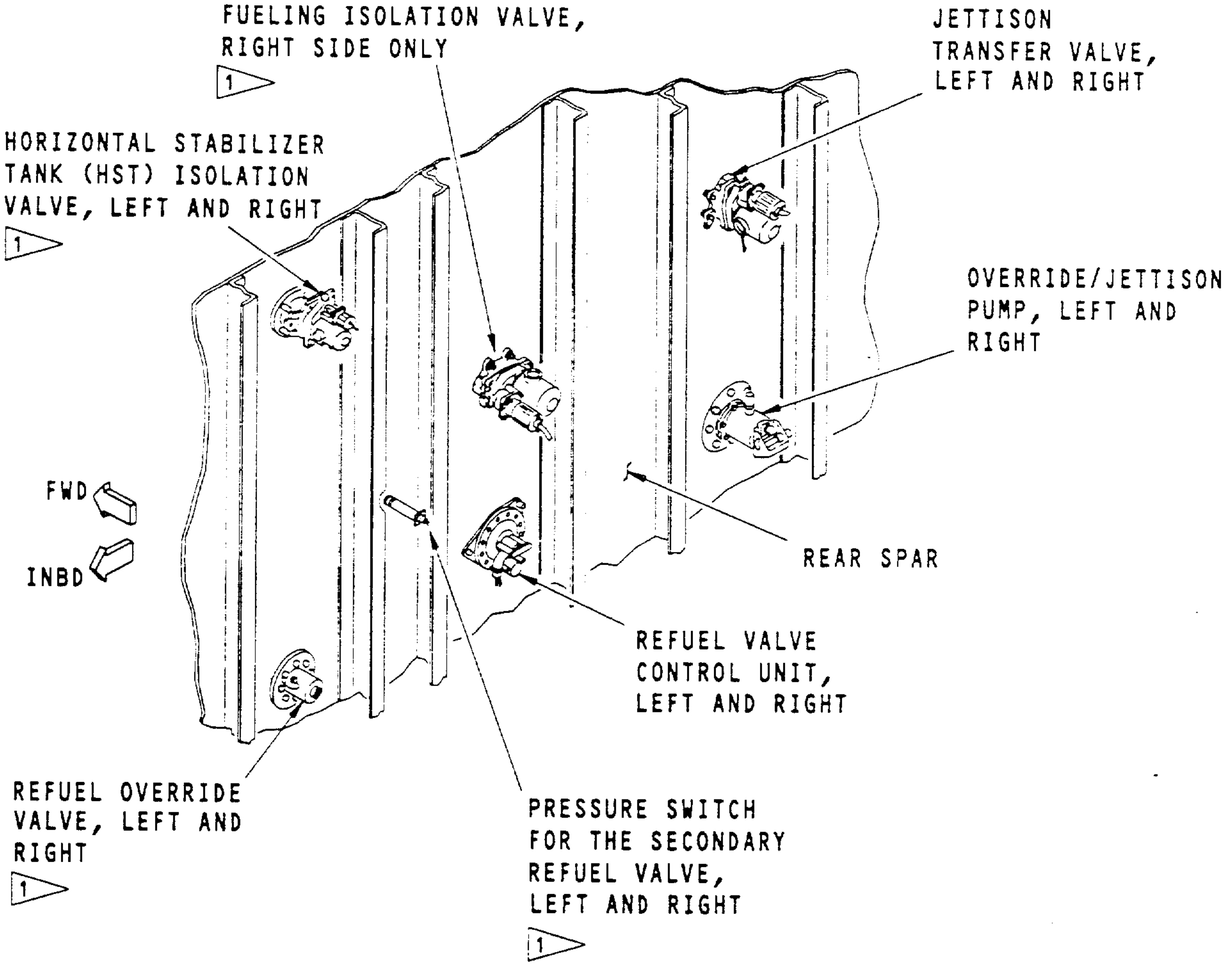
FIGURE 1. GENERAL INFORMATION AND COMPONENT LOCATION

SYSTEMS FACTUAL
ATM 28-00-00



Ⓐ

1 ▷ IF INSTALLED

CENTER WING TANK COMPONENTS
(DRY SIDE)
(RIGHT SIDE SHOWN, LEFT SIDE SIMILAR)

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FIGURE 1. GENERAL INFORMATION AND COMPONENT LOCATION

SYSTEMS FACTUAL
ATA 28-00-00

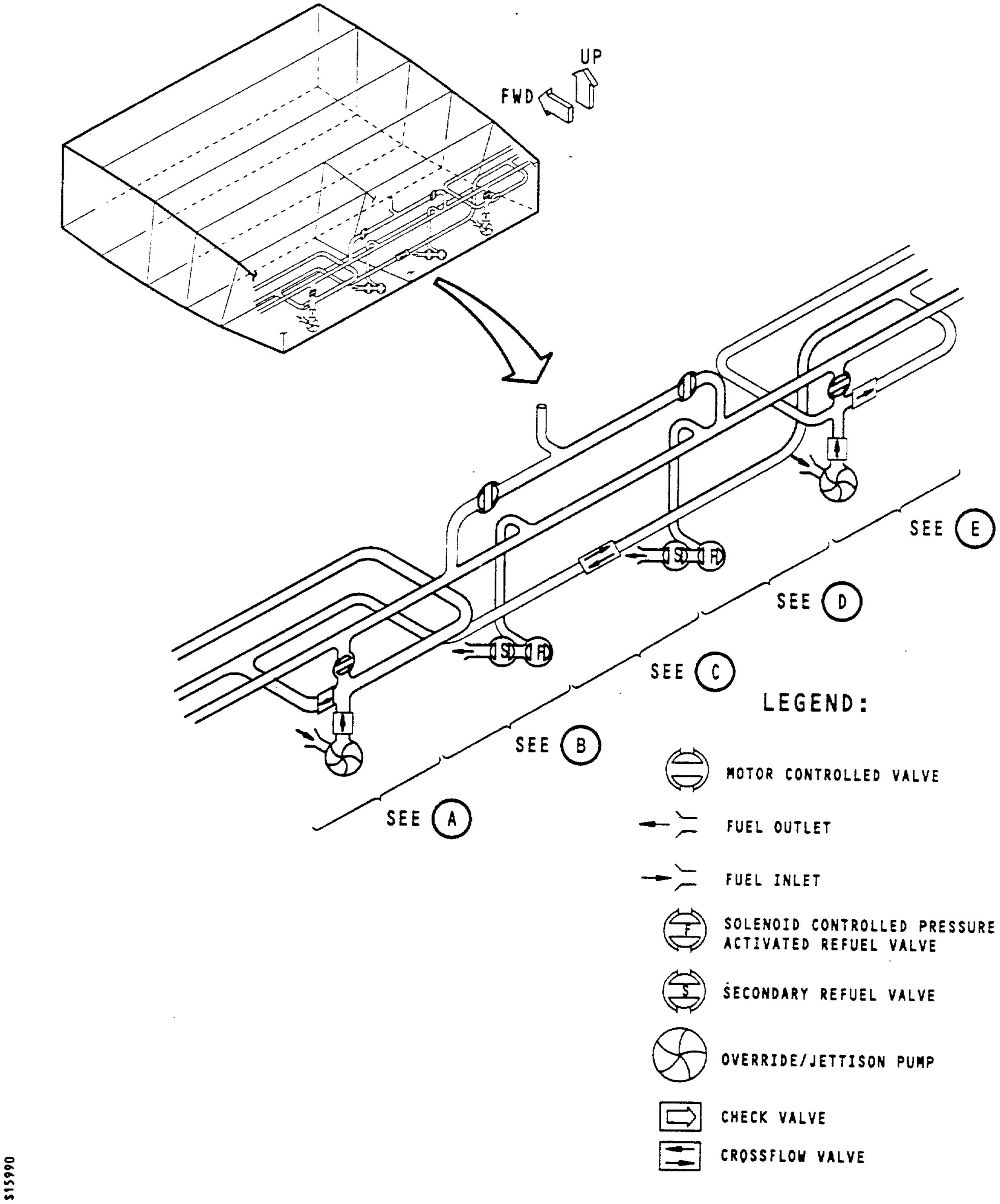

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FIGURE 2. FUEL SYSTEM PRESSURE MANIFOLDS AND COMPONENTS

ATA 28-00-00

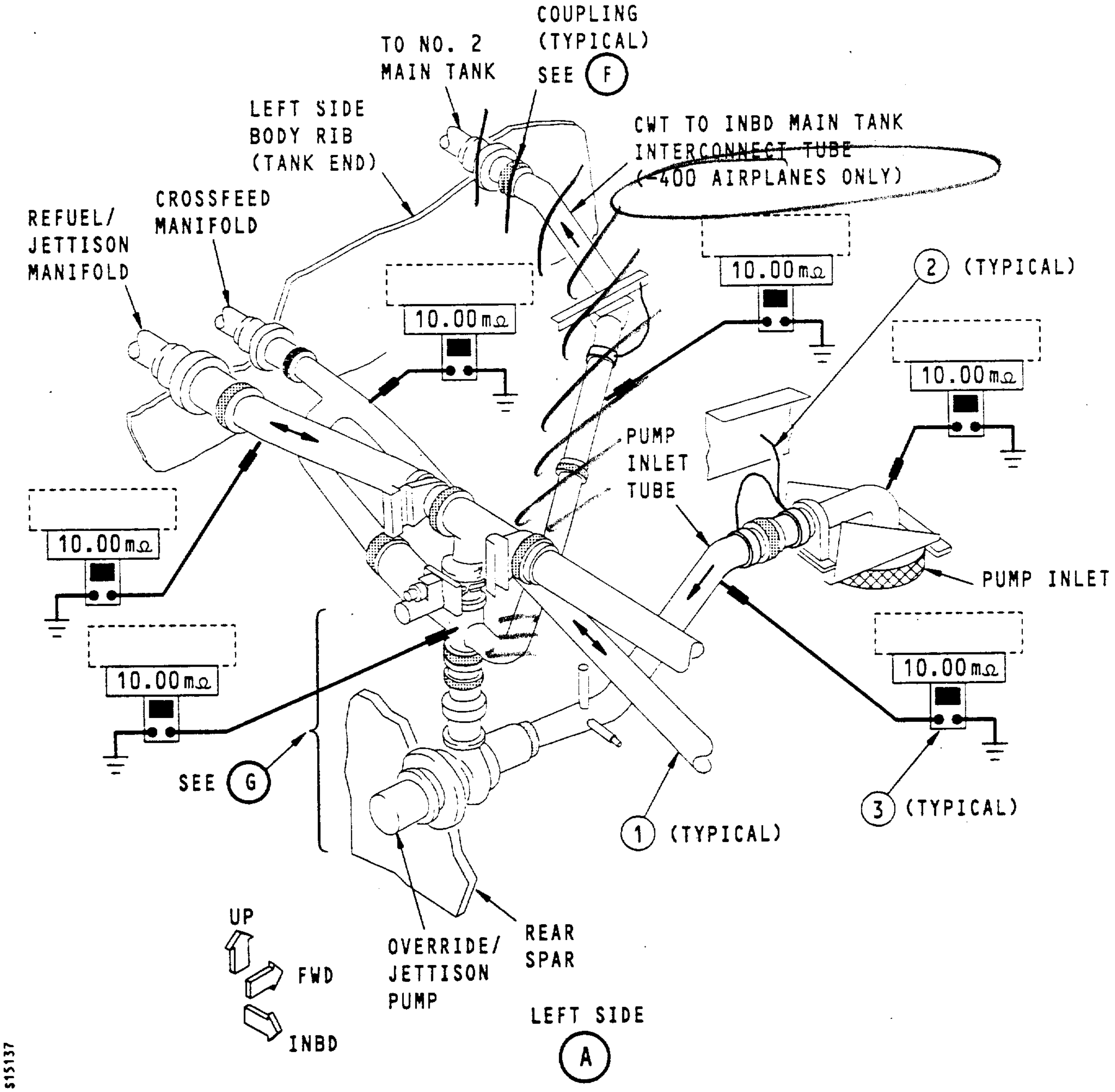

FIGURE 2. FUEL SYSTEM PRESSURE MANIFOLDS AND COMPONENTS

SYSTEMS ENG [illegible]
ATA 28-00-00

The step numbers shown below agree with the numbers shown in the circle symbols in the figure.

STEP	TASK	NAME	PROCEDURE	REFERENCES	NOTES
1	Examine	Tubing		AMM 28-22-07/401	For installation security and/or condition.
2	Examine	Bonding Jumpers		BSWPM 20-20-00	
3	Measure Electrical Bonding	(see bonding meter symbol)		BSWPM 20-20-00	Measure and record the bonding resistance of the components shown.
4	Examine	Override/Jettison Pumps L and R			
5	Examine	Override/Jettison Pumps (L and R) Bonding Jumpers			See ground build-up detail.
6	Examine	Jettison Transfer Valve L and R			
7	Examine	Refuel Valve L and R			
8	Examine	Flow Limiting Valve			
9	Examine	Forward HST Isolation Valve L and R			On airplanes with HST
10	Examine	Fueling Isolation Valve			On airplanes with Fueling Isolation Valve only

FIGURE 2. FUEL SYSTEM PRESSURE MANIFOLDS AND COMPONENTS

ATA 28-00 00

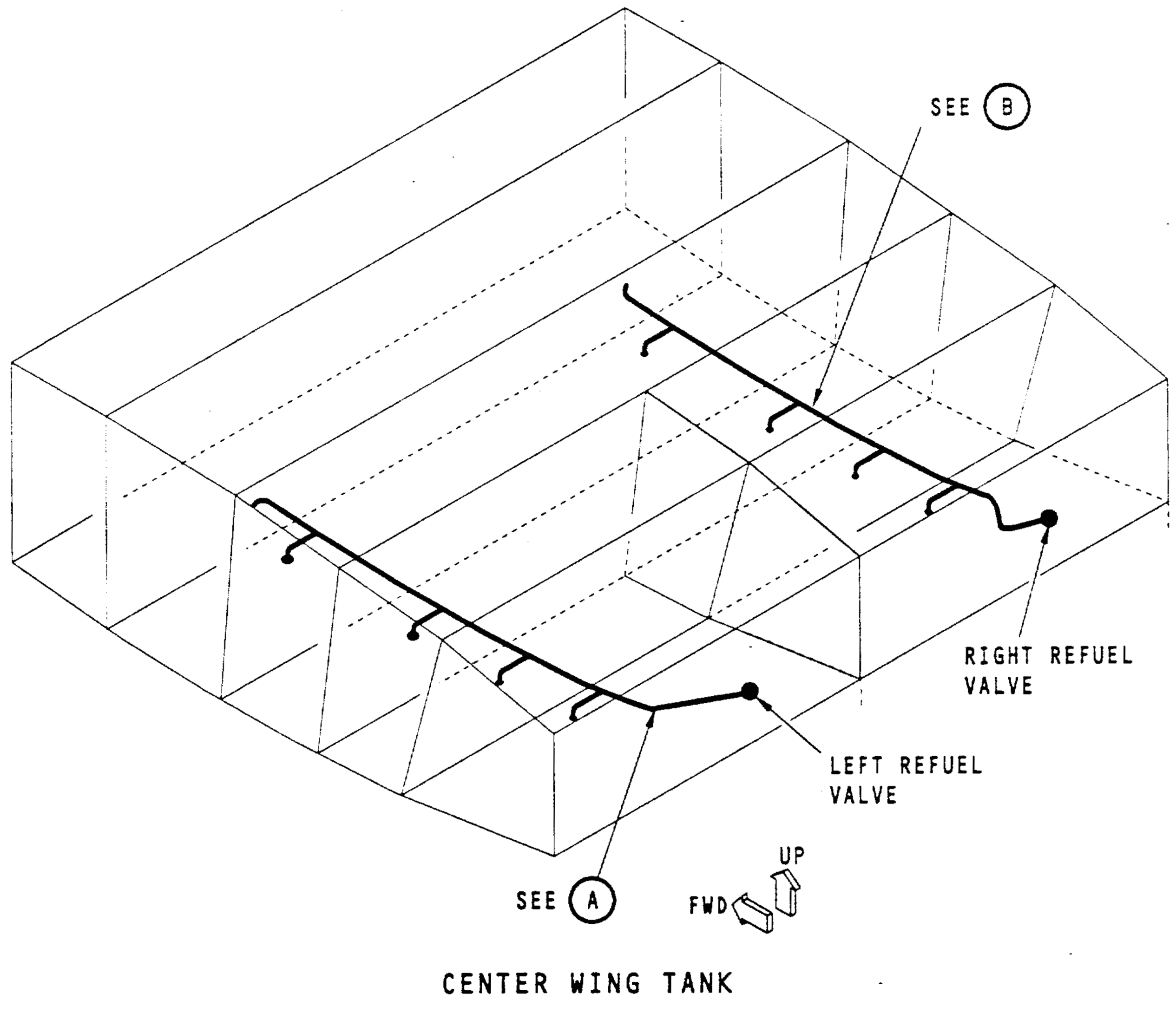

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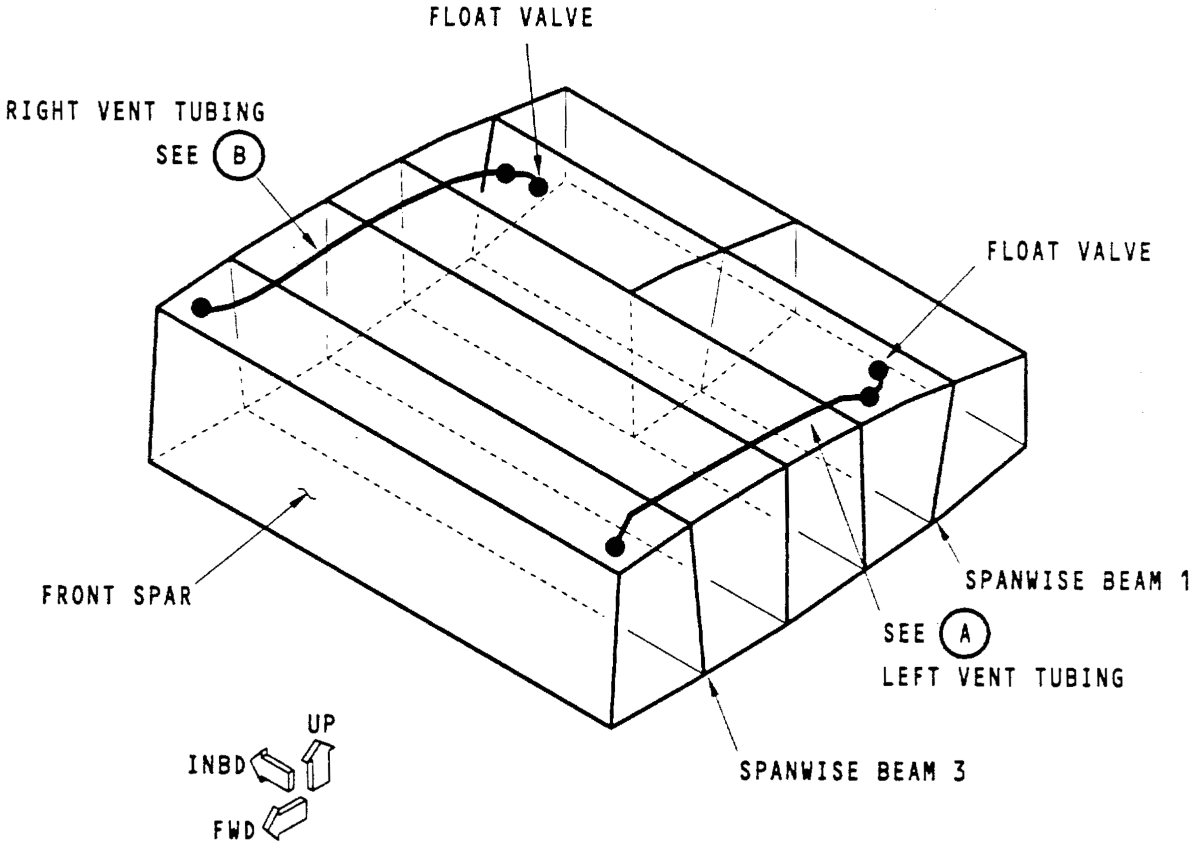
FIGURE 3. REFUEL DISTRIBUTION MANIFOLDS

SYSTEMS FACTUAL
ATM 28 00 00

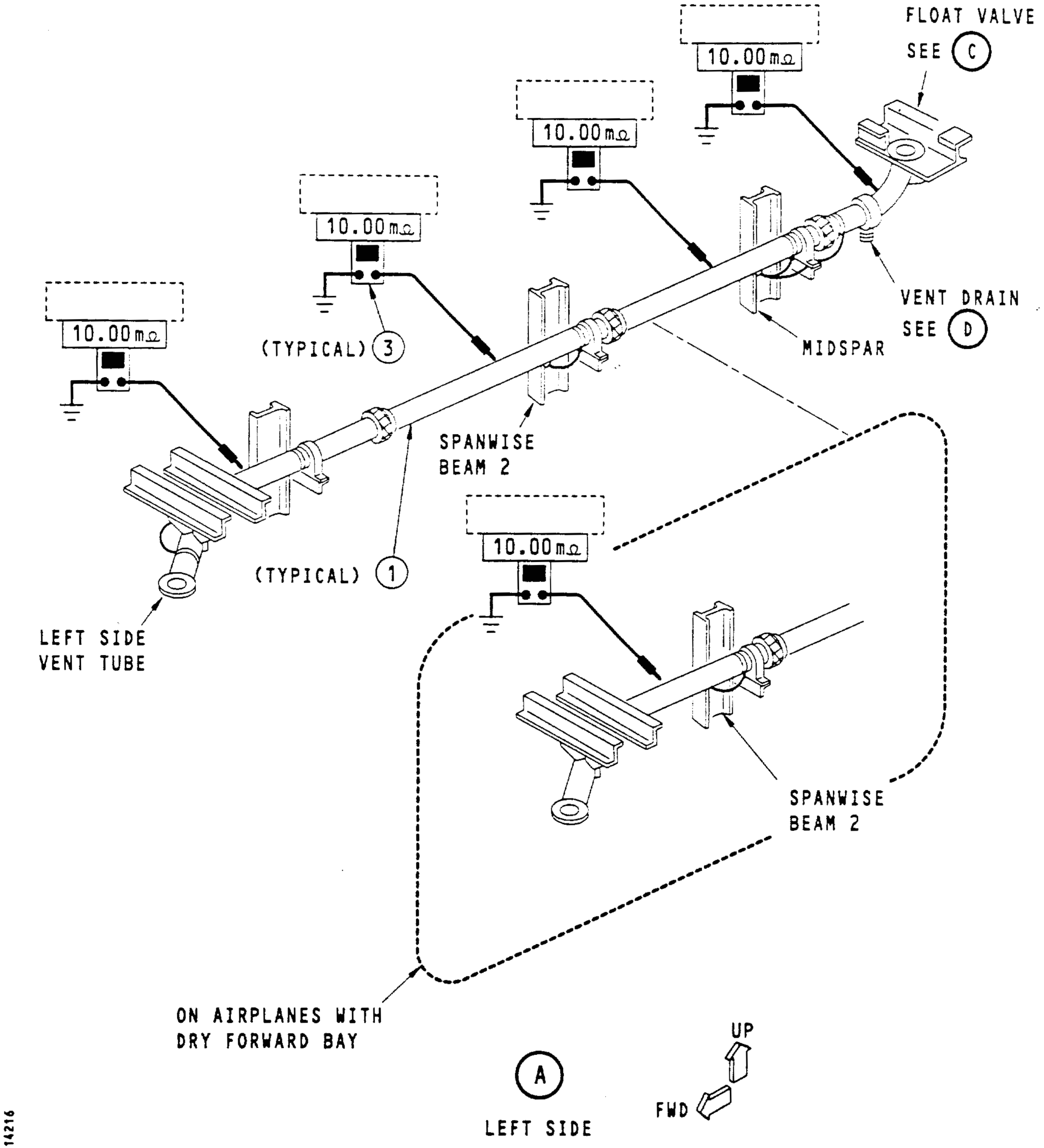


S16736

CENTER WING TANK

FIGURE 5. VENT SYSTEM - TUBING AND COMPONENTS

SYSTEMS [illegible]
AM 28-00-00

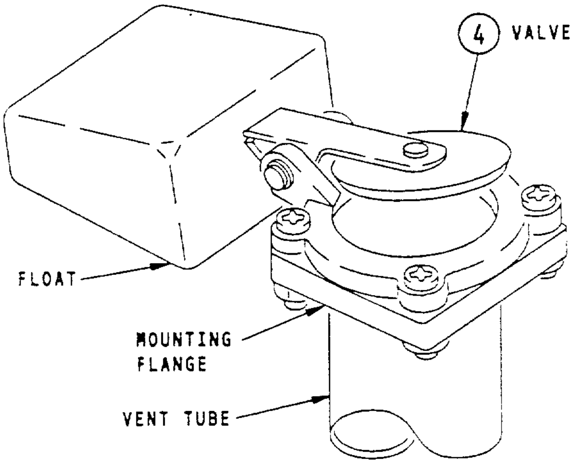


000088

FIGURE 5. VENT SYSTEM - TUBING AND COMPONENTS

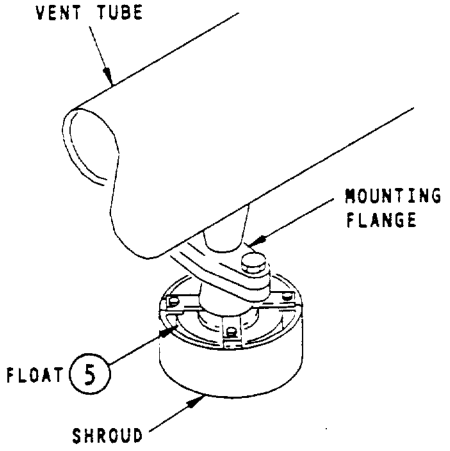
SHEET 2 OF 5

ATA 28-00-00



C

FUEL VENT FLOAT VALVE



D

FUEL VENT DRAIN VALVE

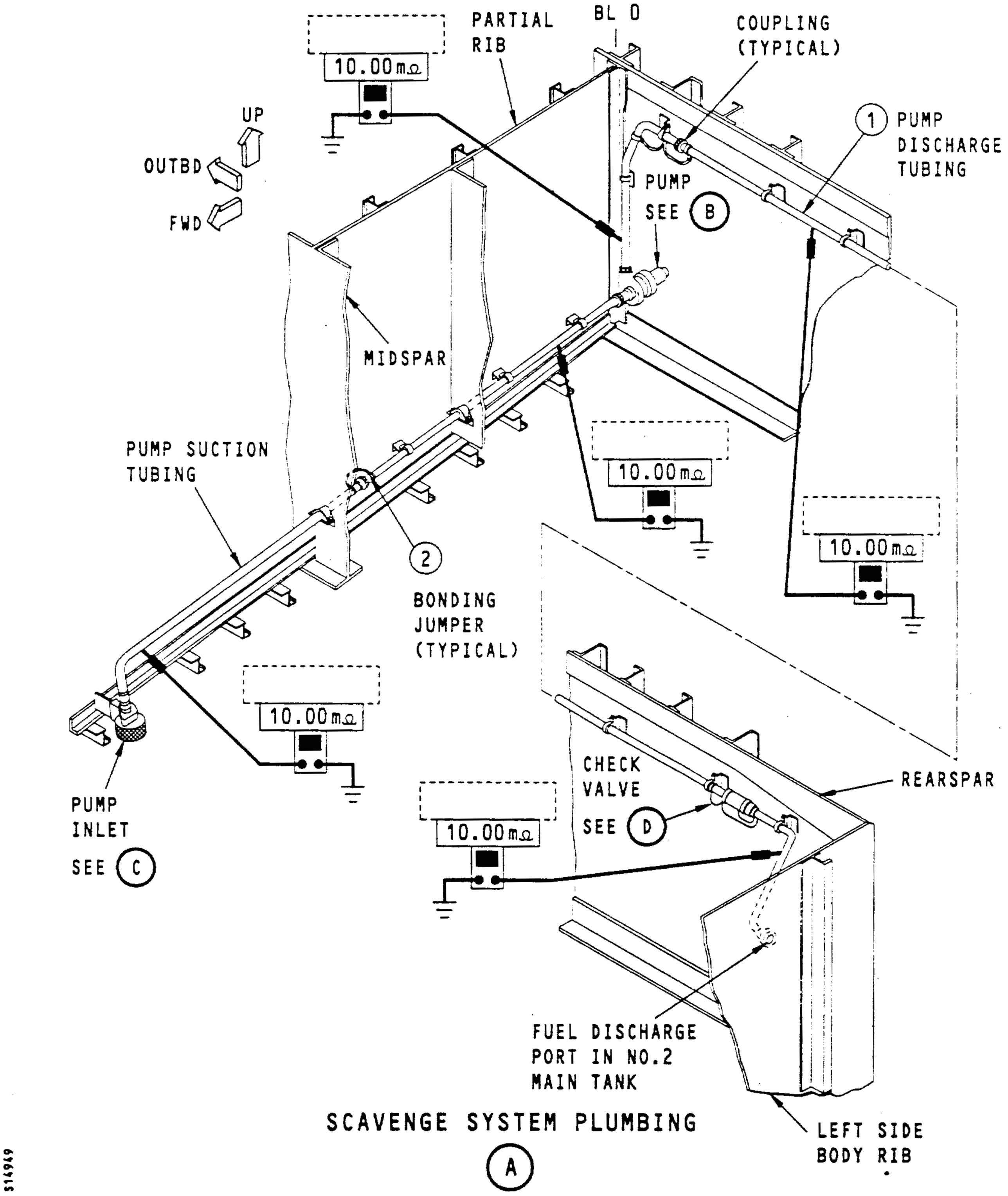
S16590

FIGURE 5. VENT SYSTEM - TUBING AND COMPONENTS

000089

SHEET 4 OF 5

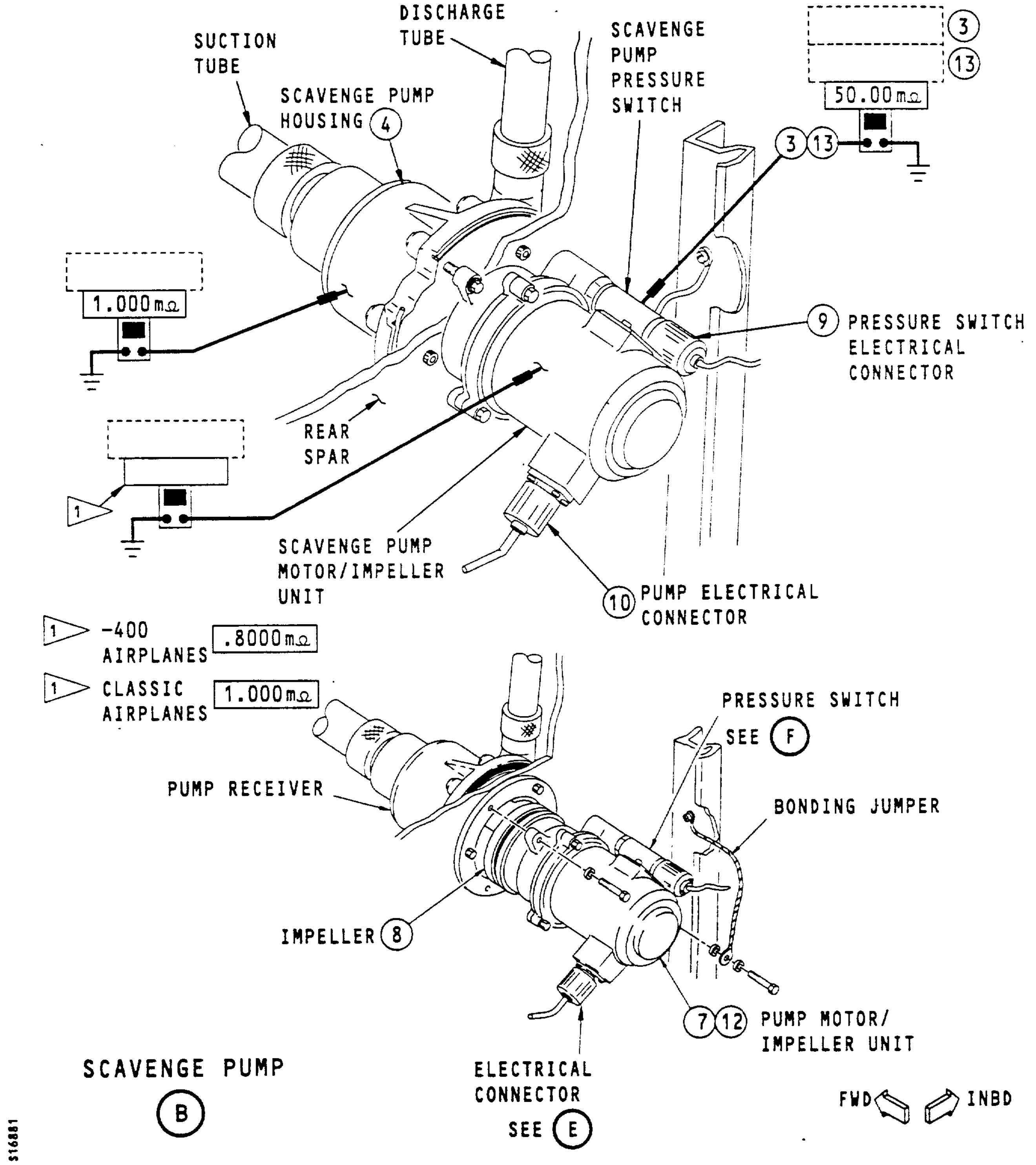
ATA 28-00-00



000090

FIGURE 6. SCAVENGE SYSTEM - ELECTRICAL PUMP

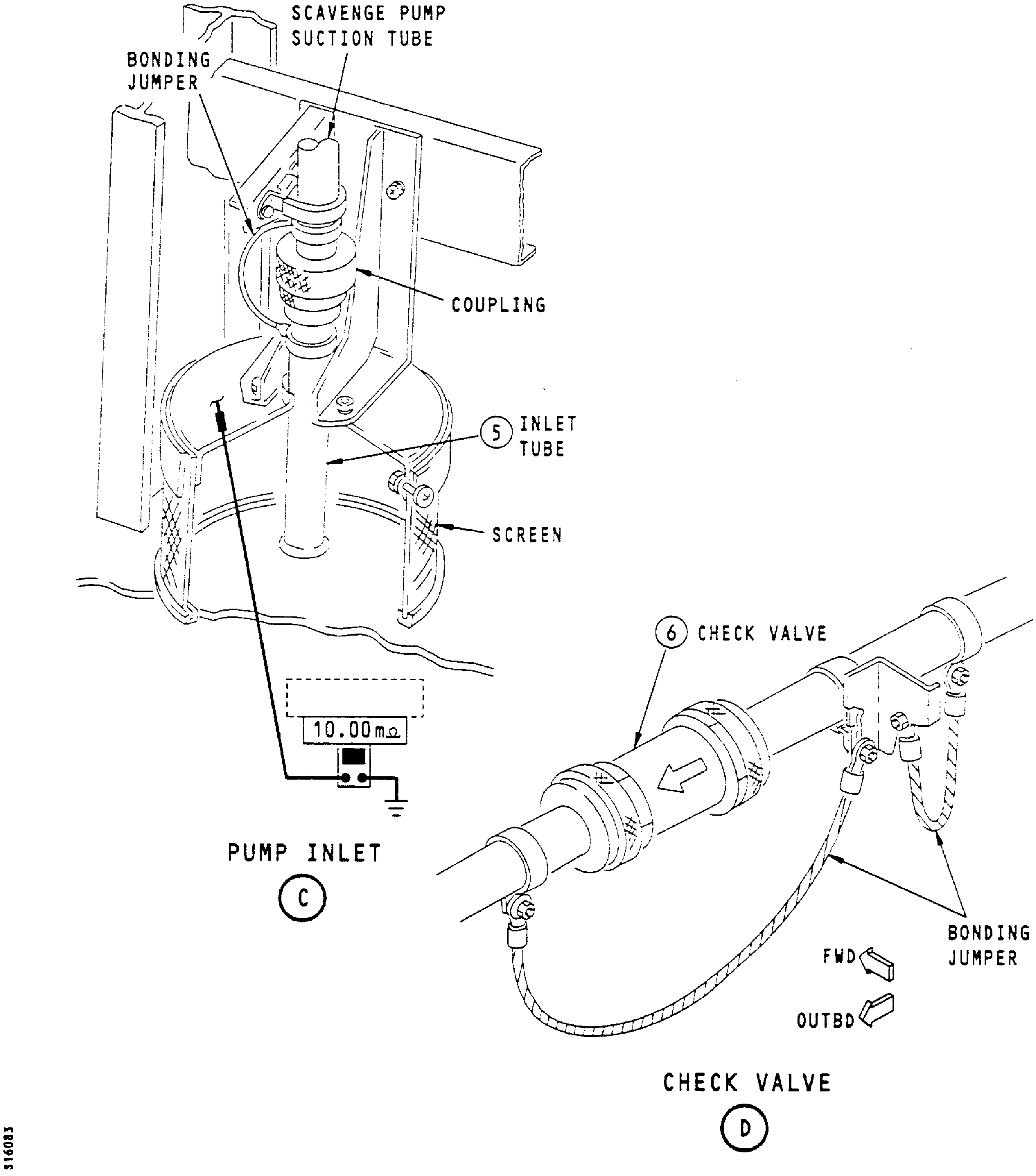
28-00-00



000091

FIGURE 6. SCAVENGE SYSTEM - ELECTRICAL PUMP

ATA 28-00-00



PUMP INLET
C

CHECK VALVE
D

FIGURE 6. SCAVENGE SYSTEM - ELECTRICAL PUMP

SHEET 4 OF 7

The step numbers shown below agree with the numbers shown in the circle symbols in the figure.

STEP	TASK	NAME	PROCEDURE	REFERENCES	NOTES
1	Examine	Tubing		AMM 28-22-07/401	For installation security and/or condition.
2	Examine	Bonding Jumpers		BSWPM 20-20-00	
3	Measure Electrical Bonding	(see bonding meter symbol)		BSWPM 20-20-00	Measure and record the bonding resistance of the components shown.
4	Examine	Pump housing			
5	Examine	Inlet Screen			
6	Examine	Check Valve			
7	Remove	Pump	See Accomplishment Instructions	AMM 28-15-01/401	
8	Examine	Pump			
9	Measure	Pressure Switch Connector			
10	Measure	Pump Connector			
11	Measure	Shipside Connector			
12	Install	Pump		AMM 28-15-01/401	
13	Measure	Pressure Switch		BSWPM 20-20-00	After installation, measure and record.

FIGURE 6. SCAVENGE SYSTEM - ELECTRICAL PUMP

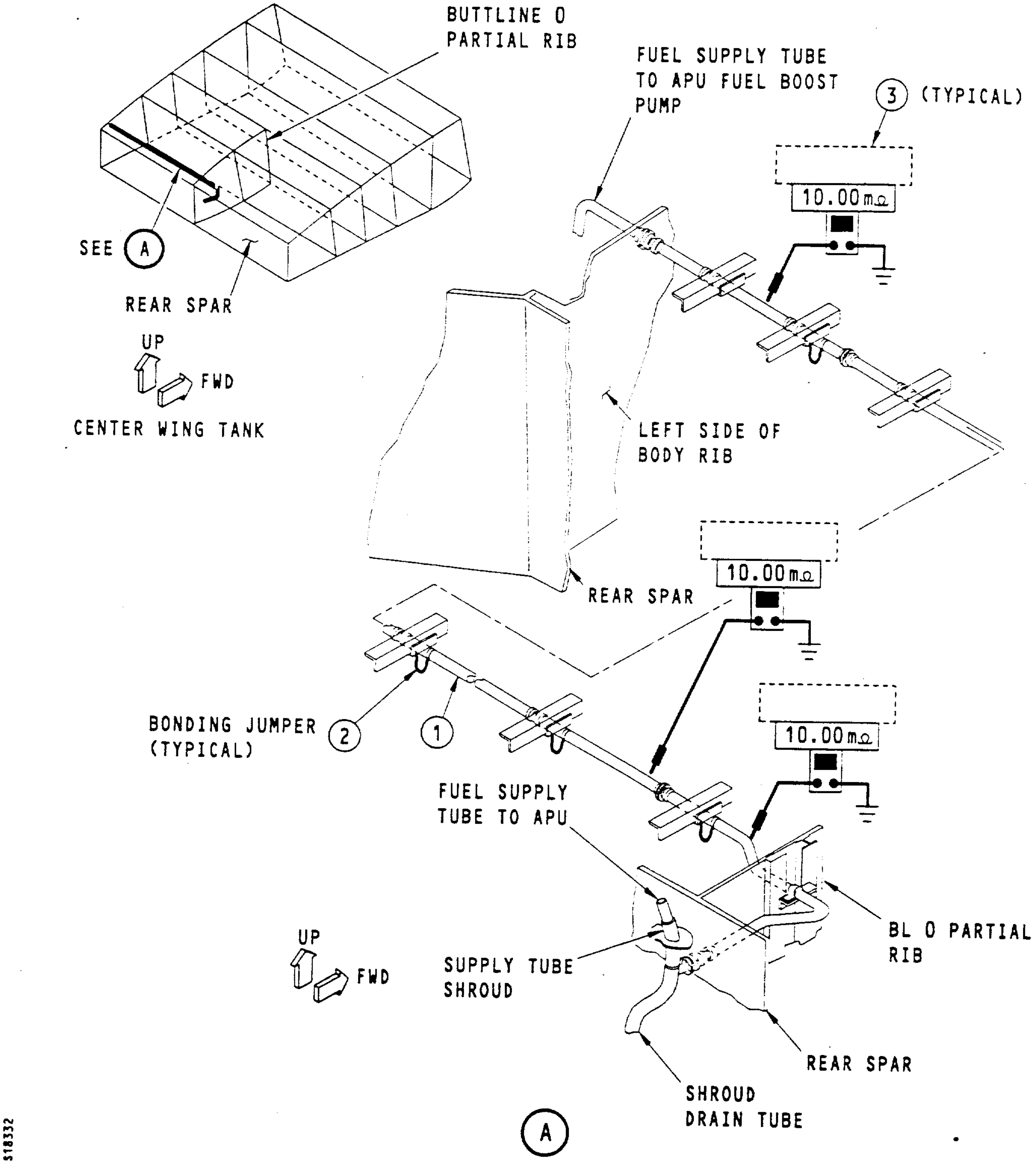
ATA 28-00-00

The step numbers shown below agree with the numbers shown in the circle symbols in the figure.

STEP	TASK	NAME	PROCEDURE	REFERENCES	NOTES
1	Examine	Tubing		AMM 28-22-07/401	For installation security and/or condition.
2	Examine	Bonding Jumpers		BSWPM 20-20-00	
3	Measure Electrical Bonding	(see bonding meter symbol)		BSWPM 20-20-00	Measure and record the bonding resistance of the components shown.
4	Examine	Check Valve			

FIGURE 8. OVERRIDE/JETTISON PUMP PRIMING TUBING

ATA 28-00-00



000095

FIGURE 9. APU FUEL SUPPLY TUBE

SHEET 1 OF 2

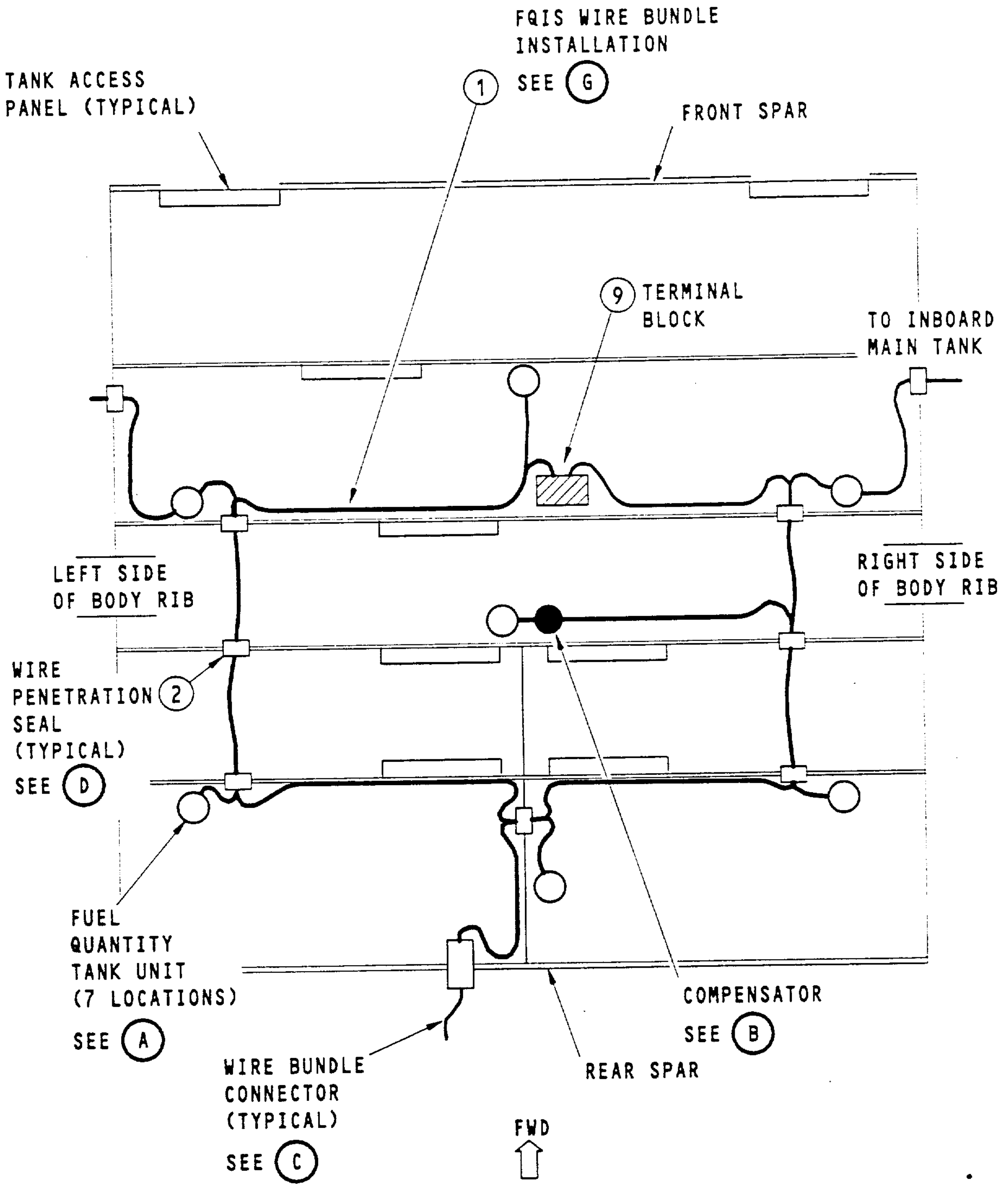
[illegible]

ATA 28-00-00

The step numbers shown below agree with the numbers shown in the circle symbols in the figure.

STEP	TASK	NAME	PROCEDURE	REFERENCES	NOTES
1	Examine	Bonding Jumpers		BSWPM 20-20-00	
2	Measure Electrical Bonding	(see bonding meter symbol)		BSWPM 20-20-00	Measure and record the bonding resistance of the pump.
3	Remove	Pump	See Accomplishment Instructions	AMM 28-25-01/401	
4	Examine	Pump			
5	Measure	Pressure Switch Connector			
6	Measure	Pump Connector			
7	Measure	Shipside Connector			
8	Install	Pump		AMM 28-25-01/401	
9	Measure	Pressure Switch		BSWPM 20-20-00	After installation, measure and record.

FIGURE 10. APU FUEL BOOST PUMP



CENTER WING TANK (ALL EXCEPT -400)

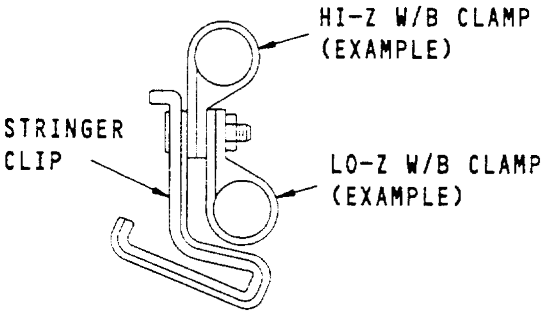
S16662

000097

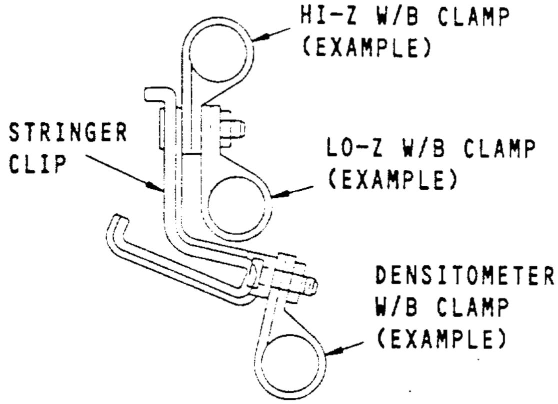
FIGURE 11. FUEL QUANTITY INDICATING SYSTEM COMPONENTS

SHEET 1 OF 7

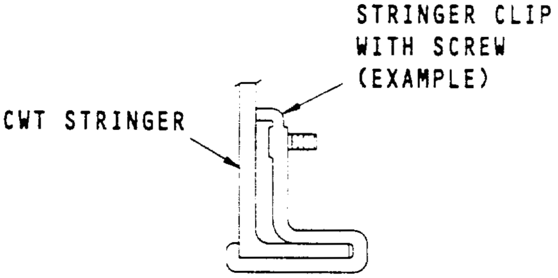
ATA 28-00-00



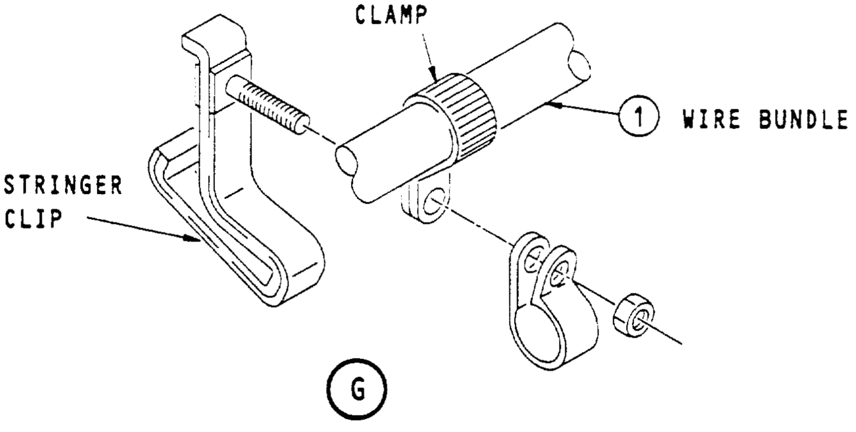
SINGLE STRINGER CLIP WITH CLAMPS



DOUBLE STRINGER CLIP WITH CLAMPS



STRINGER CLIP INSTALLED ON STRINGER



CLAMPS INSTALLATION (EXAMPLE)
FQIS WIRE BUNDLE CLAMPS

S16747

FIGURE 11. FUEL QUANTITY INDICATING SYSTEM COMPONENTS

000098

ATA 28-00

The step numbers shown below agree with the numbers shown in the circle symbols in the figure.

STEP	TASK	NAME	PROCEDURE	REFERENCES	NOTES
1	Examine	Wiring			For: satisfactory installation, connector corrosion
2	Examine	Grommets and Seals (where the wires penetrate the structure)			For: physical degradation or damage
3	Measure Electrical Bonding	(see bonding meter symbol)		BSWPM 20-20-00	Measure and record the bonding resistance of the components shown.
4	Examine	Tank units		AMM 28-41-01/401 28-41-03/401	For: correct clearance minimums between the units and tank structure
5	Examine	Compensator			
6	Examine	Electrical connectors On the rear spar.			For: Fuel leakage
7	Examine	Densitometer			
8	Examine	Single Point Sensors			
9	Examine	Terminal Block			

FIGURE 11. FUEL QUANTITY INDICATING SYSTEM COMPONENTS

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

SYSTEMS FACTUAL
ATA 28-00-00

October 30, 1997
B-B600-16281-ASI

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

Subject: Center Wing Tank Probe Inspection/Rework

Reference: a) Telecon Boeing/NTSB on Oct 28, 1997
b) Telex M-7220-97-1725, dated Oct 27, 1997

Dear Mr. Swaim:

Here is a summary of the items noted during the reference a) telecon in regards to the upcoming Service Bulletin on Probe/Wiring inspections and items that the NTSB noted were important to include.

Summary of 747 Center Wing Tank Probe Inspection/Rework

Boeing is in the process of issuing a Service Bulletin pertaining to the Fuel Quantity Probes and wiring in the 747 Center Wing Tank. Damage to the CWT wiring has been observed which degrades the insulating capabilities of the wiring.

The Service Bulletin, discussed in the reference b) telex, will contain the following instructions:

A procedure to remove/replace/rework probes with Series 3 terminal blocks and wiring attached to those probes

- For R0001-R0058, R0501-R0506 recommend replacement of center tank wire harness. These airplanes have been identified as delivered with probes that had Series 3 terminal blocks.
- For all airplanes, if the fuel quantity probe has a Series 3 terminal block, replace probe with a probe that has a Series 4

SYSTEMS MANUAL
ATA 28-00-00

terminal block <u>and</u> reterminate wires to affected probe or replace Center Tank FQIS Wire Harness
- Utilize maintenance manual and ATA 20 instructions for probe/wiring replacement/rework.

Inspection of probe terminal blocks for correct wire routing/wire damage:

BOEING

- Inspect probe terminal block wiring to ensure conformance to drawing.
- If wiring has been misrouted, inspect for damage (abrasion against terminal block edges or terminal studs).
- Reterminate wiring to terminal block if wire is damaged.
- Reroute wiring to terminal block if not per drawing.
- Utilize maintenance manual and ATA 20 instructions for probe/wiring replacement/rework.

Includes a test procedure to perform an insulation resistance test of the Center Wing Tank wiring. This test can be performed without entering the tank:

- Conduct a low voltage insulation resistance test of the in-tank FQIS wiring utilizing approved explosion proof equipment.
- If this test fails, troubleshoot the failure per the approved MM procedures.

Estimated release date for this Service Bulletin is January 1998.

<u>NTSB Telecon Notes</u>

In a follow-on telecon with the NTSB, the following NTSB recommendations were noted and will be included in the Service Bulletin:

1) In regards to the retermination of the wire - a strong statement needs to be made in the SB that "<u>only</u> those repair procedures relating to the repair of ATA 28 in-tank FQIS wire may be utilized and that wire repair procedures for other wire in the airplane are <u>not</u> to be used." The NTSB wants both the positive statement on ATA 28 wire repair and the negative statement regarding other wire repair procedures. This is due to a repair that was found where tape was used to secure the shield on an FQIS in-tank wire bundle. The procedure used to repair this wire was not approved for use in fuel tanks.

SYSTEMS [illegible]
ATA 28 00 00

2) Include reporting requirements on the findings of the probe replacement and repair. The NTSB specifically requested that we try to get removed harnesses and probe wire terminations. They also requested that we add a request to report the results of the insulation resistance test - the pass/fail values and what was done to fix the airplane.

3) The NTSB also asked that we include data collection on any problems and rework required for Series 4 terminal block probes.

If you have any further questions, please do not hesitate to contact me at any time.

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

CC Mr. Al Dickinson, IIC

SYSTEMS FACTUAL
ATA 28-00-00

From: Rodrigues, J D[SMTP:J.Rodrigues@PSS.Boeing.com]
Sent: Tuesday, October 28, 1997 3:21 PM
To: Swaim Bob
Subject: FW: M-7240-97-1725 (BC2-EXT-COMM-4618782)

> ----------
> From: Hulm, Jerome R
> Sent: Tuesday, October 28, 1997 11:53 AM
> To: Rodrigues, J D
> Subject: FW: M-7240-97-1725 (BC2-EXT-COMM-4618782)
>
> Here's the telex on the Probe Inspection that you wanted to forward to
> B. Swaim.
>
> Jerry Hulm
> Manager - Electrical Systems
> Phone: 425-294-4638 FAX: 425-342-4616
> Pager: 986-6031 Home Phone: 425-338-2496
> E-mail: jerome.r.hulm@boeing.com MS: 04-JU
>
> ----------
> From: esebc2.boecom@boeing.com[SMTP:esebc2.boecom@boeing.com]
> Sent: Monday, October 27, 1997 8:15 PM
> To: jerome.r.hulm@boeing.com
> Subject: M-7240-97-1725 (BC2-EXT-COMM-4618782)
>
> BOECOM DISTRIBUTION COPY
>
> MESSAGE NUMBER: M-7240-97-1725
>
> MESSAGE OWNER: ROD SOMERS - PRO STATUS: DUE 20 NOV 97
>
> DISTRIBUTION:
> J. HULM - EDV
>
> B. STAUFENBERG - EAD, B. VANNOY - EAD, D. HAWKINS - ELE,
> D. KALOTAY - FSA, I. FERGUSON - COR, J. BURK - EDV,
> J. HULM - EDV, K. HENSHAW - RAD, M. MAHESH - PRO,
> R. BREUHAUS - , R. CANNON - EVS, R. LIDICKER - EDV,
> R. PARKS - EDV, R. SOMERS - PRO, S. HATCH - EDV,
> T. DUNNIGAN - EDV, T. LANNERD - RDV
>
> MULTIPLE EXTERNAL DISTRIBUTION
>
> SUBJECT: CENTER WING FUEL TANK INSPECTION UPDATE
>
> ____
>
> M-7240-97-1725 27 OCT 97
> ATA 2800-00 MODEL 747 20 NOV 97 H
> CENTER WING FUEL TANK INSPECTION UPDATE
> REF /A/ M-7240-97-1649

Systems [illegible]
ATA 28-00 00

> /B/ BOEING SERVICE BULLETIN NUMBER 747-28-2205, RELEASED
> 27 JUNE 1997
> /C/ M-7240-97-1242
>
>
> THE FOLLOWING MESSAGE SENT TO ALL 747 FIELD SERVICE BASES FOR DISTRIBUTION TO THE APPROPRIATE AIRLINE PERSONNEL. A COPY IS PROVIDED TO BOEING REGIONAL DIRECTORS, THE AIR TRANSPORT ASSOCIATION, INTERNATIONAL AIR TRANSPORT ASSOCIATION AND AIRLINE RESIDENT REPRESENTATIVES IN EVERETT AND RENTON.
>
> ---
> SUMMARY
> THE INTENT OF THIS MESSAGE IS TO ADVISE OPERATORS OF UPCOMING ADDITIONAL SERVICE BULLETIN ACTIVITY FOR THE CENTER WING TANK ON 747 AND 747-400 AIRPLANES.
> ---
>
> THE REF /B/ SERVICE BULLETIN WAS RELEASED IN JUN 97 TO INSPECT THE CENTER WING TANK FUEL SYSTEM. REF /A/ PROVIDED A SUMMARY OF INSPECTION RESULTS RECEIVED TO DATE. REF /B/ AFFECTS APPROXIMATELY 1125 AIRPLANES AT 90 OPERATORS. REF /C/ REQUESTED OPERATORS PROVIDE THEIR SCHEDULES FOR PERFORMING REF /B/. WE HAVE RECEIVED SCHEDULES FOR 354 AIRPLANES FROM 29 OPERATORS TO DATE.
>
> BASED ON OUR ONGOING INVESTIGATION OF THE FUEL SYSTEM AND REF /B/ INSPECTION RESULTS, BOEING IS PLANNING TO ISSUE ADDITIONAL SERVICE BULLETINS PERTAINING TO THE CENTER WING TANK. DAMAGE TO THE FQIS CENTER IN-TANK WIRING HAS BEEN OBSERVED WHICH MAY DEGRADE THE INSULATING CAPABILITY OF THE WIRING. ADDITIONALLY, BOEING IS EVALUATING BONDING REQUIREMENTS FOR SPECIFIC COMPONENTS IN THE CENTER WING TANK.
>
> THE NEW SERVICE BULLETINS WILL REQUIRE REWORK AND/OR REPLACEMENT OF DESIGNATED FQIS PROBES AND WIRING AND MAY INCLUDE ADDITIONAL BONDING REQUIREMENTS FOR SOME COMPONENTS INSIDE THE TANK. BOEING'S PHILOSOPHY ON RELEASING SEPARATE SERVICE BULLETINS IS TO KEEP REF /B/ AS STRICTLY AN INSPECTION SERVICE BULLETIN. ANY MODIFICATIONS OR REWORK RELATED TO THE CENTER WING TANK WILL BE RELEASED VIA SEPARATE SERVICE BULLETINS.
>
> WE ARE PLANNING TO RELEASE A NEW SERVICE BULLETIN TO REPLACE ALL P/N 60B92010-XX /SERIES 3 OR EARLIER/ FQIS PROBES WITH /SERIES 4 OR LATER/ PROBES IN THE CENTER WING TANK AND REPLACE OR RETERMINATE THE WIRING TO THESE PROBES ON ALL 747 CLASSIC AIRPLANES. THE /SERIES 3 OR EARLIER/ PROBE INCORPORATES KNURLING ON THE PROBE TERMINAL BLOCK ALONG WITH A COMPRESSION STYLE METAL CLAMP TO RESTRAIN THE WIRE HARNESS. DAMAGE TO THE FQIS CENTER IN-TANK WIRING HAS BEEN OBSERVED DUE TO CONTACT WITH THE PROBE BASE ON THE /SERIES 3 OR EARLIER/ PROBE CONFIGURATION. THE FIRST 64 747 AIRPLANES (LINE POSITIONS 1 - 64) WERE DELIVERED WITH PROBES WITH SERIES 3 OR EARLIER TERMINAL BLOCKS. HOWEVER, DUE TO INTERCHANGEABILITY, THESE PROBES COULD BE INSTALLED ON ANY 747 CLASSIC AIRPLANE.
>
> ON AIRPLANE LINE POSITIONS 1 - 64, IN ADDITION TO REPLACEMENT OF THE PROBE, BOEING WILL RECOMMEND THAT THE ENTIRE WIRE HARNESS

SYSTEMS [illegible]
ATA 28-00-00

> ASSEMBLY P/N 60B40037-308 AND JUMPER P/N 61B40498-XX BE REPLACED.
> ON AIRPLANES AFTER LINE POSITION 64, REPLACEMENT OF THE PROBE
> WILL ONLY BE REQUIRED IF A /SERIES 3 OR EARLIER/ PROBE IS
> INSTALLED. THE OPERATOR WILL HAVE THE OPTION OF EITHER
> RETERMINATING THE WIRE TO THE AFFECTED PROBE(S) OR REPLACING THE
> WIRE HARNESS ASSEMBLY. THE SERVICE BULLETIN WILL PROVIDE
> INSTRUCTIONS TO REWORK THE /SERIES 3 OR EARLIER/ PROBE TO A
> /SERIES 4 OR LATER/ CONFIGURATION. NO 747-400 AIRPLANES ARE
> AFFECTED AS A DIFFERENT TANK PROBE DESIGN IS UTILIZED WHICH IS
> NOT INTERCHANGEABLE WITH THE 747 CLASSIC.
>
> IN ADDITION TO THE PROBE AND WIRING REWORK/REPLACEMENTS, AN
> INSULATION RESISTANCE CHECK WILL BE REQUIRED ON THE CENTER
> IN-TANK WIRING ON ALL 747 MODELS (INCLUDING 747-400 AIRPLANES
> ALTHOUGH THE AFFECTED LINE NUMBERS HAVE NOT YET BEEN DETERMINED).
> THE INSULATION RESISTANCE CHECK WILL BE PERFORMED PER AMM
> 28-41-01 AND AMM 28-41-02 FOR 747 MODELS WITH HONEYWELL SYSTEMS.
> PER AMM 28-41-01 FOR 747 MODELS WITH SMITHS SYSTEM, AND PER AMM
> 28-41-00 FOR 747-400 AIRPLANES. THIS CHECK WILL NOT REQUIRE TANK
> ENTRY UNLESS THE TEST FAILS. FAILURE OF THIS TEST WILL REQUIRE
> REPLACEMENT OF THE FAILED PART, THE CENTER WING TANK HARNESS OR
> THE PROBE IF IT CAN BE IDENTIFIED.
>
> WE ARE ANTICIPATING RELEASE OF THIS SERVICE BULLETIN BEFORE THE
> END OF THE YEAR IF SUFFICIENT PARTS ARE AVAILABLE. WE ARE
> REVIEWING THE PARTS AVAILABILITY WITH OUR VENDORS AND WILL
> PROVIDE AN UPDATE BY 20 NOV 97. THE FAA HAS INDICATED THEY MAY
> TAKE REGULATORY ACTION ON THIS ISSUE.
>
> BOEING HAS NOT YET MADE A DECISION REGARDING FQIS PROBES AND
> ASSOCIATED WIRING WITH /SERIES 3 AND EARLIER/ CONFIGURATION IN
> THE MAIN TANKS. WE WILL KEEP OPERATORS APPRAISED ON THIS ISSUE
> IN FUTURE UPDATES.
>
> A SECOND NEW SERVICE BULLETIN MAY BE REQUIRED TO PROVIDE
> ADDITIONAL OR REVISED BONDING OF SOME COMPONENTS IN THE CWT.
> BOEING IS STILL EVALUATING THE FULL SCOPE OF THIS CHANGE. WE ARE
> ANTICIPATING RELEASE OF THIS SERVICE BULLETIN DURING THE 1ST
> QUARTER OF 1998 IF REQUIRED.
>
> BOEING ACKNOWLEDGES THAT THESE FORTHCOMING SERVICE BULLETINS WILL
> REQUIRE ANOTHER CENTER WING TANK ENTRY ON SOME AIRPLANES TO
> ACCOMPLISH. WE ARE CONTINUING TO WORK WITH THE INDUSTRY TO
> MINIMIZE THE IMPACT OF MULTIPLE TANK ENTRIES. WE CONTINUE TO
> ENCOURAGE INSPECTIONS PER REF /B/ SERVICE BULLETIN WHERE THE
> CENTER TANK IS ALREADY ACCESSED DURING NORMAL MAINTENANCE.
>
> IN ADDITION, A REVISION TO REF /B/ IS PLANNED FOR DEC 97. THIS
> REVISION WILL INCORPORATE THE CLARIFICATIONS AS OUTLINED IN NSC
> 01 DATED 25 SEP 97. THE REVISION WILL NOT INCLUDE ANY ADDITIONAL
> INSPECTIONS OR REWORK INSTRUCTIONS.
>
> WE WILL PROVIDE A FOLLOW UP TO ADVISE STATUS OF THE UPCOMING
> SERVICE BULLETINS BY 20 NOV 97.
>
>
> BILL STAUFENBERG
> 747/767/777 AIRLINE SUPPORT MANAGER

SYSTEMS MANUAL
ATA 28-00 00

> SERVICE ENGINEERING
> CUSTOMER SERVICES
> BOEING M-7250 04-ER MRZ
>
>
> 27 OCT 97 2015
>
>
> BOECOMII-FSE-ID-5020285-EMAIL
>
>

ATA 28-11-21

ENGINES P&W Model JT9D-3A

ENGINE THRUST

Takeoff and maximum continuous thrust EPR are presented on the appropriate engine thrust setting charts in Section 4.

ENGINE RPM

The maximum operational limits are;

N1 - Low Pressure Compressor Rotor 101.4%
N2 - High Pressure Compressor Rotor 100.6%

ENGINE EGT

Operating Condition	Temperature Limits	Time Limit
Takeoff (Wet)	846 deg C	2-1/2 Minutes (Plus Dry to 5 Minutes Total)
Takeoff (Dry)	846 deg C	5 Minutes
Maximum Continuous	816 deg C	Continuous
Starting	650 deg C	
Acceleration	846 deg C	

ENGINE INSTRUMENT MARKINGS

Maximum and minimum limits............Red radial/band
Cautionary limits.....................Yellow arc/band
Normal operating range................Green arc/band

ENGINE FUEL SYSTEM

The fuel designation is in Pratt & Whitney Service Bulletin 2016, as revised. Anti-icing fuel additive PFA 55MB at a concentration not to exceed 0.15% by volume may be used. No fuel system anti-icing credit is allowed.

Ref. → RLS

The maximum tank fuel temperature is 54.5 deg C (130 deg F), except JP-4 which is 43 deg C (110 deg F).

Inflight tank fuel temperature must be maintained at least 3 deg C above the freezing point of the fuel being used.

ENGINE IGNITION

ON for all approaches and landings. ON while operating in heavy rain, severe turbulence or volcanic dust; or upon entering icing conditions; or when standing water or slush exists on the runway. ON* for all operations when the throttle bar is in the high altitude thrust lever idle stop position.

* Ignition ON is not required if Boeing Service Bulletin 74-2003, or equivalent, is incorporated.

Delta Airlines checks
conducted upon NTSB
request. R Swain

SYSTEMS FACTUAL
ATA 28-11-00

January 27, 1997

Mr. Robert Swain
National Transportation
Safety Board

Dear Bob,

The following resistance and capacitance readings were taken from three aircraft that utilize wiggins fittings fuel couplings per the NTSB sketch provided.

A/C	Resistance	Capacitance	Comments
B-727	> 1 Megaohm	275 pf	
	> 1 Megaohm	525 pf	
	> 1 Megaohm	650 pf	
	> 1 Megaohm	270 pf	
	> 1 Megaohm	382 pf	
	> 1 Megaohm	632 pf	
	.5 Ohm		
	.6 Ohm		
	.7 Ohm		
	.4 Ohm		
B-767	<.01 Ohm		Left Wing
	<.01 Ohm		Left Wing
	<.01 Ohm		Right Wing
	<.01 Ohm		Right Wing
L-1011	3 Megaohms		Left Fuel Tank
	75 Ohms		Left Fuel Tank
	0 Ohms		Left Fuel Tank
	2 Megaohms		Center Fuel Tank
	0 Ohms		Center Fuel Tank
	2 Ohms		Center Fuel Tank
	.2 Megaohms		Right Fuel Tank
	9 Ohms		Right Fuel Tank
	30 Megaohms		Right Fuel Tank

SYSTEMS [illegible]
ATA 28-11-00

Technical Report Documentation Page

1. Report No.
DOT/FAA/CT-89/22

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
AIRCRAFT LIGHTNING PROTECTION HANDBOOK

5. Report Date
September 1989

6. Performing Organization Code

7. Author(s)
F. A. Fisher and J. A. Plumer* R. A. Perala**

8. Performing Organization Report No.
DOT/FAA/CT-89/22

9. Performing Organization Name and Address
*Lightning Technologies Inc.
10 Downing Parkway
Pittsfield, MA 01201

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFA03-86-C-00049

12. Sponsoring Agency Name and Address
U. S. Department of Transportation
Federal Aviation Administration
Technical Center
Atlantic City International Airport, NJ 08405

13. Type of Report and Period Covered
Handbook

14. Sponsoring Agency Code
ACD-230

15. Supplementary Notes
** Electro Magnetic Applications Inc., Denver, Colorado 80226
Program Manager: Michael Glynn, FAA Technical Center

16. Abstract

This handbook will assist aircraft design, manufacturing, and certification organizations in protecting aircraft against the direct and indirect effects of lightning strikes, in compliance with Federal Aviation Regulations. It presents a comprehensive text to provide the essential information for the in-flight lightning protection of all types of fixed/rotary wing and powered lift aircraft of conventional, composite, and mixed construction and their electrical and fuel systems.

The handbook contains chapters on the natural phenomenon of lightning, the interaction between the aircraft and the electrically charged atmosphere, the mechanism of the lightning strike, and the interaction with the airframe, wiring, and fuel system. Further chapters cover details of designing for optimum protection; the physics behind the voltages, currents, and electromagnetic fields developed by the strike; and shielding techniques and damage analysis. The handbook ends with discussion of test and analytical techniques for determining the adequacy of a given protection scheme.

17. Key Words
Lightning Protection
Fuel Vapor Ignition
Fuel System Safety
Atmospheric Electrical Hazards
Lightning Safety
Lightning Simulation
Aircraft Certification
Atmospheric Electromagnetism
Induced Currents & Voltages
Electromagnetic Shielding

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Assume that the leading and trailing edge sections of a wing are nonconductive or sufficiently isolated as to be unavailable for conduction and that the remaining wing box is comprised of skins and spars having the dimensions as shown in Fig. 7.26. The cross sectional area of the spars and skins forming this box is 135 cm^2 (21 in^2). The tank also contains an aluminum vent pipe electrically bonded to the structure at each end of the tank. This tube has an outside diameter of 10 cm (4 in), a wall thickness of 0.5 mm (0.02 in^2) , and a cross sectional area of 1.56 cm^2 (0.24 in^2).

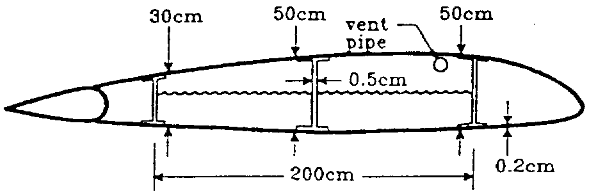

Fig. 7.26 Hypothetical wing box with integral fuel tank.

Assume an intermediate strike with an average amplitude of 2000 A for 5 ms, in accordance with Component *B* of [7.28]. The current in the pipe can be calculated as follows:

$$I_{pipe} \approx [\frac{1.56\ cm^2}{135\ cm^2}] \times 2000\ A = 23.1\ A \qquad (7.2)$$

Currents of this order of magnitude have produced arcs at movable, poorly conducting, interfaces in some couplings. More common examples of electric arc sources include motor commutators.

Bond straps: Electrical bond straps or jumpers are sometimes installed across poorly conducting pipe couplings, as shown in Fig. 7.27. These bond straps should not be relied upon to prevent sparking from lightning currents. Current is apt to divide in proportion to resistance which may be the result of a small contact area in the coupling. Some current in the coupling could lead to sparking even with the bond strap in place.

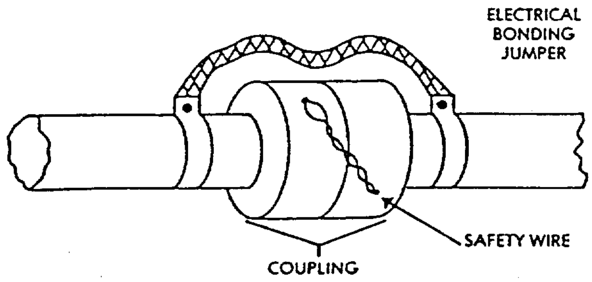

Fig. 7.27 Electrical bonding jumper across insulated coupling.

Conduction through couplings and interfaces: The extensive use of anodized coatings to provide noncorrosive mating surfaces in pipe couplings would seem to preclude arcing across the pipe interface, but relative motion between these surfaces can wear through the anodized coating, forming a conductive path. If there happens to be a large, bare metal–to–metal contact within the coupling, this could provide a spark free path. However, a slight change in the relative position of the mating surfaces, or introduction of dirt or residue might drastically change the electrical capability of a coupling. It is probable that the electrical capability of a typical pipe coupling changes many times during a flight as a result of relative motion caused by structural vibrations and flexing.

Some of the commercially available couplings and bulkhead fittings have been designed to conduct impulse currents up to 2500 amperes without sparking. These couplings should be adequate for use in most metal tanks where currents are of the order of a few hundred amperes or less.

Fuel tanks fabricated of CFC materials, however, are more highly resistive than aluminum. Currents on the exterior skin surface of such tanks will diffuse more rapidly to internal conductive plumbing and currents might greatly exceed 2500 amperes.

Guidelines for protection: In the absence of definitive data on the electrical conductivity of pipe couplings under in–service conditions, it is advisable to take the following approach:

1. Determine, by analysis or test, the fraction of lightning current expected in a particular pipe.
2. Inject this current into a sample of the coupling under simulated in–flight vibration and contamination conditions.
3. Perform this test in a darkened enclosure and observe whether any arcs or sparks occur. Repeat the test until a reliable result is established.

Non–conducting interfaces: One solution to the problem of arcs and sparks at couplings and plumbing interfaces with aircraft structure is to insert electrically non–conductive isolation links into these lines to eliminate them as current carrying paths. This solution, of course, requires additional couplings, which may add additional weight compared to the traditional all aluminum plumbing.

Another solution is to make the pipes of a non-conductive material. Various solid polymers or fiber reinforced resins may be used for this purpose. Some electrical conducting material must be provided in the interior linings of pipes transferring fuel however, to

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Lightning tests induced current into fuel tubes that created sparks at Wiggins couplings, as documented here. R. Swain

This reduced the peak current in pipes to the following values:-

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Mil-C-22263 Joint 2.3kA
Glued Joint 2.2kA.

AEA Industrial Technology
Culham Laboratory, Abingdon, Oxon, UK

It did not however prevent sparking at the Mil-C-22263 joint.

A final test approaching full threat level was done to try and identify if sparking was taking place elsewhere and what would be the level of current in the pipes. This was done with a clamped current waveform, i.e., a unidirectional pulse. This produced a great burst of sparking at the Mil-C-22263 joint seriously over-exposing the film in the cameras, so that it was not possible to identify any other sparking. Some signs of internal sparking was detected by fibre-optics on the glued pipe joint, and subsequent analysis revealed slight pitting.

The test parameters from this final shot were as follows:

Total Peak Current 175kA Action Integral $2.3 \times 10^6 A^2s$.
Peak Current in Mil-C-22263 Joint 12kA. Peak Current in Glued Joint 17kA.

7 CONCLUSIONS OF BOX TESTS

It is clear from these tests that the best surface protection that could be provided i.e., covering the box with metal foil would not prevent the Mil-C-22263 joint from sparking. It was therefore felt there would be no point in investigating further the effects of lightning protection on the box.

8 GAS IGNITION TESTS FROM THERMAL SPARKS

It has been claimed by some manufacturers that although considerable sparking can be seen and recorded on cameras during arc tests these would not be adequate to ignite a 1.2 stoichiometric mixture of Propane and air.

A considerable amount of information is available on the ignition of gas mixtures by voltage sparks. The data from thermal sparks is much more limited and we did not have the information available for this type of spark. It was therefore proposed to test whether the type

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SUMMARY AND CONCLUSION

1 Mil-C-22263 Joint

The construction of the Mil-C-22263 joint with the thin wire spring fingers is such that sparking is bound to occur at comparatively low lightning pulse currents. In our case we could only reduce the levels to 2 to 3kA peak.

2 Expected Pulse Currents

Tests to the experimental wing box section provided showed peak currents in the pipes could be of the order of 12 to 17kA for a full threat level of 200kA during conduction shots with aluminium foil covering the surface of the box. Even with arc attachments to the surface of the box a peak current of 6 to 8kA was observed in the pipes.

3 Foil Protection

The use of protective aluminium foil on the surface of the box is only likely to halve the currents in the pipes.

4 Ignition of Gas Mixtures

It was confirmed that the sparks at the Mil-C-22263 joint at 3kA would ignite stoichiometric mixtures of Propane and air and Ethylene and air. Ignition occurred on all tests made.

5 Use of Promel to Suppress Sparking

Since it is understood that it is not practical to modify the Mil-C-22263 joint, the effect of Promel, a suppressant foam to prevent spark/ignition propagation was tested. The foam did not prevent ignition from occurring, but does reduce the volume in which it occurs, and hence reduces its severity. The success of this approach would appear to depend on the geometry of the box and how completely it can be filled with foam.

6 Arc Tests to Box

Arc tests to the box at 200kA showed about 5 to 8kA peak current could flow in the fuel pipes. The damages to the CFC was over an area of about 100 × 150mm and 5 to 6 plies deep from visual inspection.

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7 Arc Tests to Bolts

Arc tests to the spar fixing bolts showed that aluminium foil 3" wide and 0.003" thick was enough to prevent internal sparking for a 187kA peak current test pulse. Having sparked however with no foil, further application of the foil did not prevent further sparking at the same bolt.

8 Ignition of Fuels

Whether the sparking seen would ignite aircraft fuels such as JP4 and JP8 under suitable conditions is not proven. It would however not meet the requirements of MIL STD 1757A. It is therefore hoped to extend this work to verify the ignition requirements for fuels with thermal sparks.

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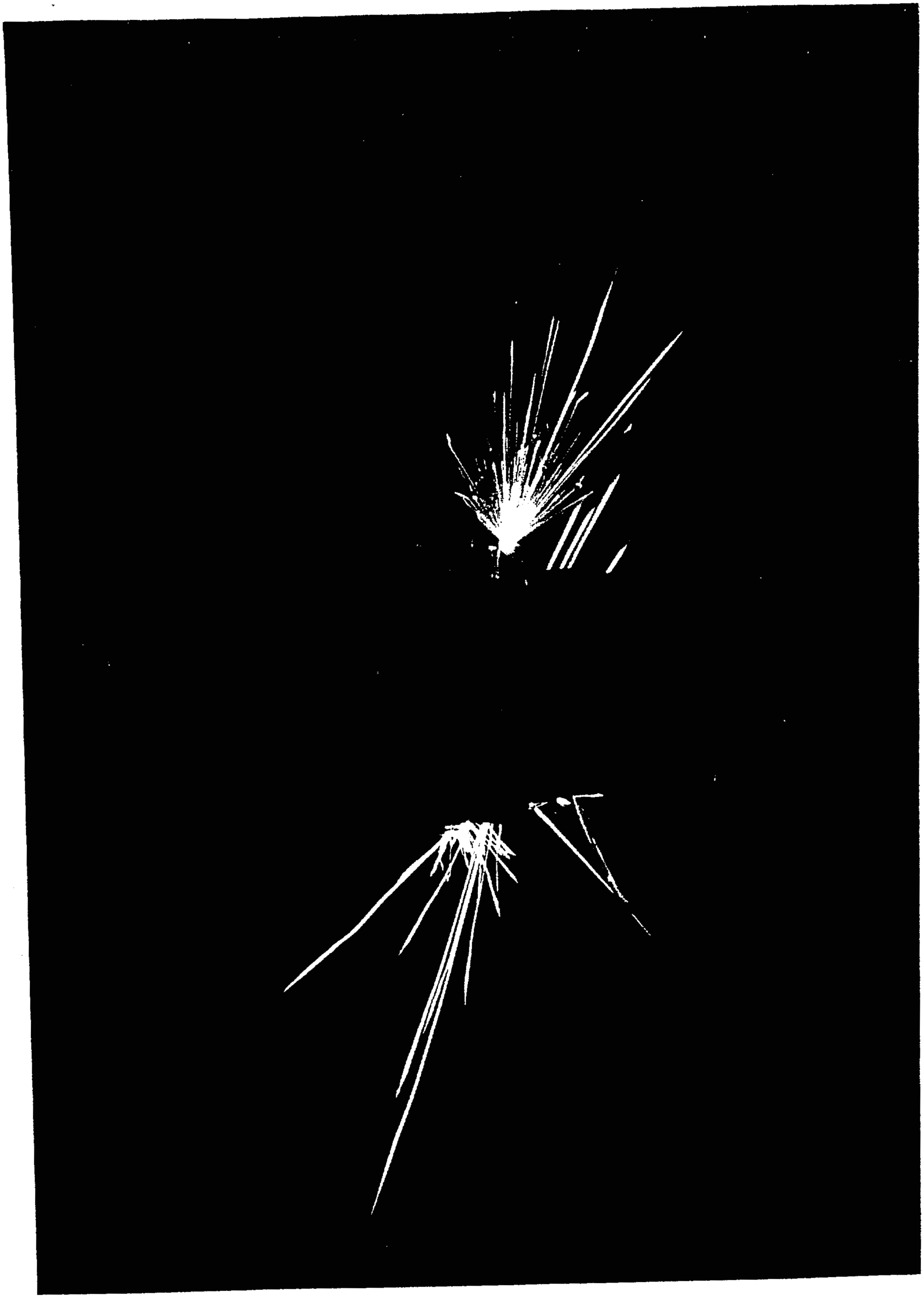

Fig 6   Pipe Joint Sparks

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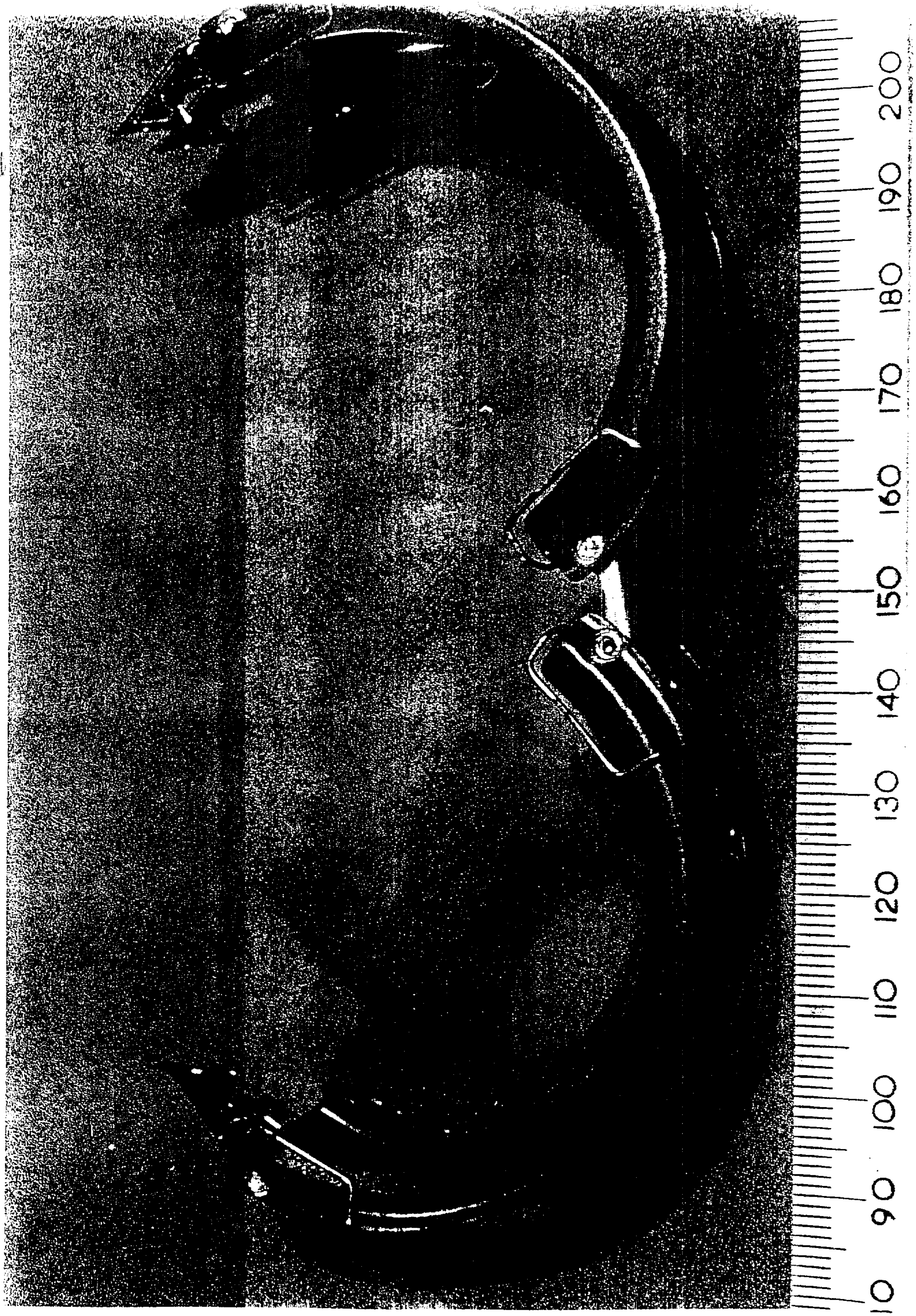

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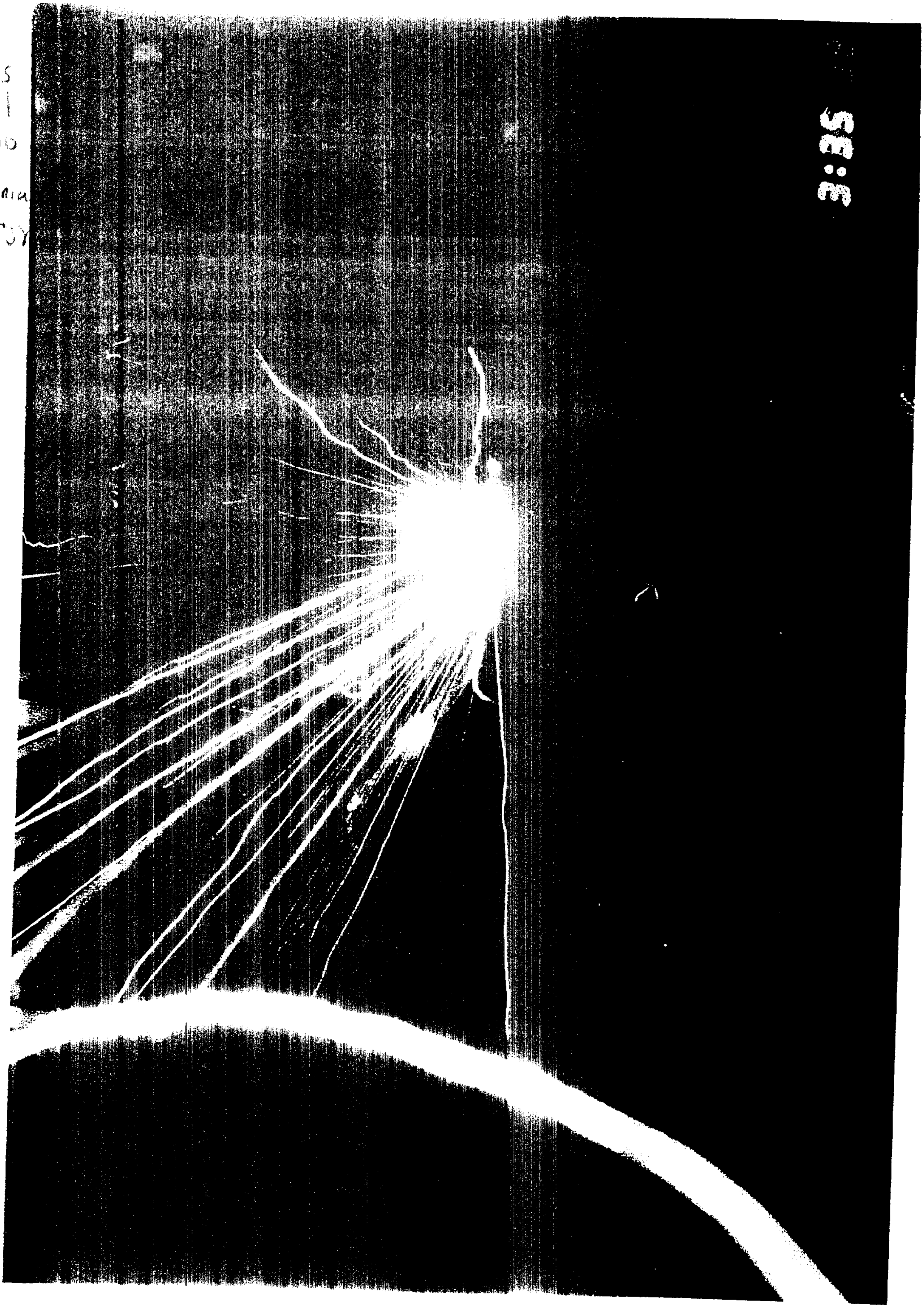

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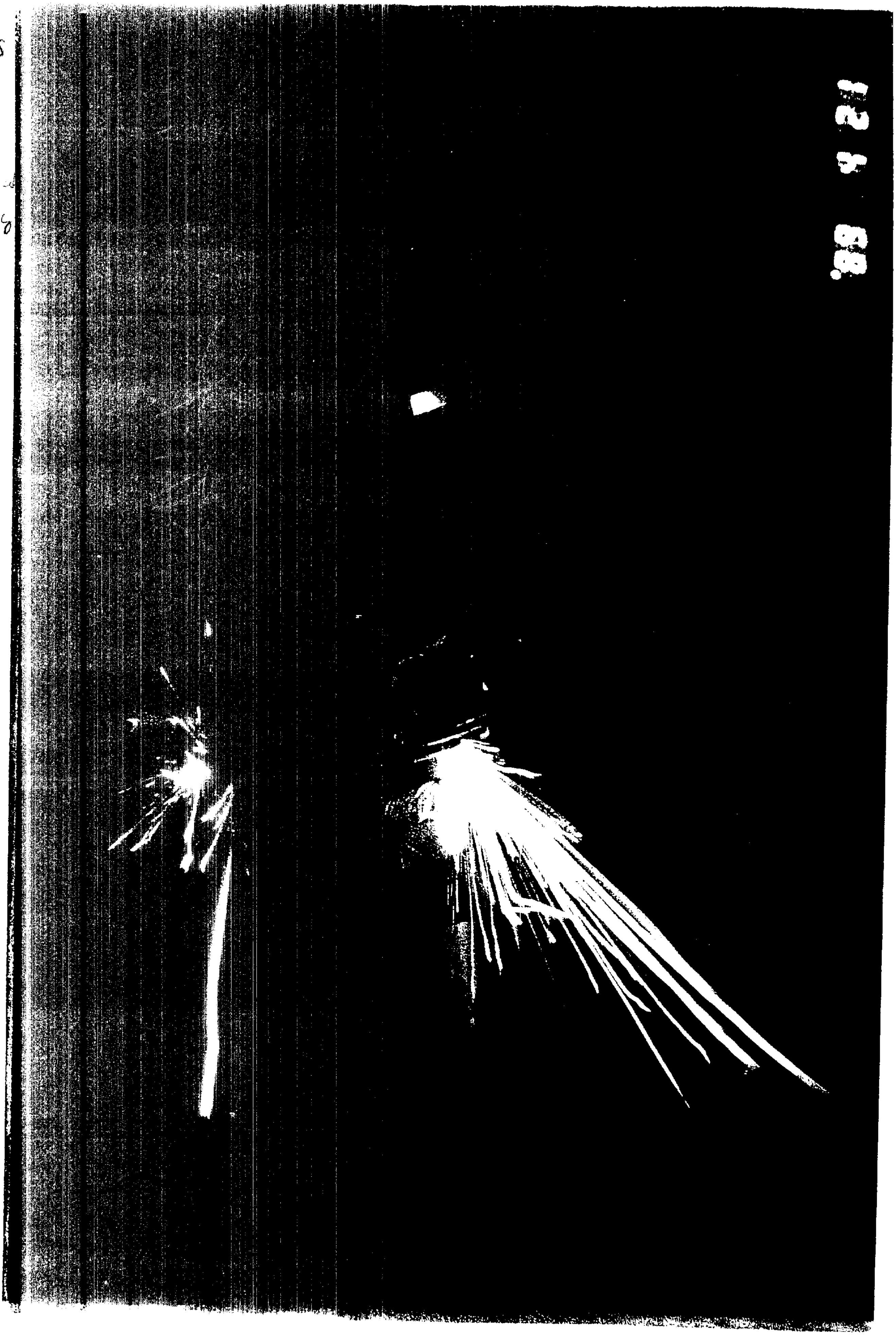

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Protection Against Ignitions Arising out of Static, Lightning, And Stray Currents

API RECOMMENDED PRACTICE 2003
FIFTH EDITION, DECEMBER 1991

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

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Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents

SECTION 1—GENERAL

1.1 Scope

This recommended practice presents the current technology in the fields of static electricity, lightning, and stray currents applicable to the prevention of hydrocarbon ignition. The recommendations for protection are based on research and practical experience in the petroleum industry; however, the principles discussed in this recommended practice are applicable to other operations in which ignitable liquids and gases are handled. Their use should lead to improved safety practices and evaluations of existing installations and procedures. Furthermore, when the narrow limits within which static electricity can cause ignition are properly understood, fire investigators can be encouraged to search more diligently for the true ignition sources in instances where ignition by static electricity is unlikely or impossible.

Several effective basic steps that may be taken to prevent static ignition are discussed in the following paragraphs. The recommended practices and precautions given in this guide are not required under the following conditions:

a. Static discharges may occur, but flammable vapors are excluded by gas freeing or inerting the atmosphere in the area of discharge.
b. Product handling occurs in a closed system, and oxygen in that system is below the minimum concentration required to support combustion, such as in the handling of liquefied petroleum gas (LPG).
c. The flammable concentration is above the upper flammable limit (UFL).
d. Flammable vapor may be present, but no mechanism exists for static accumulation and discharge. Included in this category are most situations in which some petroleum liquids, such as crude oils, residual oils, asphalts (including cutbacks), heavy fuel oils (No. 6, bunker, and so forth), and water-soluble liquids (such as alcohols) are handled in grounded conductive equipment. These liquids do not accumulate electrostatic charges because of their relatively high electrical conductivity (greater than 50 picosiemens per meter). Experience indicates that these materials do not present a significant electrostatic hazard unless they are broken up into fine droplets so that a charged mist is formed. In the presence of such mists, electrically insulated conductive objects may become highly charged.

1.2 Fundamentals

This publication considers the practical procedures for protecting specific operations. Fundamentals of static electricity and definitions are covered in Appendix A. Static measurement and detection techniques are covered in Appendix B. Appendix C is a copy of the static ignition questionnaire used to collect data for analysis of electrostatic incidents. Readers who have experienced an ignition of hydrocarbon from a static ignition source are encouraged to fill out a copy of the questionnaire and forward it to API. The data collected will be used for future analysis.

1.3 Referenced Publications

No single publication covers all the material needed to understand electrostatic ignition of hydrocarbons or to provide appropriate protection against such ignition. The following publications, to the extent specified in the text, form a part of this recommended practice:

AGA[1]
Plastic Pipe Manual for Gas Service.

API

Publ 1003	*Precautions Against Electrostatic Ignition During Loading of Tank Truck Motor Vehicles*
Publ 2015	*Cleaning Petroleum Storage Tanks*
Publ 2027	*Ignition Hazards Involved in Abrasive Blasting of Atmospheric Hydrocarbon Tanks in Service*

ASTM[2]

D 4308	*Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter*

NFPA[3]

30	*Flammable and Combustible Liquids Code*
77	*Static Electricity*
78	*Lightning Protection Code*

OCIMF[4]
International Safety Guide for Oil Tankers and Terminals

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[1] American Gas Association, 1515 Wilson Boulevard, Arlington, Virginia 22209.
[2] American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187.
[3] National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts 02269.
[4] Oil Companies International Marine Forum, 12th Floor, Portland House, Stag Place, London SW1E 5BH, England, United Kingdom.

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SECTION 2—PRECAUTIONS FOR TANK VEHICLES

2.1 General

The study of static electricity is concerned with the accumulation of electrical charges on materials, the mechanisms by which these charges are generated, and the processes of dissipating the accumulated charges. The flow of electricity during generation and accumulation can produce potential differences of thousands of volts, even though the actual flow of electricity is small—in the range of millionths of an ampere. For this reason, bonding or grounding through a resistance as large as 1 megohm (1 million ohms) will act as a short circuit to dissipate a static charge.

A primary manifestation of static electricity is the discharge of the accumulated charges by sparking. Because static electricity is different from power electricity, the measurement instruments and techniques are quite different (see Appendix B).

2.2 Ignition by Static Electricity

To prevent a fire, one or more of the three elements required for combustion—fuel (in vapor or mist form), air, and a source of ignition—must be controlled. Sparks from static electricity are a significant source of ignition. Control procedures should prevent the presence of either sparks or flammable vapor–air mixtures.

For an electrostatic charge to be a source of ignition, four conditions must be present:

a. A means of generating an electrostatic charge.
b. A means of accumulating an electrostatic charge capable of producing an incendiary spark.
c. A spark gap.
d. An ignitable vapor–air mixture in the spark gap.

Ignition hazards from static sparks can be eliminated by controlling the generation or accumulation of static charges or by eliminating flammable mixtures at points where static electricity may be discharged as sparks. The ignition risk can be reduced if the presence of spark promoters in areas of potentially high electric fields is avoided.

2.3 Spark Promoters

Care should be exercised to avoid spark promoters, such as unbonded conducting objects, within a tank compartment. Tanks should be inspected and any unbonded object removed before loading.

A tank gauging rod or other device that projects into the cargo space of a tank truck can provide a gap between itself and the rising liquid, allowing static sparking. In top loading, a conductive downspout at ground potential extends into the liquid. If the downspout is near the projection, the voltage gradient on the liquid surface near the projection may be reduced enough to diminish the possibility of static discharge.

Gauging rod projection is of greater concern in bottom loading because there is no downspout. On trucks with projecting gauging rods, the rod should be connected to the bottom of the tank by a wire or chain.

Where flammable mixtures can be expected in the vapor space, metal or conductive objects, such as gauge tapes, sample containers, and thermometers, should not be lowered into or suspended in a compartment, either during filling or immediately afterward. In addition, the downspout should not be removed until any electrostatic charge on the product has had the opportunity to relax. A waiting period of about 1 minute after filling has stopped will normally permit substantial relaxation of the electrostatic charge. However, when very low conductivity hydrocarbons are loaded into tank vehicles, a longer relaxation period is recommended (see 4.5).

Petroleum liquid should not be freely discharged from a hose into a tank unless all metal fittings are bonded to the tank.

Two types of spark promoters are shown in Figures 1A and 1B.

2.4 Flammable Vapor–Air Mixtures

2.4.1 GENERAL

The probability of a vapor–air mixture being flammable depends on the product's vapor pressure and flash point and the temperature at which it is handled. These properties are used to classify refined products whose electrical resistivities are high enough to enable them to accumulate significant electrostatic charges under some handling conditions. These classifications are low-vapor-pressure products, intermediate-vapor-pressure products, and high-vapor-pressure products (see A.9 of Appendix A for details).

2.4.2 LOW-VAPOR-PRESSURE PRODUCTS

Low-vapor-pressure products are products with closed-cup flash points above 100°F (38°C). Examples of these products include furnace oil, kerosene, diesel fuel, commercial aviation turbine fuel (Jet A), and safety solvents. Since these products are normally handled at temperatures well below their flash points, they do not develop flammable vapors under normal handling conditions. However, a condition for ignition may exist if these products are handled at temperatures above their flash points, are contaminated with intermediate- or high-vapor-pressure products, or are transferred into containers where vapors at concentrations at or above those necessary to produce a flammable mixture are present from previous use. This may occur during switch loading, as described in 2.4.5.

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APPENDIX A—FUNDAMENTALS OF STATIC ELECTRICITY

A.1 General

The study of static electricity is concerned with the accumulation of electrical charges on materials, the mechanisms by which these charges are generated, and the processes of dissipating accumulated charges. The flow of electricity during generation and accumulation is small, in the range of millionths of an ampere, but the potential differences involved may amount to thousands of volts. For this reason, resistances of less than 1 megohm act as short circuits. A primary manifestation of static electricity is the discharge or sparking of the accumulated charges. Because static electricity is different from power electricity, the instruments and techniques for measurement are unique (see Appendix B).

A.2 Generation of Static Electricity

Static electricity is generated by the separation of like or unlike bodies. Both positive and negative electrostatic charges always occur in pairs and are separated and become evident when two bodies that have been in contact are separated. For significant charges to be developed, the bodies must become and remain insulated with respect to each other so that the electrons that have passed over the boundary surface or interface are trapped when separation occurs. Insulation may occur because the bodies are completely physically separated or because at least one of the bodies is an insulator. In the latter instance, charging may arise from friction or rolling contact between bodies. Examples of static producers are shown in Figure A-1.

Of more importance to the petroleum industry is the static charge resulting from contact and separation that takes place in a flowing liquid. Before flow, the liquid contains equal quantities of positively and negatively charged ions and is electrically neutral. However, ions of one sign are preferentially adsorbed by the surface of the container or pipe, leaving a surplus of ions of the opposite sign in the liquid at the interface. When the liquid flows, charging occurs because the adsorbed ions are separated from the free ions, which are carried into the body of the liquid by turbulence. Figure A-2 shows how the charges are mixed with the liquid and carried downstream. The opposite charge is usually conducted through the metallic pipe wall in the same direction because of the natural attraction between opposite charges. Impurities (water, metal oxide, and chemicals) increase the static-generating characteristics.

The flow of electricity caused by the entrainment of charged particles in the flowing fluid is known as the streaming current. If this charged stream enters a metal container or tank, charge separation will be induced on the tank wall. A charge equal in magnitude to the fluid charge, but of opposite sign, will be induced on the inside surface of the tank, and a charge of the same sign as the incoming stream will be left on the outside surface of the tank. If the tank is grounded, this charge on the outside surface will flow to ground. The charge on the inside will remain, held by the attraction of the charge in the fluid. Ultimately, the charge in the fluid and on the wall will come together by movement of the charge through the fluid (see Figure A-3).

Strong electrostatic fields may also be generated by droplets or solid particles settling in a medium of low conductivity or by agitation of such particles within the medium. If a liquid in a tank containing ionizable impurities is subject to turbulence, the separation of ions can result in electrostatic charging within the body of the liquid. Such charging may cause significant variations in voltage within the liquid or on the liquid surface.

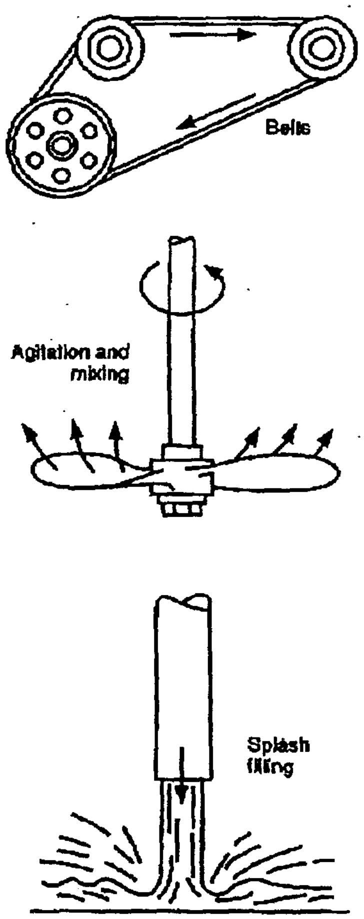

Figure A-1—Static Producers

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that can accumulate on an insulated body depends on the rate at which the static charge is being generated and the resistance of the paths through which the charge dissipates.

A.5 Conductivity

The ability of a liquid to retain an electrostatic charge is a function of its conductivity. This characteristic can be expressed in terms of conductivity [1 conductivity unit = 1 picosiemen per meter (10^{-14} ohm^{-1}·cm^{-1})] or in the inverse form as resistivity (1 resistivity unit = 10^{14} ohm-cm)]. Another commonly used measure is the half-value time, which is the time it takes for the charge in a liquid inside a metal container to decrease to one-half its original value. The half-value time is inversely proportional to the liquid's specific conductivity and is directly proportional to its dielectric constant. Table A-1 lists the conductivity, resistivity, and half-value times of typical liquids.

cosiemen per meter (10^{-14} ohm^{-1}·cm^{-1})] or in the inverse

Except for mists, electrostatic accumulation is not significant when the conductivity of the liquid exceeds 50 picosiemens per meter and the fluid is handled in conductive containers. Above this value, the charges recombine as fast as they are separated.

Liquids with conductivities less than about 1 picosiemen per meter do not, in practice, relax charges as slowly as the half-value time would suggest. As explained in Reference 1 (see Appendix D), when such liquids are highly charged, the usual relationship described by Ohm's law does not apply.

A.6 Static Discharge

A.6.1 GENERAL

In practice, electrostatic charges constantly leak from a charged body because they are always under the attraction of an equal but opposite charge. This characteristic is called charge relaxation, and because of this, most static sparks are produced only while the generating mechanism is active. It is possible, however, for charges generated during movement of some refined petroleum products to remain for a short time after the fluid has stopped moving, because of the fluid's insulating qualities.

A.6.2 SPARKS AND ARCS

Although popular usage does not distinguish between sparks and arcs, a technical difference is recognized. A spark results from the sudden breakdown of the insulating strength of a dielectric (such as air) that separates two electrodes of different potentials. This breakdown produces a transient flow of electricity across the spark gap and is accompanied by a flash of light, indicating a high temperature. In contrast to a spark, an arc is a low-voltage, high-current electrical discharge that occurs at the instant two points, through which a large current is flowing, are separated. Technically, electrostatic discharges are always sparks.

A.6.3 SPARKING POTENTIAL

For static electricity to discharge as a spark, the voltage across the spark gap must be above a certain magnitude. In air, at sea level, the minimum sparking voltage is approximately 350 volts for the shortest measurable gap. Larger gaps require proportionately higher voltages; the actual voltage depends on the dielectric strength of the materials (or gases) that fill the gap and on the geometry of the gap. For dry air and large gaps, the dielectric strength is approximately 30,000 volts per centimeter.

dry air and large gaps, the dielectric strength is approxi-

In the petroleum industry, spark gaps assume many forms and appear at various locations. For example, a spark gap may be formed between a tank vehicle and the overhead filling downspout if they are not bonded together or in metallic contact. In this case, a static potential difference is developed between the tank vehicle and the downspout as a result of the static charges generated during the flow of the product into the compartment.

The potential developed is related to the amount of charge on a body and to the capacitance of the body with respect to its surroundings. The relationship is expressed as follows:

$$V = \frac{Q}{C}$$

Where:

V = potential, in volts.
Q = charge, in coulombs.
C = capacitance, in farads.

Since the capacitance of a body with respect to its surroundings depends on its size and position, the same charge will not always result in the same voltage, and hence sparking may or may not occur. For instance, a large steel plate supported parallel to the earth's surface and insulated from it has a larger capacitance with respect to the earth than does a smaller plate mounted in a similar manner at the same distance from the earth. If the same charge is placed on both plates, the larger plate will have a lower voltage with respect to ground than will the smaller plate. Thus, the smaller plate might spark to the earth (discharge), but the larger plate would not have sufficient voltage for sparking.

Table A-1—Conductivity, Resistivity, and Half-Value Times for Typical Liquids

Liquid	Conductivity (picosiemens per meter)	Resistivity (ohm-centimeters)	Half-Value Time (seconds)
Highly purified hydrocarbons	0.01	10^{16}	1500
Light distillates	0.01–10	10^{16}–10^{13}	1500–1.5
Black oils	1000–100,000	10^{11}-10^{9}	0.015–0.00015
Distilled water	100,000,000	10^{6}	4×10^{-4}

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Under the continuous influence of a charge-generating mechanism, the voltage of an insulated body continues to grow. Since no insulation is perfect, as the voltage becomes greater, the rate at which the charge leaks through the insulation increases. At some voltage, the leakage of charge will equal the rate at which the charge is being placed on the insulated body and a stable condition will be reached. If this stabilized voltage is below the required sparking potential, no sparking will occur. If the stabilized voltage is above the sparking potential, sparking will occur before stabilization is reached. For this reason, individual and discrete spark discharges are sometimes observed under conditions of continuous electrostatic generation. As charges are deposited on a body, the voltage begins to grow; then, if the charge leakage through the insulation is not rapid enough, sparking potential is reached. The spark then discharges from the body and the voltage immediately drops. At this point, the entire process is repeated.

A.6.4 IGNITION ENERGY

The mere fact that a spark results from high voltage does not mean that ignition of a flammable mixture will occur. For combustion to be initiated, sufficient energy must be transferred from the spark to the surrounding flammable mixture. The energy that is stored and available from a capacitive discharge is related to voltage and capacitance by the following formula:

$$E = 0.5CV^2$$

Where:

E = energy, in joules.
C = capacitance, in farads.
V = potential, in volts.

Experiments under the most favorable conditions have ignited petroleum vapor–air mixtures at approximately 0.25 millijoule. The energy requirement increases as the mixture's composition approaches the lean or rich sides of the flammable range; it is at a minimum near the stoichiometric mixture.

The energy requirement is also increased by other factors that tend to decrease the availability of the stored energy to the flammable mixture. These factors include the following:

a. A portion of the energy will be dissipated in a resistive portion of the discharge circuit and will not be available at the spark gap.
b. The electrode across which the sparking occurs will be of a shape and material such that a portion of the energy in the spark will be wasted in heating the electrode and will not be available to heat the material in the gap. This is more pronounced with short gaps and is known as the electrode's *quenching effect.*
c. The spark gap may be so long that the energy is distributed over too long a path to heat the mixture to ignition.

Gas temperature and pressure may also increase or decrease the requirement for ignition energy.

Practical experience indicates that under normal conditions, it takes substantially more energy than the experimentally determined minimum to ignite flammable mixtures. This accounts for many situations in which sparks have been observed but ignition has not occurred. When the gap distance is smaller than that required for a 1500-volt spark-over, static potentials of less than 1500 volts are not likely to cause ignition because of the quenching effect of electrodes.

Sparks that release enough energy to result in the ignition of flammable vapors are known as *incendive sparks*. Sparks that do not release enough energy are known as *nonincendive sparks*. A form of discharge known as *corona* is manifested by a violet glow at locations of high field strength and results from ionization of the gas molecules under electron impact. Corona is usually nonincendive in the presence of flammable hydrocarbon vapor–air mixtures. However, the presence of corona is indicative of electrostatic charging and may be followed by an incendive spark discharge.

A.7 Ignition by Static Electricity

For an electrostatic charge to be a source of ignition, four conditions must be fulfilled:

a. A means of generating an electrostatic charge must be present.
b. A means of accumulating an electrostatic charge that is capable of producing an incendive spark must be present.
c. A means of discharging the accumulated electrostatic charge in the form of an incendive spark (that is, a spark gap) must be present.
d. An ignitable vapor–air mixture must be present in the spark gap.

A.8 Static Control

A.8.1 GENERAL

Ignition hazards from static sparks can be eliminated by controlling the generation or accumulation of static charges, the discharge of static charges, or the vapor–air mixture at points where static charges can be discharged as sparks. Several basic and effective steps that can be taken to prevent static ignition are discussed in A.8.2 through A.8.8.

A.8.2 BONDING

Sparking between two conducting bodies can be prevented by means of an electrical bond attached to both bodies. This bond prevents a difference in potential across the gap because it provides a conductive path through which the static charges can recombine. Therefore, no spark can occur. This is shown in Figures A-4 through A-6, which also show the relationship between voltages and assumed values of charge and capacitance.

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FA[illegible]
MA 28 11-[illegible]

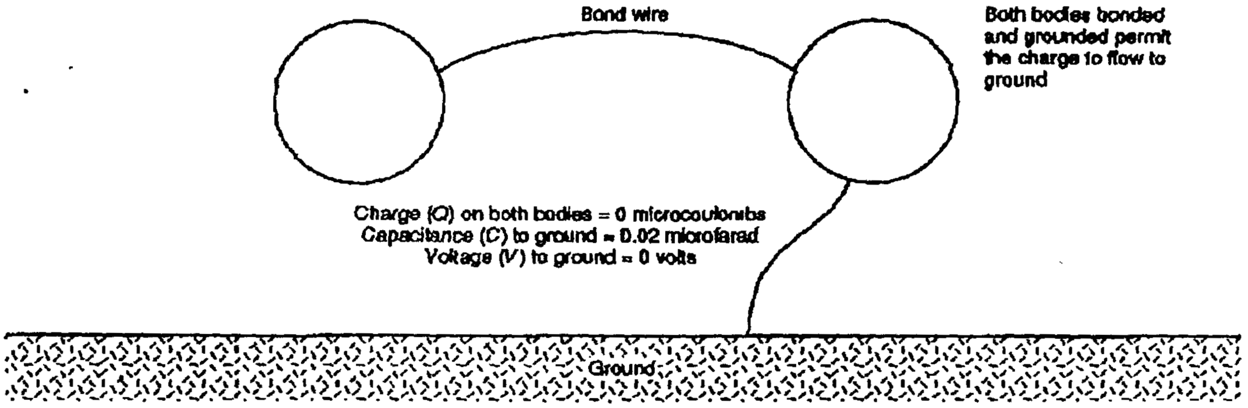

Figure A-6—Both Bodies Are Grounded and Have No Charge

ing the sparking potential by restricting or reducing the rate of static generation. In the case of liquid hydrocarbon products, the rate of generation can be reduced by decreasing or eliminating the conditions or activities that produce static. Thus, reducing agitation by avoiding air or vapor bubbling, reducing flow velocity, reducing jet and propeller blending, and avoiding free falling or dropping of liquid through the surface of stored product will decrease or eliminate the generation of static. Electrostatic charging is also reduced by preventing droplets of water or other particulate matter from settling through the body of the liquid.

A.8.5 INCREASING STATIC DISSIPATION

A charge on the liquid will dissipate at a rate that is a function of time and the liquid's conductivity. The charge on the liquid can be reduced by increasing its conductivity through the use of antistatic additives, which will permit the charge to dissipate more quickly, or by retaining the liquid in an enclosed pipe or relaxation tank at low turbulence to provide more time for the charge to dissipate.

When antistatic additives are used, they should be introduced at the beginning of the distribution train. It should be noted that the initially adjusted conductivity can be reduced significantly by repeated shipments and passage through clay filters. It is essential that the additive manufacturer's instructions be followed.

A.8.6 CONTROLLING THE ENVIRONMENT

When static discharge cannot be avoided by bonding, grounding, reducing static generation, or increasing static dissipation, ignition can be prevented by excluding ignitable vapor–air mixtures where the spark may occur. This is particularly difficult in the case of a flammable petroleum liquid whose vapor pressure produces ignitable mixtures at handling temperatures. However, a vapor–air mixture cannot be ignited unless the vapor-to-air ratio lies within certain well defined limits, called the *lower and upper flammability limits*. The accepted values for various petroleum products are given in U.S. Bureau of Mines Bulletin 627 [2].

If the atmosphere in a vapor space is in the flammable range, the hazard can be reduced or eliminated either by lowering the oxygen content by displacing the air with an inert gas or by keeping the vapor space well above the upper flammability limit through the introduction of natural gas or the vapors of a volatile product. Care must be taken in the use of these methods to avoid contamination of the product.

A.8.7 ELECTROSTATICALLY ACTIVE FUELS AND PROSTATIC AGENTS

In some cases accidents attributable to static electricity have occurred even where operations have been carried out for years in substantially the same manner without incident. In an attempt to account for these unusual occurrences it has been postulated that in these instances, the fuel was unusually electrostatically active because of the presence of unknown trace components that increased the charging tendency without significantly changing the fuel's conductivity [3]. API-sponsored research has eliminated most simple polar compounds and common fuel additives as having prostatic effects; however, it has been found that petroleum-derived sodium sulfonates are electrostatically active in trace concentrations. Water was found to be the most nearly ideal prostatic agent. The magnitude of its effect varied between fuels, leading to the conclusion that interaction with some undetermined constituent of the fuel provides the observed effect.

Present knowledge is inadequate to permit prediction of so-called "hot" fuels. Conventional fuel inspections give no

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indication of this potential hazard. However, hot fuels do occur occasionally, and the possibility must not be overlooked when loading precautions are considered or accidents are investigated.

A.8.8 ELECTROSTATIC CHARGING OF CLOTHING AND PERSONNEL

In a dry atmosphere, such as in a heated building in the winter, electrostatic charging of personnel can become noticeable. Static discharges from clothing are very unlikely to ignite ordinary hydrocarbon gases in the air. However, sparks from the body to ground may have sufficient energy for ignition, since the body is a fairly good conductor and may retain a charge. Physical separation of dissimilar materials is always involved in the generation of a high body voltage. Some typical examples are removal of an outer garment (charge separation between the garment and the remaining clothing and body) and walking on a rug (charge separation between the rug and the soles of the shoes, which results in charging of the body). Clothing is not likely to generate high body voltage except by its removal. As a practical matter, static charging of personnel has not proven to be a significant safety problem in normal petroleum industry operations, probably because of the normal lack of actions such as those just mentioned, coupled with the normal absence of personnel being exposed to a flammable atmosphere.

The need for control of personnel charging usually arises in situations in which workers are exposed to very easily ignitable materials indoors, such as in hospital operating suites (with mixtures of oxygen and anesthesic gas) and in the manufacture of munitions. In these situations, prevention of personnel charging is achieved by continuous body grounding through the use of conductive footwear and conductive flooring.

Note: As used here, grounding of personnel for electrostatic hazards does not mean a short circuit but a resistance on the order of 100 kilohms from the body to ground. However, for protection from electric shock, resistance to ground should not be less than 10,000 ohms. Body grounding is the most basic and essential control measure. In addition, outer clothing can be chemically treated to make it somewhat conductive, and the use of synthetic fibers can be restricted. However, such controls are apt to be ineffective in a very dry atmosphere, so humidity control is usually employed as well. A possible alternative to conductive clothing that does not depond on humidity is the use of a cloth containing a small percentage of metal fibers in the thread. The purpose of the metal fibers is not to provide conduction but to promote safe corona discharge at a relatively low voltage.

These control measures are cited to illustrate that where a substantial risk from personnel static exists, the use of antistatic clothing alone is not sufficient. First, it is necessary to provide body grounding. Furthermore, most antistatic clothing requires at least moderate humidity to be effective. As stated above, experience indicates that personnel static is not a significant safety problem in normal petroleum industry operations, and special measures to ground personnel and provide antistatic clothing are not normally necessary. However, removal of clothing in a potentially flammable atmosphere must not be allowed, since ignitions have been caused by removal of hydrocarbon-saturated outer clothing. In such cases, it is important to adequately ground the body before removing the hydrocarbon-saturated garments.

A.9 Definitions

The following definitions from NFPA 30 can be used as a reference for 2.4, 2.5, and 2.6:

Combustible liquid shall mean a liquid having a flash point at or above 100°F (37.8°C). Combustible liquids shall be subdivided as follows:

Class II liquids shall include those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

Class IIIA liquids shall include those having flash points at or above 140°F (60°C) and below 200°F (93.4°C).

Class IIIB liquids shall include those having flash points at or above 200°F (93.4°C).

Flammable liquid shall mean a liquid having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 pounds per square inch absolute at 100°F (37.8°C) and shall be known as Class I liquid. Class I liquids shall be subdivided as follows:

Class IA liquids shall include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C).

Class IB liquids shall include those having flash points below 73°F (22.8°C) and having a boiling point at or above 100°F (37.8°C).

Class IC liquids shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

Note: All flashpoints are determined by the closed-cup method.

ATA 28-11-00

FROM SAE AEROSPACE INFORMATION REPORT (AIR) 1662

- Some military aircraft use explosion suppressant foam in their fuel tanks to reduce combat vulnerability. These foams are a sponge-like material composed of skeletal networks of tiny lightweight strands of polyester-polyurethane or polyether-polyurethane. Unless precautions are taken, entering fuel can impinge on the foam and depending on the porosity of the foam, the impingement velocity, and the surface area impinged upon, can constitute a potent charge generator. In such a case, as with plastic pipes, one charge is left on the foam, and charge of the opposite sign is convected away by the fuel. The charge which resides on the foam (which is a good insulator) cannot easily migrate to ground, and so can quickly accumulate to levels where an incendiary discharge can occur. Incidents traceable to the presence of explosion suppressant foam began to surface in 1974 (Fig. 13) and continue to be a problem for the military services.

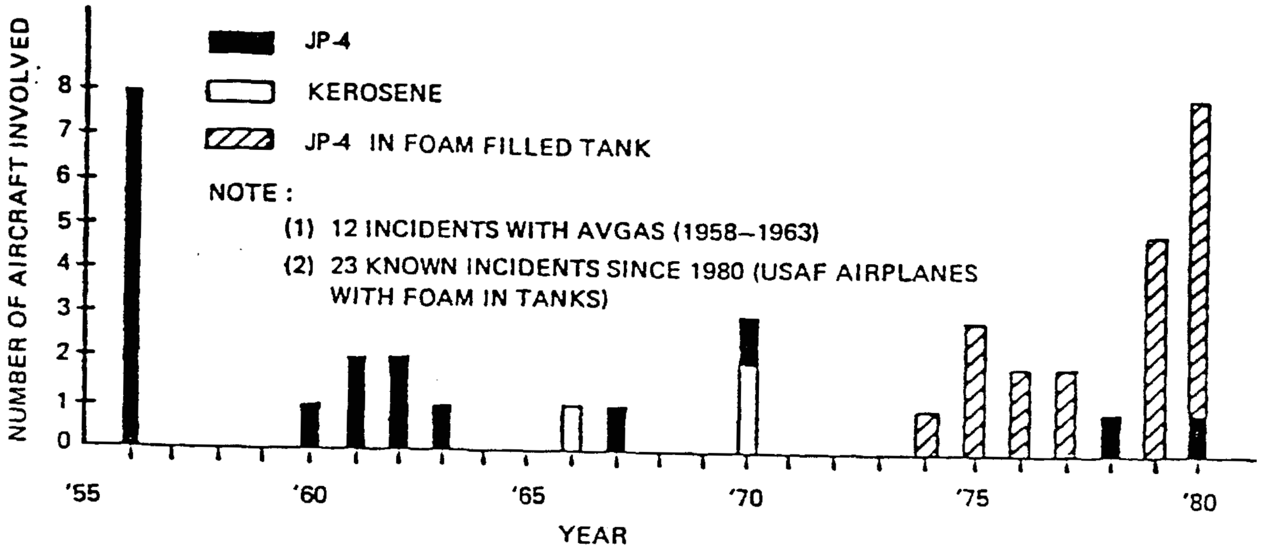

Figure 13. Aircraft Accidents Attributed to Static Electricity (Ref 1)

When incendiary events induced by discharges occur in foam protected tanks, the foam prevents explosion, and prevents large scale fire spreading; however, the charred foam must be replaced which is an expensive, time consuming task. Subtle problems with explosion suppressant foam found in the past have included the following:

WING SURGE TANK VENT
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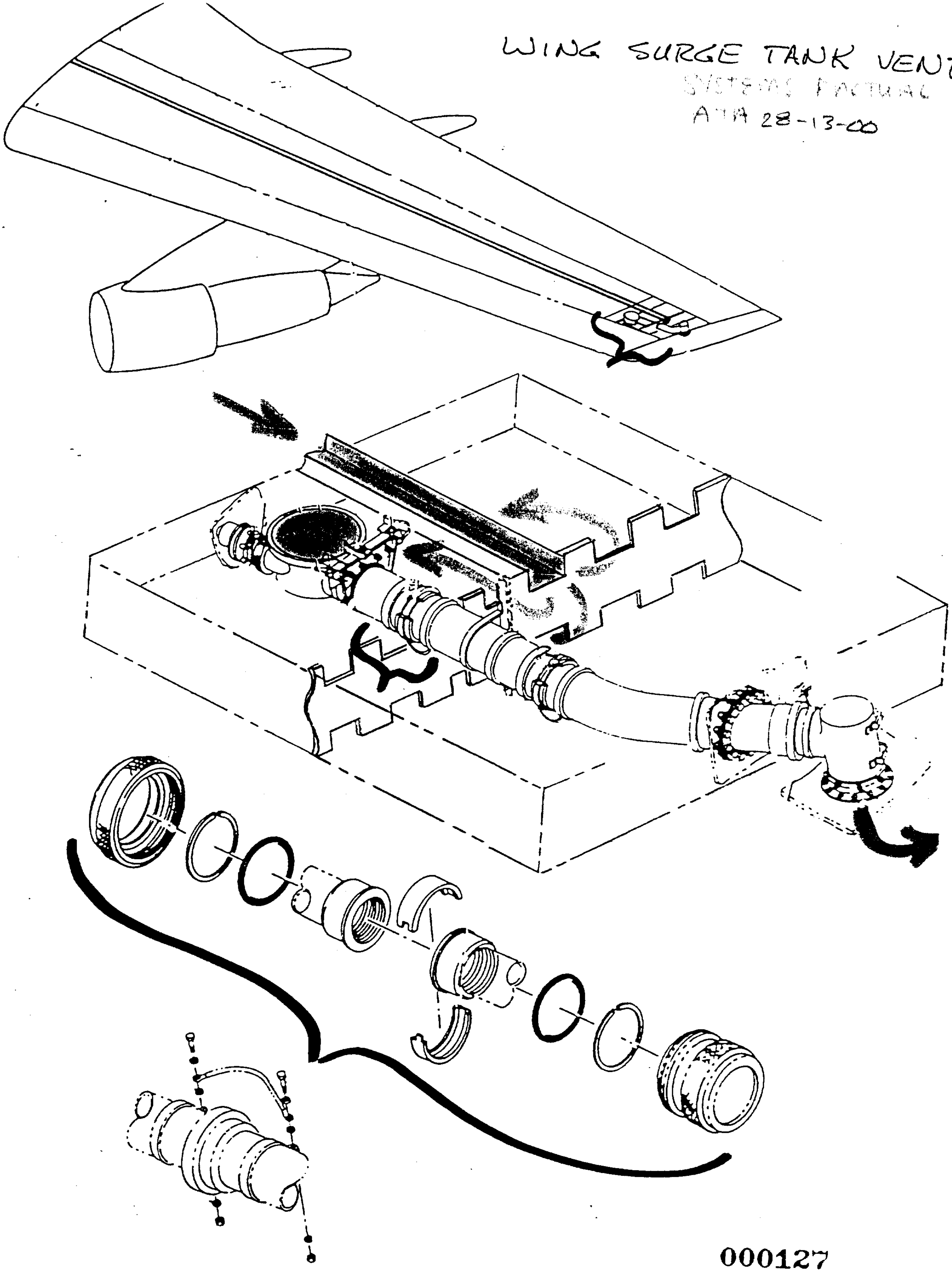
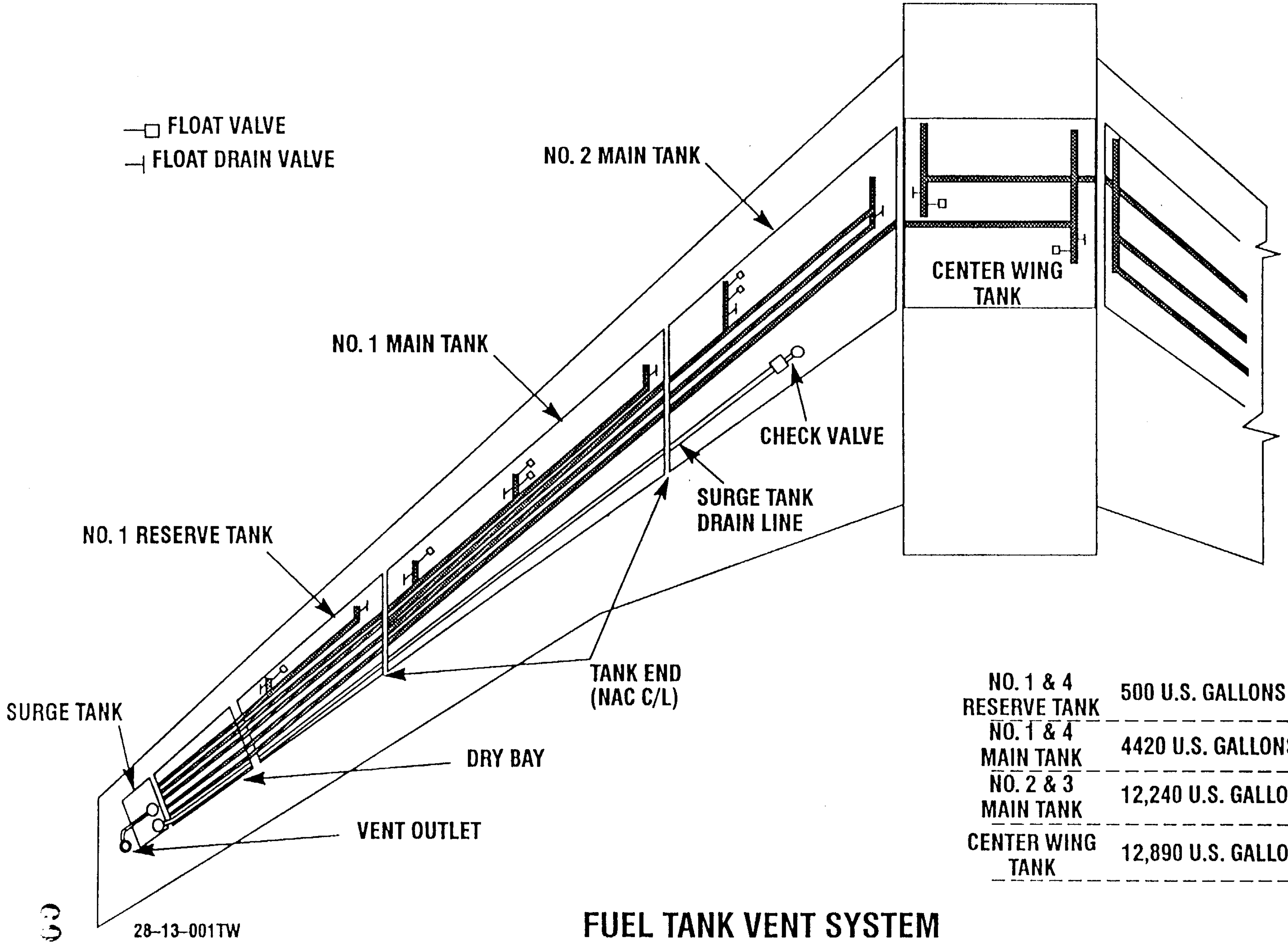


A/P 28-13-00



NO. 1 & 4 RESERVE TANK	500 U.S. GALLONS
NO. 1 & 4 MAIN TANK	4420 U.S. GALLONS
NO. 2 & 3 MAIN TANK	12,240 U.S. GALLONS
CENTER WING TANK	12,890 U.S. GALLONS

FUEL TANK VENT SYSTEM

747 ALL
10/88

C00128

SYSTEMS MANUAL
ATA
28-15-00

ANALYTICAL ENGINEERING REPORT

TO: R. D. Roy 04-03
CC:

NO.: 9-5576-WP-97-280
ITEM NO.: Chem 6016
DATE: July 31, 1997
MODEL: Ev. EQA

GROUP INDEX: 9-5576 - Analytical Engineering, Chemical/Physical

SUBJECT: Identification of Five Contaminant Samples from a Fuel Scavenge Pump
(FROM N93105. R Swain)

Five samples of solid debris that had been removed from a fuel scavenge pump from a 747 were submitted for identification. The samples consisted of the rear grommet of a P/N MS24264R1075PNX connector, two fragments of gray elastomer, a fragment of metal and a small chunk of what appeared to be a mineral material.

FINDINGS

The five samples have been identified as follows:

(1) From Damaged Connector Rear Grommet - Silicone Polymer, Not Recommended for Use in a Fuel Environment

(2) From Discharge Relief Valve Cavity - Non-chromate Polysulfide Fuel Tank Sealant

(3) From Pressure Relief Valve - Chromated Polysulfide Fuel Tank Sealant

(4) From Pump Discharge Chamber - Metallic Aluminum Fragment (1000-Series or Pure Aluminum)

(5) From Service Shut-Off Valve - Crystalline Silica Mineral Particle

EXPERIMENTATION AND RESULTS

The samples were inspected optically, and were analyzed by infrared microspectroscopy and/or electron microprobe.

Connector Rear Grommet. The damaged grommet, shown in Figure 1A, had a strong fuel odor. An electron microprobe elemental survey and infrared spectrum of the grommet material, presented in Figure 2, show that the elastomer consists of a dimethylsiloxane type silicone polymer. Reference spectra of silicone and fluorosilicone products are presented in Figure 3 for comparison. Silicone polymers of this class are not rated for fuel exposure, and can be expected to swell and soften when exposed to fuel. Fluorosilicone, fluorocarbon and nitrile rubber are fuel-compatible elastomers.

FACTUAL
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Elastomer Fragment from the Discharge Relief Valve Cavity. The dark gray elastomer fragment from the discharge relief valve cavity is shown in Figure 1B. Analytical results, presented in Figure 4, are indicative of a non-chromate polysulfide sealant such as BMS 5-26 Type II, containing calcium carbonate and titanium dioxide fillers and manganese oxide catalyst. Reference spectra of a polysulfide polymer and of calcium carbonate are presented in Figure 5 for comparison (the titanium dioxide and manganese dioxide absorptions are too weak to contribute significantly to 4B). This type of sealant is compatible with the BMS 10-20 Type II chromate primer used in fuel tanks, and some green primer was observable on the surface of the sealant fragment.

Elastomer Fragment from the Pressure Relief Valve. This larger fragment of elastomer, shown in Figure 1C, is represented by the data in Figure 6. This fragment is also polysulfide sealant, but is a different product than that found in the discharge relief valve cavity. This fragment contained no calcium carbonate, but did contain strontium chromate. Other particulates, including what appear to be aluminum silicate, were present.

Metal Fragment from Pump Discharge Chamber. The sample is shown in Figure 1D, and an electron microprobe elemental survey is presented in Figure 7. Clearly, the particle consists of aluminum. With the exception of a low concentration of magnesium (0.3 percent) and a location-dependent varying concentration of silicon (1 to 3 percent), only trace concentrations of other elements (Cu, Mn, Zn, Ni) were detectable. Based on these results, the particle has been tentatively identified as a low strength 1000 series alloy, which is essentially pure aluminum. The origin of the particle is not known. A small quantity of polysulfide sealant like that recovered from the discharge relief valve cavity was present on the surface of the sample.

Mineral Particle from Service Shut-Off Valve. Results for the mineral fragment, shown in 1E, are presented in Figure 8. As demonstrated by the data and the reference spectrum, the particle consists of crystalline silica and most likely had its origin in the environment.

Prepared by D. Bruce Skoropinski
D. B. Skoropinski
M/S 73-09, 234-2666

Approved by
W. L. Plagemann
M/S 73-09, 234-3025

Electron Microprobe: J. C. Wessel
Photography: J. M. Packard

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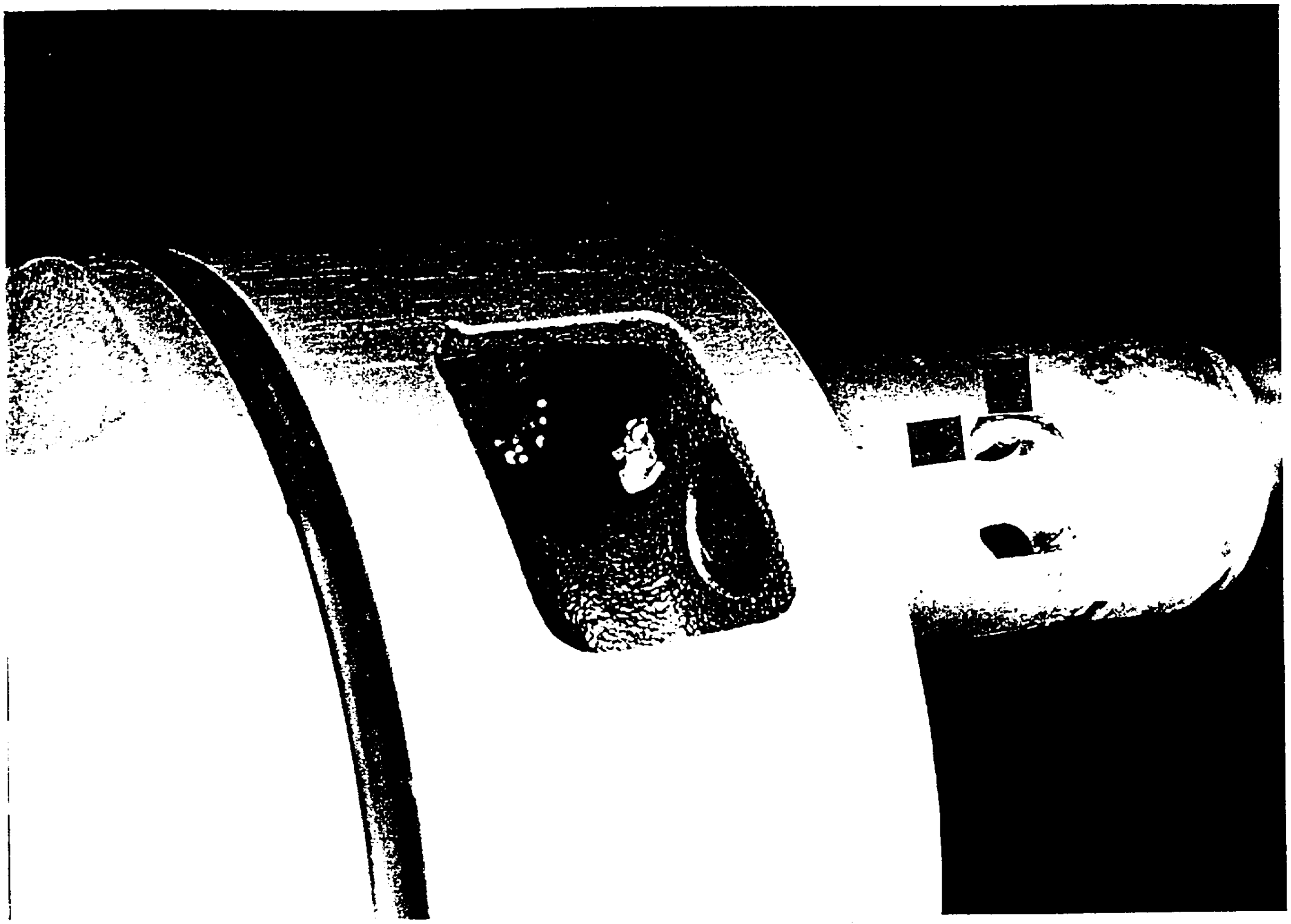
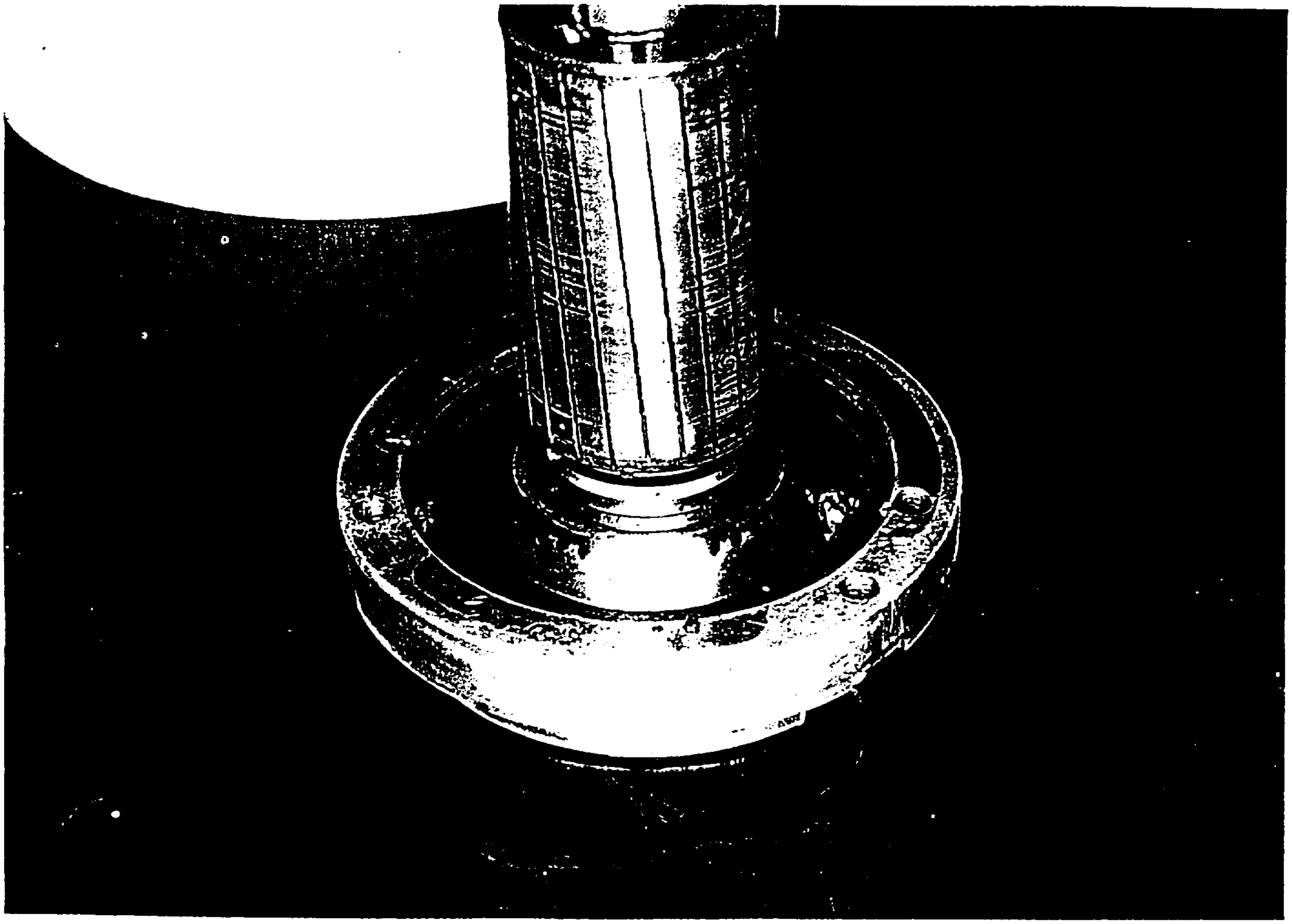
ATA 28.15.00



Reference paragraph 5.3.4 &5.3.5, A piece of non magnetic metal approximately 0.194" by 0.092"was found in the pump discharge chamber of the pump housing [P/N RR24675-1]. Red arrow indicates a piece of rubber type material approximately 0.297" by 2.16" by 0.048" thick, was also found jammed in the pressure relief valve [P/N RD24684].

EQUIPMENT QUALITY ANALYSIS
EQA NUMBER: 1659T
PHOTO NUMBER: 9

ATA 28-15-00



Reference paragraph 5.8, Examination of the AC motor stator assembly [P/N RG21865] revealed several pieces of red rubber through out the assembly.

EQUIPMENT QUALITY ANALYSIS
EQA NUMBER: 1659T
PHOTO NUMBER: 24

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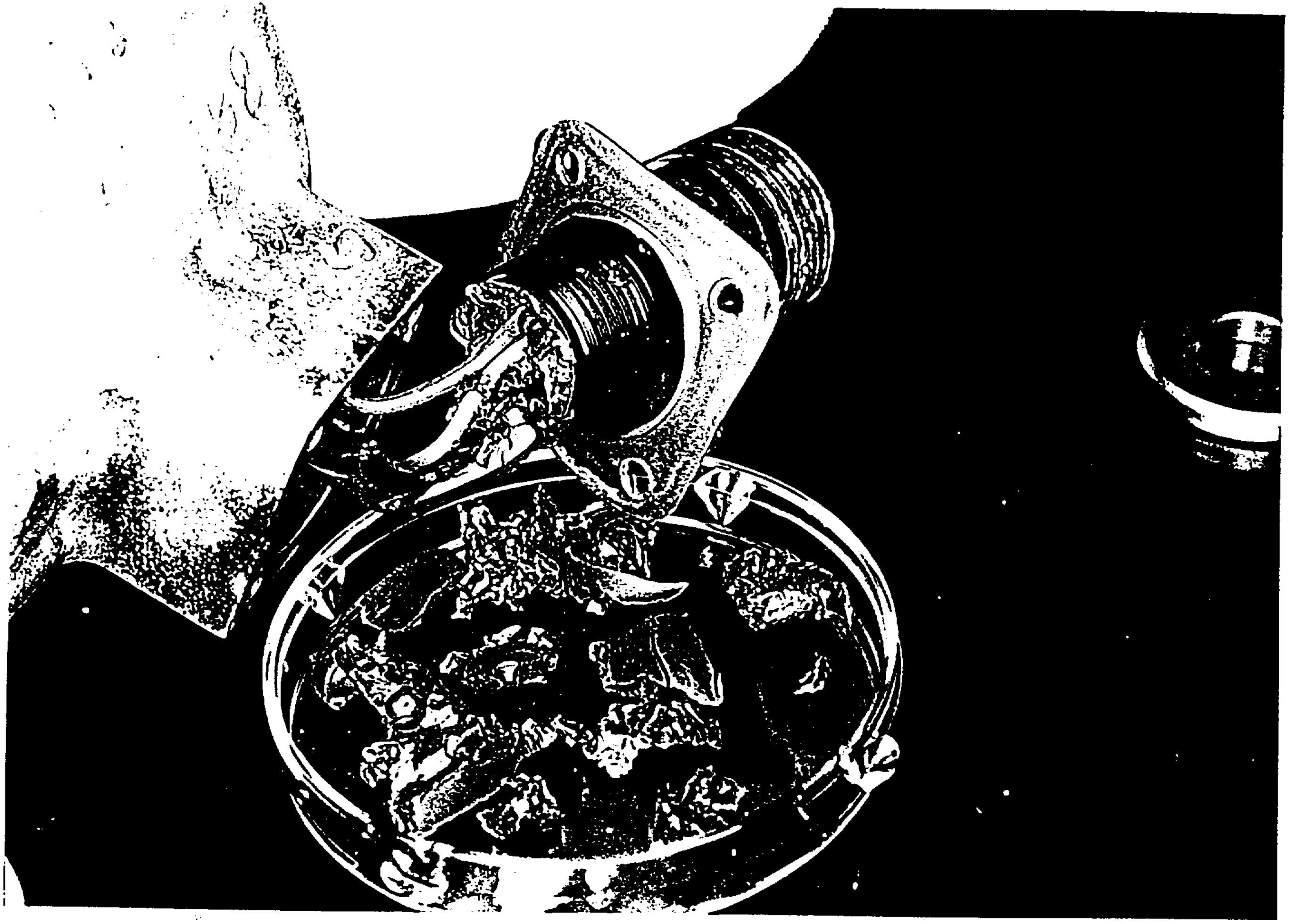
ATA 28-15 00

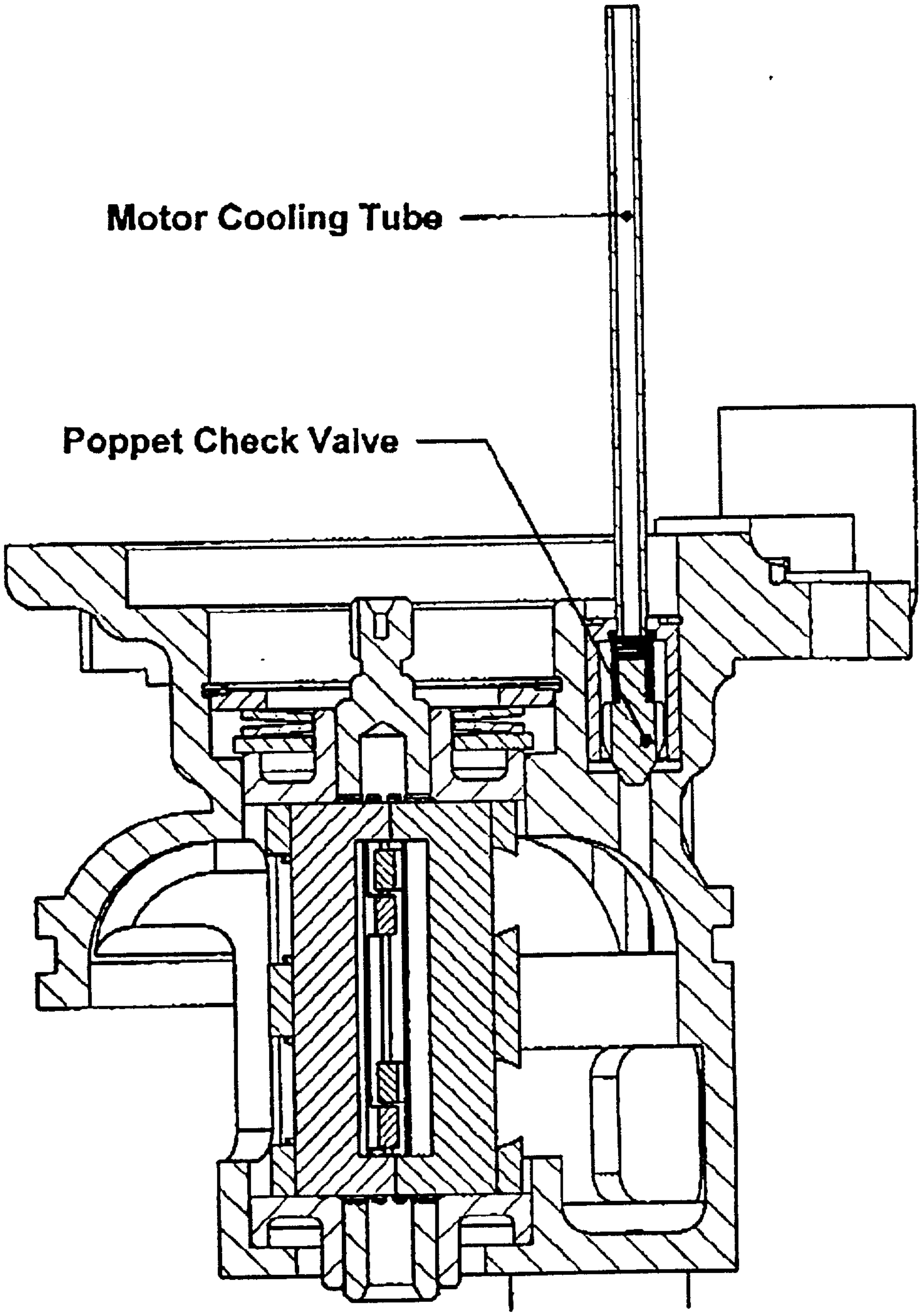


Reference paragraph 5.8.2, The protective sleeving and connector grommet had deteriorated due to contamination and exposure to fuel.

EQUIPMENT QUALITY ANALYSIS
EQA NUMBER: 1659T
PHOTO NUMBER: 26

SYSTEMS FACTUAL

ATA 28-15-00



B-747 Scavenge Pump Subassembly Cross-Section

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

SYSTEMS FACTUAL
ATA 28-15-00

May 12, 1997
B-B600-16120-ASI

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

BOEING

Subject: Fuel Pump Materials, TWA 747-100 N93119, Accident off Long Island, New York on July 17, 1996

Reference: Your e-mail to Kevin, dated 3/25/97

Dear Mr. Swaim:

In questions 1 through 5 of your reference fax, you requested that we identify the materials used in the scavenge and override/jettison pumps.

Enclosed with this letter is the information you requested in your questions 1 through 5. Our responses to questions 6 through 15 were provided to you earlier. This completes our reply to the reference message.

If you have any further questions, please feel free to contact me at any time.

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

Enclosure: As noted (14 pages)

cc: Mr. A. Dickinson, IIC

SYSTEMS FACTUAL
ATA 28-15-00

(1) What is the material used for the scavenge pump vanes?

The Scavenge Pump part number from R0103/RA164 is unknown at this time. The original Pump that would have been installed, according to the tabulation on the installation drawing 65B92406, is the 60B92403-2/-5 combination. Later this part number was superceded by 60B92403-12, -13 and -18. Backwards compatibility was maintained. A spares provisioning note in the drawing states that the "-18 can replace or be replaced by -5 or -12 or -13. 60B92403-18 is the preferred spare." It may be possible to confirm, from TWA maintenance records, the exact part number that was flying on the airplane at the time of the accident.

The following is a summary of Pump and the corresponding detail part data:

60B92403	Supplier	Supplier Assy	Blade P/N	Material/Finish
-5	Lear Siegler, Inc. Romec Div.	RR24680	RS26179-114	Steel
	" "		RS26177-114	Steel
-12	Intertechnique			
-13	Intertechnique	218 386-2	218 668	Carbon Composite
			218 496	Carbon Composite
-18	Intertechnique	218 386-3	218 941	Carbon Composite
			218 942	Carbon Composite

(2) Is there any point in the fuel pump where two steel parts would come in contact (or nearly so)?

For the Scavenge Pump; yes, there are pump configurations having steel parts that *would* be in contact with each other. See the attached figures. There are other steel parts in the pumps such as screws, washers and springs that are not necessarily in contact, but are "nearly so".

The -5 pump, which would have been included with the original delivered configuration of R0103/RA164, has all pumping elements, rotor, blades and sleeve, made of a case hardened steel. In the case of the -18 pump, the current configuration, the rotor and liner, are steel, and blades are a carbon composite.

SYSTEMS
ATA 28-15-00

(3) Override/Jettison Pump Steel Parts.

One TWA800 O/J Pump assembly P/N is known to be the 60-703104 (Hydro-aire). This pump was the Right Center Tank pump, recovered from the wreckage. The Left Center Tank pump P/N is not known. According to the engineering drawing spares notes, any one of the pump assemblies below could possibly have been installed in the Left Center pump location.

60B92403	Supplier		Supplier Assy. P/N	Inlet Impeller P/N Priming Impeller	Material/Finish
-3	Crane/Hydro-aire		60-70303	60-70321 60-75538	2024-T351 Aluminum Type 316 CRES
-7	"	"	60-70306	60-70321 60-75538	2024-T351 Aluminum Type 316 CRES
-9	"	"	60-70307	60-70321 60-75538	2024-T351 Aluminum Type 316 CRES
-10	"	"	60-70308	60-70385 60-75538	2024-T351 Aluminum Type 316 CRES
-11	"	"	60-70309	60-70385 60-75538	2024-T351 Aluminum Type 316 CRES
-13	"	"	60-703103	60-70385 60-75538	2024-T351 Aluminum Type 316 CRES
-14	"	"	**60-703104**	60-70385 60-75538	2024-T351 Aluminum Type 316 CRES
-15	"	"	60-703113	60-70385 60-75538	2024-T351 Aluminum Type 316 CRES
-17	"	"	60-72101	60-72118/60-72112 60-75538	2024-T351/2024-T351 Type 316 CRES
-18	"	"	60-72301		

The Override/Jettison pump has both a priming impeller and inlet impeller. Although the materials used in these parts are the same for all configurations, they are used in combination with adjacent parts of various materials including aluminum, bronze and CRES. The attached figures are representative of the above configurations with respect to the presence of steel parts used in the pumps.

In response to question (2), for the Override/Jettison Pump; yes, there are pump configurations having steel parts that *would* be in intimate contact with each other. There are other steel parts in the pumps such as screws, washers and springs that are not necessarily in contact, but could be considered "nearly so".

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What materiel is used to seal the scavenge and jettison pump electrical connectors?

Hydro-Aire Fuel Pumps (override/jettison)

220(A) Potting compound (uses 951 hardener) to pot wires on back side of connector. Used for over 27 years for this application on all 747 fuel pumps.

RTV 730 (with RTV 1205 and 1200 primers) is used on new production 60B89004 and overhauled pumps approximately between 1993 and 1996. This was used to stop the accumulation of contaminates (water trap) next to the connector body. Also the potting was used to stop ingress of moisture into the interfaces of the feed through connector. This is a silicone based sealant.

The hermetic seal connector uses glass between the pins and the connector case as the sealing material.

On all new configuration pumps starting Nov 1996 tank sealant (Pro-Seal 890, B-2 per BMS 5-26 Type II CL B-2) is used on the environmental side of the connector to seal the gaps/interface between the feed through connector and its backshell from ingress of water and contaminates.

Lear Siegler Fuel Pumps (CWT scavenge pump).

The feed through connector is an environmentally sealed connector with a standard part number MS24264R10T5PNX (per MIL-C-26500) that has a silicone rubber grommet/insert.

No sealants or potting compounds are applied to this connector/interface.

The Supplier Component Maintenance Manual recommends the use of DC-200 Silicone oil or equivalent be applied to ease the insertion of the contacts.

Post-it™ Fax Note 7671

To TIM MITCHELL
Co./Dept. BOEING
Phone #
Fax # % LOU TAYLOR
612 957 4195

Date
# of pages ▶ 19
From MAC MAHESH
Co.
Phone # 342 4099
Fax #

BOEING

Commer
Airplane
Group

ALERT

Number: 747-28A2208
Date: September 25, 1997

Summary

ATA System: 2815

SYSTEMS FACTUAL
ATA 28-15-00

SUBJECT: FUEL - STORAGE - CENTER WING TANK SCAVENGE PUMP INSPECTION

BACKGROUND

This inspection will make sure the center wing tank scavenge pump connector is not damaged and will not leak fuel.

The Lear Romec component maintenance manual (CMM) 28-20-01 for the RR24360 scavenge pump had the wrong connector part number specified. Contact with fuel may cause deterioration of the MS24264 connector that was specified in this CMM.

We have not received any reports of leaking center tank scavenge pumps. We have not received any reports that scavenge pumps have been removed because of damage to the electrical connector.

The Lear Romec scavenge pump which is the subject of this inspection was delivered on 747 airplanes through line number 344. It is possible the pump was installed on airplanes after line number 344 as an interchangeable spare part.

An inspection of the scavenge pump electrical connector part number will make sure that the correct connector is installed.

ACTION

Disconnect the center tank scavenge pump airplane electrical connector. Do an inspection of the pump's electrical connector part number. If the correct part number connector is installed, put back the airplane electrical connector.

If a different pump connector part number is installed, replace the scavenge pump with one that has the correct pump connector part number or is a different part number pump.

Do an operational test of the scavenge pump.

If a spare pump is not available, the airplane can be operated with the scavenge pump deactivated. For the 747, refer to the 747-100/-200/-300/SP Dispatch Deviations Procedures Guide page 2.28.22.0 for more data. For the 747-400, refer to the 747-400 Dispatch Deviations Guide page 2-28-25-1.0 for more data.

COMPLIANCE

Boeing recommends that this inspection be done at the earliest opportunity where manpower and facilities are available.

EFFECTIVITY

All 747 airplanes line positions 001-971.

INDUSTRY SUPPORT INFORMATION

At the time of release of this service bulletin, warranty remedies have not been determined. A subsequent revision or Notice of Status Change will address the warranty remedies available, if any.

MANPOWER

These man-hours necessary to do the inspection:

Total Man-hours - 1.0 for each airplane
Elapsed Time - 1.0 Hours

These man-hours necessary to replace the pump:

Total Man-hours - 4.0 for each airplane
Elapsed Time - 1.0 Hours

SYSTEMS MANUAL
ATA 28-15-00

B. Reason

This inspection will make sure the center wing tank scavenge pump connector is not damaged and will not leak fuel.

The Lear Romec component maintenance manual (CMM) 28-20-01 for the RR24360 scavenge pump had the wrong connector part number specified. Contact with fuel may cause deterioration of the MS24264 connector that was specified in this CMM.

We have not received any reports of leaking center tank scavenge pumps. We have not received any reports that scavenge pumps have been removed because of damage to the electrical connector.

The Lear Romec scavenge pump which is the subject of this inspection was delivered on 747 airplanes through line number 344. It is possible the pump was installed on airplanes after line number 344 as an interchangeable spare part.

An inspection of the scavenge pump electrical connector part number will make sure that the correct connector is installed.

C. Description

The center tank scavenge pump airplane electrical connector is disconnected. An inspection of the pump's electrical connector part number is done. If the correct part number connector is installed the airplane electrical connector is put back.

If a different pump connector part number is installed, the scavenge pump is replaced with one that has the correct pump connector part number or is a different part number.

An operational test of the scavenge pump is done.

If a spare pump is not available, the airplane can be operated with the scavenge pump deactivated. For the 747, refer to the 747-100/-200/-300/SP Dispatch Deviations Procedures Guide page 2.28.22.0 for more data. For the 747-400, refer to the 747-400 Dispatch Deviations Guide page 2-28-25-1.0 for more data.

D. Compliance

Boeing recommends that this inspection be done at the earliest opportunity where manpower and facilities are available.

E. Approval

This service bulletin was examined by the Federal Aviation Administration (FAA). The changes specified in this service bulletin comply with the applicable Federal Aviation Regulations (FAR) and are FAA approved. This service bulletin and the FAA approval were based on the airplane in its original Boeing delivery configuration or as modified by other FAA approved Boeing changes

If an airplane has a non-Boeing modification or repair that affects a component or system also affected by this service bulletin, the operator is responsible for obtaining appropriate regulatory agency approval before incorporating this service bulletin.

F. Industry Support Information

At the time of release of this service bulletin, warranty remedies have not been determined. A subsequent revision or Notice of Status Change will address the warranty remedies available, if any.

SYSTEMS FACTUAL
ATA 28 15-00

III. ACCOMPLISHMENT INSTRUCTIONS

NOTES:

1. The paragraphs identified with a letter give the general work instructions and the necessary tests. The instructions identified with numbers on the figures give the recommended sequence of steps.

2. Obey all of the warnings and cautions given in the specified manual sections.

A. Find the part number of the installed center tank scavenge pump motor. If the part number is not RR24680 (Boeing Specification number 65B92403-5) , no more action is necessary. If the part number is RR24680, do these steps:

   1. For the 747:

      a. On the P12 panel, open the SCAVENGE PUMP CONTROL circuit breaker and attach a DO-NOT-CLOSE tag.

      b. On the P6 panel, open the SCAVENGE PUMP circuit breaker and attach a DO-NOT-CLOSE tag.

      For the 747-400:

      a. On the P180 panel, position H2, open the SCAV PUMP CONT circuit breaker and attach a DO-NOT-CLOSE tag.

      b. On the P414 panel, position M2, open the SCAVENGE PUMP circuit breaker and attach a DO-NOT-CLOSE tag.

   2. Do an inspection of the scavenge pump motor as specified in Figure 1.

      WARNING: DO NOT REMOVE THE LANDING GEAR DOOR LOCKS AS SPECIFIED IN THE AMM PROCEDURES IN THE NEXT STEP. RAPID ACTION OF THE DOORS CAN CAUSE INJURY TO PERSONNEL OR DAMAGE TO EQUIPMENT.

   3. If the part number of the connector is ZZY-AC-1710-5P or ZZL-AC-1710-5P, continue to the next step. If any other part number connector is installed, replace the scavenge pump. Refer to the 747 AMM 28-15-01 or 747-400 AMM 28-15-01 for the removal and installation procedures. Make sure the new pump has the correct connector part number or is a different part number pump. Refer to the 747 or 747-400 IPC 28-15-01-01 to get the replacement pump part numbers. It is not necessary to do a test of a replaced scavenge pump at this time.

      If a spare pump is not available, the airplane can be operated with the scavenge pump deactivated. For the 747, refer to the 747-100/-200/-300/SP Dispatch Deviations Procedures Guide page 2.28.22.0 for more data. For the 747-400, refer to the 747-400 Dispatch Deviations Guide page 2-28-25-1.0 for more data.

      NOTE: Refer to the Lear Romec Service Bulletin RR24360-28-001 to replace the electrical connector of any removed pump.

SYSTEMS MANUAL

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4. For the 747:

   a. On the P12 panel, remove the DO-NOT-CLOSE tag and close the SCAVENGE PUMP CONTROL circuit breaker.

   b. On the P6 panel, remove the DO-NOT-CLOSE tag and close the SCAVENGE PUMP circuit breaker.

   For the 747-400:

   a. On the P180 panel, position H2, remove the DO-NOT-CLOSE tag and close the SCAV PUMP CONT circuit breaker.

   b. On the P414 panel, position M2, remove the DO-NOT-CLOSE tag and close the SCAVENGE PUMP circuit breaker.

5. For the 747-400, do an operational test of the scavenge pump as specified in the 747 AMM 28-15-01, Do the Operational Test for the Scavenge Pump.

   For the 747, do these steps:

   a. On the P4 panel, set the SCAVENGE PUMP switch to the ON position.

   b. Make sure the scavenge pump operates (listen or feel for a vibration).

   c. On the P4 panel, set the SCAVENGE PUMP switch to the OFF position.

<u>WARNING:</u> DO NOT TRY TO REMOVE THE LANDING GEAR DOOR LOCKS WHEN THERE IS PRESSURE TO THE HYDRAULIC SYSTEM. RAPID ACTION OF THE DOORS CAN CAUSE INJURY TO PERSONNEL OR DAMAGE TO EQUIPMENT.

B. Remove the wing and body gear door locks. Refer to the 747 AMM 32-00-30 or the 747-400 AMM 32-00-30 for the necessary procedures.

C. Remove the electrical power if it is not necessary. Refer to the 747 AMM 24-22-00 or the 747-400 AMM 24-22-00 for the necessary procedures.

D. For airplanes RA161-RA163 only, another scavenge pump can be installed. Refer to the 747 IPC 28-15-01-10, Item 612, to get the location of the second scavenge pump. Use the usual airplane maintenance practices to do the connector part number inspection on this scavenge pump.

E. Put the airplane back into serviceable condition.

SYSTEMS FACTUAL
ATA 28-15 00

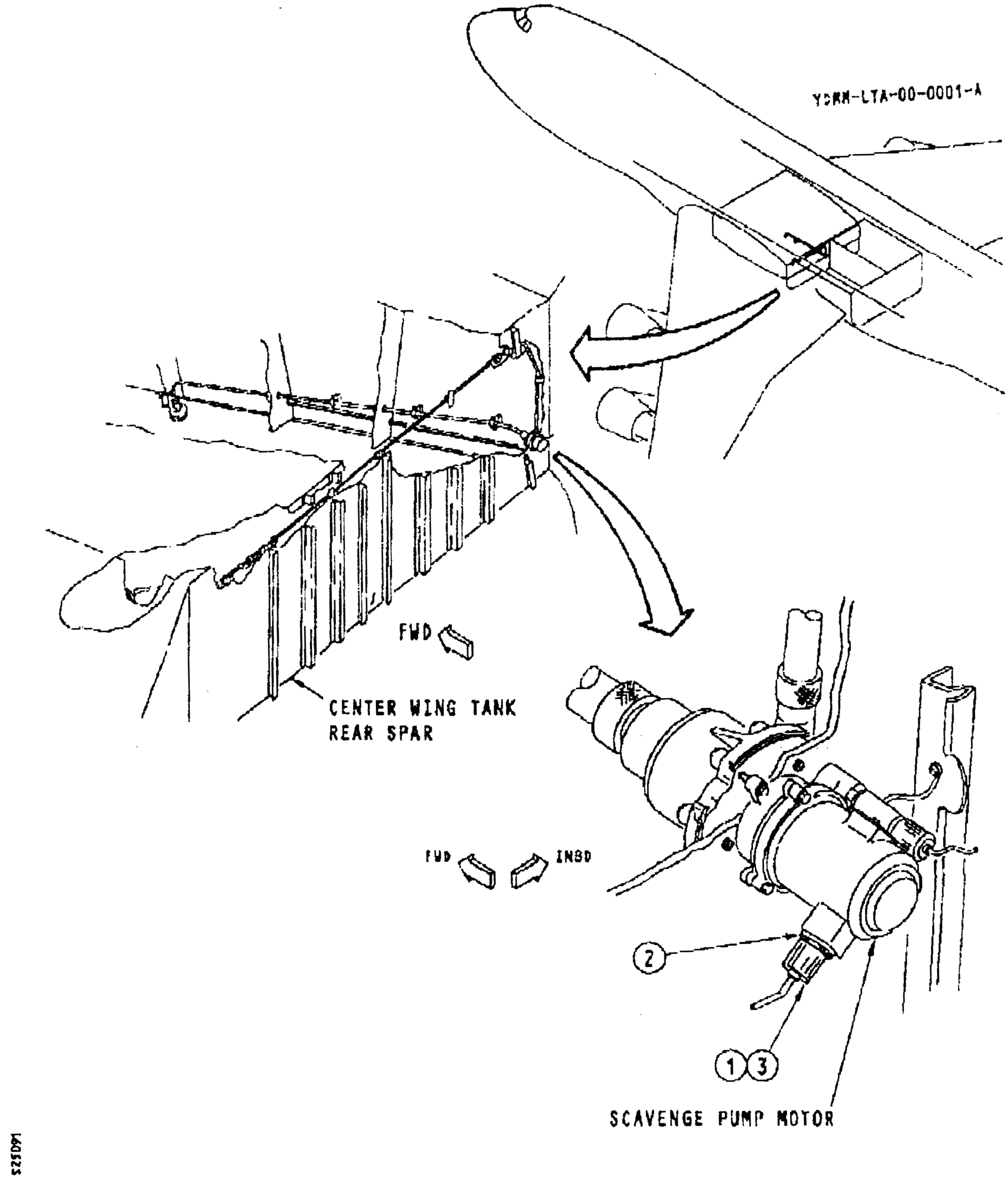


FIGURE 1. DO AN INSPECTION OF THE SCAVENGE TANK CONNECTOR PART NUMBER

SYSTEMS FACTUAL
ATA 28 15 00

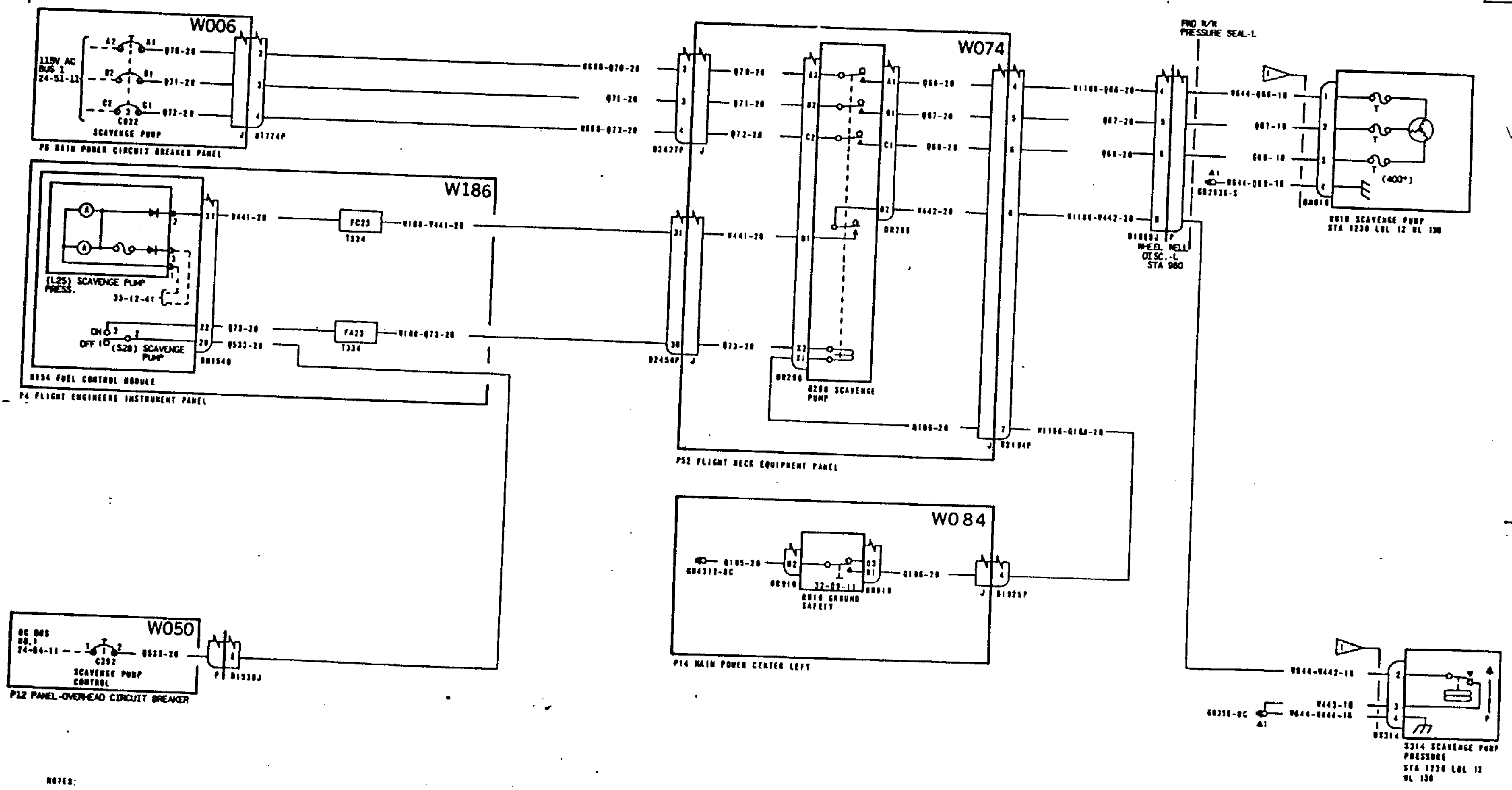
The step numbers shown below agree with the numbers shown in the circle symbols in the figure.

STEP	TASK	NAME	PART NUMBER	QTY	NOTES
1	Disconnect	Connector	--	1	
2	See	Part Number	--	1	Look at the part number of the electrical connector installed on the scavenge pump. Write the part number of the connector.
3	Connect	Connector	--	1	

FIGURE 1. DO AN INSPECTION OF THE SCAVENGE TANK CONNECTOR PART NUMBER

SHEET 2 OF 2

ATA 28-15-11



NOTES:

1 20 GAGE WIRE FOR 102-108 (RA102-RA109)

DRAFTED BY Gill
CHECKED BY

DRAWING NO. 61B74702
PAGE DATE. SEP 27/77

DCN: U
CHANGE:

M.O.			SCAVENGE PUMP
TWA	DWG NO. 1-04251	SHT 1	CHG
RA101-RA109			EFFECTIVITY ALL

SYSTEMS MANUAL

ATA 28-22-00

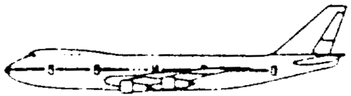
BOEING

BOEING COMMERCIAL AIRPLANE COMPANY P.O. BOX 3707 SEATTLE, WASHINGTON 98124

ALERT

PLEASE NOTIFY BOEING
OF YOUR PLANNED ACTION
AND INSPECTION RESULTS

SERVICE BULLETIN



747

ATA 2820
SYSTEM:

NO: 747-28A2092
DATE: February 12, 1979
REVISION 1: April 27, 1979

SUBJECT: MAIN FUEL TANK PUMP WIRING INSPECTION, REWORK, AND MODIFICATION

NOTE: THIS SERVICE BULLETIN IS BEING SENT TO ALL AFFECTED OPERATORS WHO NORMALLY RECEIVE SERVICE BULLETINS FROM BOEING. OPERATORS WHO HAVE LEASED AIRPLANES SHOULD FORWARD THIS INFORMATION TO THE LESSEE. OPERATORS WHO HAVE SOLD AIRPLANES SHOULD FORWARD THIS INFORMATION TO THE NEW OWNER, UNLESS 30 DAYS HAS ELAPSED SINCE BOEING HAS RECEIVED NOTIFICATION OF THE SALE.

I. Planning Information

A. Effectivity

1. Airplanes Affected

An equivalent change will be incorporated in production in accordance with PRR 79382 on applicable airplanes other than those listed below.

CUSTOMER & CUSTOMER NO.	MODEL & SERIES	MFG. SERIAL NO.	REGISTRY NO.
GROUP I			
AF (AIR FRANCE) RA251-RA254	747-128	19749 THRU 19752	F-BPVA THRU F-BPVD

ATA 28 22 00

B. Reason

This inspection, repair, and modification will preclude electrical arcing into main fuel tanks No. 2 and 3 that may result from damaged wires which provide power to the No. 1 and 4 main fuel tank boost pumps.

Two main fuel boost pumps for each of the Nos. 1 and 4 main fuel tanks are located in a dry bay area (dog house) near the outboard end of the Nos. 2 and 3 main fuel tanks. Electrical wiring to the pumps is installed in aluminum conduit routed through the Nos. 2 and 3 tanks between the wing rear spar and the dog house.

Recently, one operator, investigating the cause of a fuel leak in an auxiliary fuel tank, found a small hole burned through the conduit that houses the electrical wires to the auxiliary fuel tank pump. Reportedly, a wire had abraded against the inner conduit wall, exposing the conductor, and arcing from the conductor to the conduit produced the hole through which fuel escaped. Alert Service Bulletin 747-28A2091 was released to four affected overseas operators and recommended an inspection, repair, and modification of auxiliary fuel tank pump wiring.

The conduit and wiring installations for the Nos. 1 and 4 fuel tank boost pumps are similar but not identical to the auxiliary fuel tank installations. An inspection of the main fuel tank boost pump wiring was initiated on selected airplane groups in order to evaluate the possible extent that wire chafing may exist in the fleet. Partial results of the survey to date indicate the existence of chafing and/or abrasion in varying degrees of the main boost pump wire insulation. Damaged wires were reported on airplanes that had accumulated approximately 40,500, 23,000, 22,000, 20,000, and 15,000 flight-hours. No wires were reported that had worn through the insulation to the conductor.

In summary, of 25 wire bundles inspected, 16 were reported to have some degree of damage. The reported chafing and abrasion is attributed to vibration of the wires against the conduit wall. Initial findings from the survey indicate that the degree of wire insulation damage is related to airplane flight-hours.

SYSTEMS FACTUAL
ATA 28 00 100

C. Description

The Nos. 1 and 4 main fuel tank forward and aft fuel boost pump wire bundles between each pump and the wing rear spar should be inspected for chafing and abrasion or other damage; repaired or replaced as necessary; and, modified by providing additional protection against damage.

Inspection of each wire bundle requires removal of electrical connectors at the pump and pulling the wires out of the conduit at the wing rear spar. The wires should then be cleaned and closely inspected for damage. Damaged wires should be replaced or repaired as necessary. If electrical arcing or burning is evident, the conduit should be inspected, and replaced if necessary.

Terminating action consists of tying the wire bundles at six inch intervals and installing two concentric teflon sleeves over the wires. The wire bundle is then reinstalled in the conduit, the electrical connectors are reinstalled, and the boost pump should be operationally checked.

Affected airplanes are divided into two groups. Group I airplanes (line position 001 through 054) were delivered with boost pump wires that exhibit better wear characteristics than the wires on later (Group II) airplanes.

It is recommended that the inspection, repair, and terminating action be accomplished at the next, planned maintenance period on Group I airplanes with less than 30,000 flight-hours and on Group II airplanes with less than 6000 flight-hours.

It is recommended that the inspection, repair, and terminating action be accomplished on Group I airplanes with 30,000 or more flight-hours, and on Group II airplanes with 6000 or more flight-hours, at the earliest opportunity when manpower and facilities are available within the next 750 flight-hours or two months calendar time, whichever is earlier.

Revision 1 changes the type of knot used to tie the wire bundles prior to sleeving. It also deletes an airplane, previously modified at Boeing, from the effectivity.

Airworthiness Directive 79-06-02 has been issued on this subject.

NOTE: PLEASE NOTIFY BOEING OF YOUR PLANNED ACTION AND INSPECTION RESULTS.

[illegible] 28 20 00

D. Approval

The inspection and rework described herein has been approved by the FAA Designated Engineering Representative at the Boeing Commercial Airplane Company and coordinated with FAA Northwest Region Engineering and Manufacturing Branch ANW-210.

E. Manpower

Approximately 20 man-hours and a crew of 4 men are required to accomplish this modification per airplane.

F. Material - Price and Availability

The kits identified in Paragraph II.A. may be obtained from Boeing within the terms and conditions defined below. After expiration of the quotation, price and delivery data will be provided upon request.

The delivery quotation below indicates the date when initial kits will be available. When source capacity is limited and tooling or material availability is the pacing factor, customer purchase orders will receive an allocation, from the available quantities, based on receipt date of purchase order by the Spares Department and based on operator's planned modification schedules. It is therefore requested that customer purchase orders include planned dates of incorporation.

Kit Number	Description	Delivery	Unit Price
61B74794-629	Kit, Standard Airplanes	Available	No Charge
61B74794-630	Kit, SP Airplanes	Available	No Charge

Date February 12, 1979

The prices quoted are subject to the terms and conditions of Boeing's standard purchase order acknowledgement. Quotations are subject to acceptance within 120 days from date hereon.

Any items which are offered at "No Charge" are subject to charge after expiration of the 120-day period.

Prices quoted in United States Dollars. Terms: Net 30 days.

Address purchase orders and correspondence pertaining to this quotation to Director of Spares, and refer to this service bulletin number.

SYSTEMS FACTUAL
ATT [illegible]

III. Accomplishment Instructions

NOTE: The following paragraphs outline the general accomplishment instructions and detailed test requirements. The suggested sequence of operations and detailed accomplishment instructions are indicated by circle notes on the figures.

A. Open the following circuit breakers:

Nomenclature	Location (Panel)
NO. 1 AFT & NO. 4 FWD BOOST PUMP CONTROL	P12
NO. 1 MAIN AFT BOOST PUMP	P14
NO. 4 MAIN FWD BOOST PUMP	P14
NO. 1 FWD & NO. 4 AFT BOOST PUMP CONTROL	P12
NO. 4 MAIN AFT BOOST PUMP	P15
NO. 1 MAIN FWD BOOST PUMP	P15
F/E IND LTS 4	P12
F/E IND LTS 5	P12

B. Remove access panel from applicable boost pump dog house (two per wing).

C. Inspect and rework wire bundle per Figures 1 and 2.

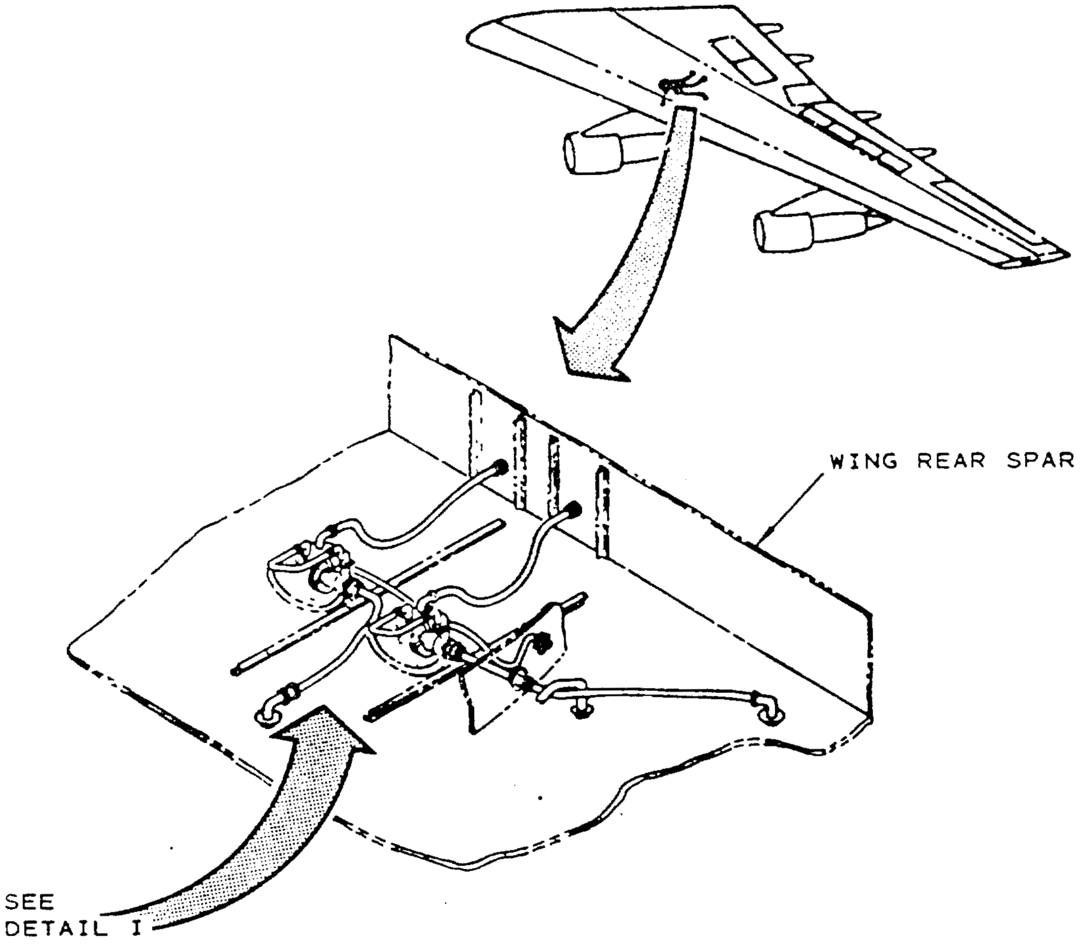
SYSTEMS [illegible]
ATA [illegible]

D. Confirm proper phase sequence, using 115/200v ac, 3-phase, ABC phase sequence meter, nominal 400 cps as follows:

1. At each pump, before attaching the plug to the receptacle, insert phase sequencing meter.
2. Ensure that the phase sequence on the plug is A, B, C for pins No. 1, 2, and 3.
3. Check for continuity to ground on pin No. 4.

NOTE: For phase check, close only the applicable pump circuit breaker and ac bus circuit breaker prior to actuating each switch on the P4 panel.

E. Restore access panel and close circuit breakers; perform operational check of pump (Ref: 747 Maintenance Manual Subject 28-22-00).



① Unclamp wire bundle W1210, W1214, (and W602 at left side inboard position), W1216 or W1212 inside pump doghouse (located approximately at WS708, WS680, WS680 and WS708, respectively).

② Disconnect pump connector DM22, DM28, DM27 or DM32 and pressure switch connector DS62, DS63 (and DS106), DS72 or DS71, respectively. Remove connectors from bundle.

③ Attach pull cord to pump end of bundle (in order to reinstall in conduit after inspection and sleeving).

FIGURE 1. WIRE BUNDLE INSPECTION AND REWORK

[illegible]
AA 28-22-00

④ Remove bundle from clamp on rear side of rear spar (inboards located at approximately WS692 and outboards at WS711).

NOTES: 1. Outboard positions may require removal of second, lower clamp to allow easier handling of bundle.

2. Right side outboard position requires extra effort and time due to proximity of cable pulley.

⑤ Pull bundle out of conduit from rear side of rear spar. Tie off pull cord at doghouse end so it will not be inadvertently drawn through. Remove any wire ties that served as a manufacturing facility and were inadvertently left installed on the wire bundle.

⑥ NOT SHOWN - Clean wires using approved solvents (Ref: 747 Wiring Diagram Manual Chapter 20). Inspect wires for burn damage or chafing. Repair or replace damaged or chafed wire as applicable (Ref: 747 Wiring Diagram Manual Chapter 20).

NOTE: If wire replacement is required, ensure that wires are spliced at a location such that the splices will be outside of the conduit.

⑦ If electrical arcing or burning is evident the conduit should be inspected, and replaced if necessary.

⑧ Tie wire bundle and encase in two concentric teflon sleeves; Size #4 inner; Size #0 outer per Figure 2.

⑨ Reinstall tied double-sleeved wire bundle in conduit using pull cord. Detach pull cord.

NOTE: Sleeves should extend from under pump connector clamp thru clamp on rear face of rear spar. No cutting of sleeves should be necessary; under no condition should sleeves be trimmed while on bundle.

⑩ Reinstall clamps, ensuring sleeving is under clamps.

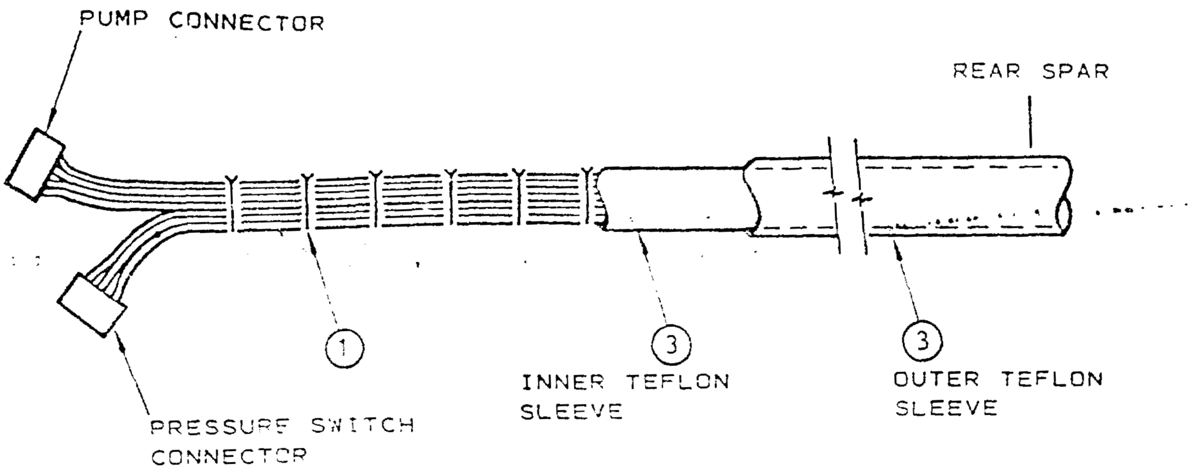
NOTES: 1. Replacement of clamps with larger size may be required due to additional thickness of two sleeves.

2. Ensure, also, that wire bundles are not pulled taut inside the conduit.

⑪ Reinstall connectors on wire bundle and make continuity check (Ref: 747 Wiring Diagram Manual Subjects 28-22-31 and 28-22-32.

FIGURE 1. WIRE BUNDLE INSPECTION AND REWORK

SYSTEMS FACTUAL
ATA 28 22 00



① Before installing sleeves on inspected/repaired wire bundle, tie bundle at 6.0 inch (maximum) intervals, using knots prescribed in 747 Wiring Diagram Manual Subject 20-10-11 (clove hitch and square knot or clove hitch and surgical knot), or the equivalent over the length to be encased in sleeve. See information below for correct sleeve part number and length for each bundle.

② (NOT SHOWN) - Remove pull card from end of bundle and attach second, separate pull cord.

③ Install sleeve (size #4) over bundle using pull cord. Slide sleeve (size #0) over first sleeve.

④ (NOT SHOWN) - Remove pull cord and reattach cord which runs through conduit.

NOTES:

1. Where 4 wire contacts (size #12) will not fit into sleeves, one wire may be bent and taped back (3 contacts will feed into sleeve and fourth will follow). Do not bend wire back sharply; maintain smooth bend.

2. "Mate - with" tag may be removed from third bundle at left inboard location to fit bundle into sleeves.

Position	Part Nos (Size 4 & Size 0) (747-100/-200)	Part Nos. (Size 4 & Size 0) (747 SP)
LS-Outboard	61B74794-62901 & -62902 (74")	61B74794-63001 & -63002 (78")
LS-Inboard	61B74794-62903 & -62904 (68")	61B74794-63003 & -63004 (73")
RS-Inboard	61B74794-62905 & -62906 (71")	61B74794-63005 & -63006 (74")
RS-Outboard	61B74794-62907 & -62908 (72")	61B74794-63007 & -63008 (88")

FIGURE 2. WIRING BUNDLE TYING AND SLEEVING

SYSTEMS MANUAL
ATA 28-22-00

BOEING

Commercial
Airplane
Group

747
Service Bulletin

ALERT

Number: **747-28A2204**
Date: December 19, 1996

ATA System: 2822

Summary

received
12-26-96

SUBJECT: FUEL - DISTRIBUTION - ENGINE FUEL FEED SYSTEM OUTBOARD MAIN TANK BOOST PUMP WIRING INSPECTION

BACKGROUND

This inspection will make sure the number 1 and number 4 main fuel tank boost pump wiring is not chafed and will not cause arcing inside the fuel tank.

The number 1 and number 4 main fuel tank boost pump wiring is installed with a double layer of teflon sleeving in the conduit. The sleeving is installed to prevent arcing between the boost pump power wiring and the conduit caused by wire chafing.

747 airplanes cumulative line numbers 329, 348 and 356 and on had the two sleeves installed in production. All other airplanes were the subject of Alert Service Bulletin 747-28A2092 which inspected the boost pump wiring for damage and installed the two sleeves.

747 airplanes cumulative line numbers 001-432 have aluminum conduits for the main tank boost pumps. All other 747 airplanes have stainless steel conduits. If the boost pump power wiring shorts to the conduit, it is more likely that the aluminum conduit can melt and make a hole. This could result in a fuel leak, fire or an explosion.

We have not been told that chafed wires have caused any conduits to be melted through since Service Bulletin 747-28A2092 was issued.

ACTION

Remove the number 1 and number 4 main tank forward and aft boost pump cover plates. Remove the boost pump wire bundle from the conduit. Inspect the sleeving/wire bundle for damage. Repair any damage that is found. Install the boost pump cover plates. Do a test of the boost pumps.

This inspection assumes that service bulletin 747-28A2092 has been incorporated.

COMPLIANCE

Boeing recommends that this inspection be done at the earliest opportunity when the manpower and facilities are available.

EFFECTIVITY

All 747 airplanes line positions 001-432.

INDUSTRY SUPPORT INFORMATION

Boeing warranty remedies are not available for the inspection given in this service bulletin.

MANPOWER

Total Man-hours - 4.0 for each airplane
Elapsed Time - 2.0 Hours

MATERIAL INFORMATION

Operator Supplied Parts

SYSTEMS FACTUAL
ATA 28-20-00

B. Reason

This inspection will make sure the number 1 and number 4 main fuel tank boost pump wiring is not chafed and will not cause arcing inside the fuel tank.

The number 1 and number 4 main fuel tank boost pump wiring is installed with a double layer of teflon sleevinc e conduit. The sleeving is installed to prevent arcing between the boost pump power wiring a e conduit caused by wire chafing.

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We have not been told that chafed wires have caused any conduits to be melted through since Service Bulletin 747-28A2092 was issued.

C. Description

The number 1 and number 4 main tank forward and aft boost pump cover plates are removed. The boost pump wire bundle is removed from the conduit. The sleeving/wire bundle is inspected for damage. Any damage that is found is repaired. The boost pump cover plates are installed. A test of the boost pumps is done.

This inspection assumes that service bulletin 747-28A2092 has been incorporated.

PLEASE SEND A REPORT OF YOUR INSPECTION PROGRAM. ALSO, SEND THE INSPECTION RESULTS WHEN EACH INSPECTION IS COMPLETE.

SEND TO: BOEING COMMERCIAL AIRPLANE GROUP
ATTENTION: MANAGER, AIRLINE SUPPORT

D. Compliance

Boeing recommends that this inspection be done at the earliest opportunity when the manpower and facilities are available.

E. Approval

This service bulletin was examined by the Federal Aviation Administration (FAA). The changes specified in this service bulletin comply with the applicable Federal Aviation Regulations (FAR) and are FAA approved. This service bulletin and the FAA approval were based on the airplane in its original Boeing delivery configuration or as modified by other FAA approved Boeing changes.

If an airplane has a non-Boeing modification or repair that affects a component or system also affected by this service bulletin, the operator is responsible for obtaining appropriate regulatory agency approval before incorporating this service bulletin.

K. References

1. Existing Data:

    a. 747 Maintenance Manual (AMM) Subject 12-09-08, 28-22-03

    b. Boeing Standard Wiring Practices Manual (BSWPM) 20-00-13, 20-10-11, 20-10-12, 20-10-13 and 20-10-18

    c. Boeing Service Bulletin 747-28-2092 "Main Fuel Tank Pump Wiring Inspection, Rework, And Modification"

2. Data supplied with this service bulletin:

    None

3. Installation Drawings:

Drawing Number	Title
65B92401	Fuel Boost Pump Installation
65B92482	Plumbing Instl. - Fuel Feed, Auxiliary Tanks 1A and 4A

These drawings were used to prepare this service bulletin. These drawings are not necessary to make the specified changes, and are not supplied with this service bulletin. These drawings may not be applicable to all airplane configurations or operators.

L. Publications Changed

None

M. Electrical Load Data

Not Changed

ATA 28 22-00

II. MATERIAL INFORMATION

A. Parts Necessary For Each Airplane

NOTE: The parts shown below are listed for the operators convenience. No parts are necessary if the installed wiring is not damaged.

Parts and Materials Supplied by the Operator:

Quantity	Part Number (Specification)	Name
-	BACC45FS14C4S	Connector, Boost Pump
-	BACC45FS14B4S	Connector, Auxiliary Tank Pump
-	BACC45FT10C5S	Connector, Pressure Switch
-	BACC45FT10B5S	Connector, Pressure Switch
-	BACC47CP1S	Contact, Pressure Switch (AWG 20 Wire)
-	BACC47CP3T	Contact, Boost Pump
(a)	BMS 13-48, Type VIII, Class 3, AWG 18 (b)	Wire, Boost Pump
(a)	BMS 13-48, Type VIII, Class 1, AWG 18 (b)	Wire, Boost Pump and Pressure Switch
(a)	BMS 13-48, Type VIII, Class 1, AWG 20 (b)	Wire, Boost Pump and Pressure Switch
-	BMS 13-54, Grade D, Type III, Class 1, Finish C, Width 0.11 inches, Color White	Lacing Tape
-	D436-37	Splice, Raychem
-	P209541	Contact, Pressure Switch (AWG 18 Wire), Pyle National
(a)	Chemplast TFE-2X, Standard Wall, Size #4 (0.37 dia.), Color Natural or an equivalent (c)	Sleeve, Inner
(a)	Chemplast TFE-2X, Standard Wall, Size #0 (0.47 dia.), Color Natural or an equivalent (c)	Sleeve, Outer

(a) 100 inch lengths are adequate for repair at any of the conduit locations.

(b) Refer to the Standard Wiring Practices Manual 20-00-13 for optional wire.

(c) Port Plastics Incorporated, 1113 Andover Parkway, Tukwila, Washington, USA 98188, Phone (206) 575-4994, Fax (206)

Port Plastics has agreed to provide this material in 100 inch lengths as necessary to support this inspection.

B. Parts Necessary to Change Spares

None

ATA 28 22-00

C. Special Tools and Equipment

No special tools or equipment are necessary to do the change in this service bulletin. But, maintenance and overhaul tools in the manuals given in Paragraph I.K., References, can be necessary. Examine operator tool supply to make sure all necessary tools are available.

D. Existing Parts Accountability

None

MTA 28 22 00

III. ACCOMPLISHMENT INSTRUCTIONS

NOTES:

1. The paragraphs identified with a letter give the general work instructions and the necessary tests. The instructions identified with numbers on the figures give the recommended sequence of steps.
2. Refer to the Boeing Standard Wiring Practices Manuals 20-10-11 and 20-10-12 for the wire installation procedures.
3. Obey all of the warnings and cautions given in the specified manual sections.

A. Open these circuit breakers:

C/B Panel	Nomenclature
P12	NO. 1 AFT & NO. 4 FWD BOOST PUMP CONTROL
P12	F/E IND LTS 4
P12	F/E IND LTS 5
P14	NO. 1 MAIN AFT BOOST PUMP
P14	NO. 4 MAIN FWD BOOST PUMP
P15	NO. 4 MAIN AFT BOOST PUMP
P15	NO. 1 MAIN FWD BOOST PUMP

B. Remove the number 1 main tank forward boost pump access door 545CB. Refer to the 747 AMM 12-09-08 for the access door location.

C. Remove the access panel 572GB. Refer to the 747 AMM 12-09-08 for the access door location.

D. Disconnect the pump and pressure switch connectors and remove and save the wire bundle clamps inside the boost pump housing.

E. Remove and save the wire bundle clamp at the other end of the conduit on the rear spar.

F. Attach a cord to the wire bundle at the boost pump end and pull the wires through the conduit. It is possible for the boost pump connector to go through the conduit.

NOTE: The cord must be long enough to go fully through the conduit. it will be used to pull the wires back through the conduit.

G. Do an inspection of the wire bundle. Repair any damage to the sleeves or wires as necessary. Replace the sleeves if they are damaged. Refer to the SWPM 20-10-18 to replace a sleeve. Repair or replace the wires if they are damaged. Refer to the SWPM 20-10-13 to repair the wires. If the wires appear to be burned, do an inspection of the conduit and replace if necessary.

H. Use the cord that is in the conduit to pull the wire bundle back through the conduit.

I. Install the saved clamps and fasteners at each end of the conduit. Both sleeves must go through the clamps.

[illegible]
AMM 28 22-03

J. Connect the pump and pressure switch connectors.

K. Do steps A through I again for the number 1 main tank aft boost pump (access door 545DB, access panel 572GB), the number 4 main tank forward boost pump (access door 645CB, access panel 672GB), the number 4 main tank aft boost pump (access door 645DB, access panel 672GB).

L. Do an operational test of the boost pumps as specified in the 747 AMM 28-22-03.

M. Put back the removed access doors and panels.

N. For airplanes RD121 and RJ151 only, this inspection must be done on the auxiliary jettison pump wire bundles if the pumps are installed. Refer to the 747 AMM for the access and test data for these pumps. The inspection procedure is the same as mentioned above for the main tank boost pumps.

O. Put the airplane back into serviceable condition.

A 28 22 00

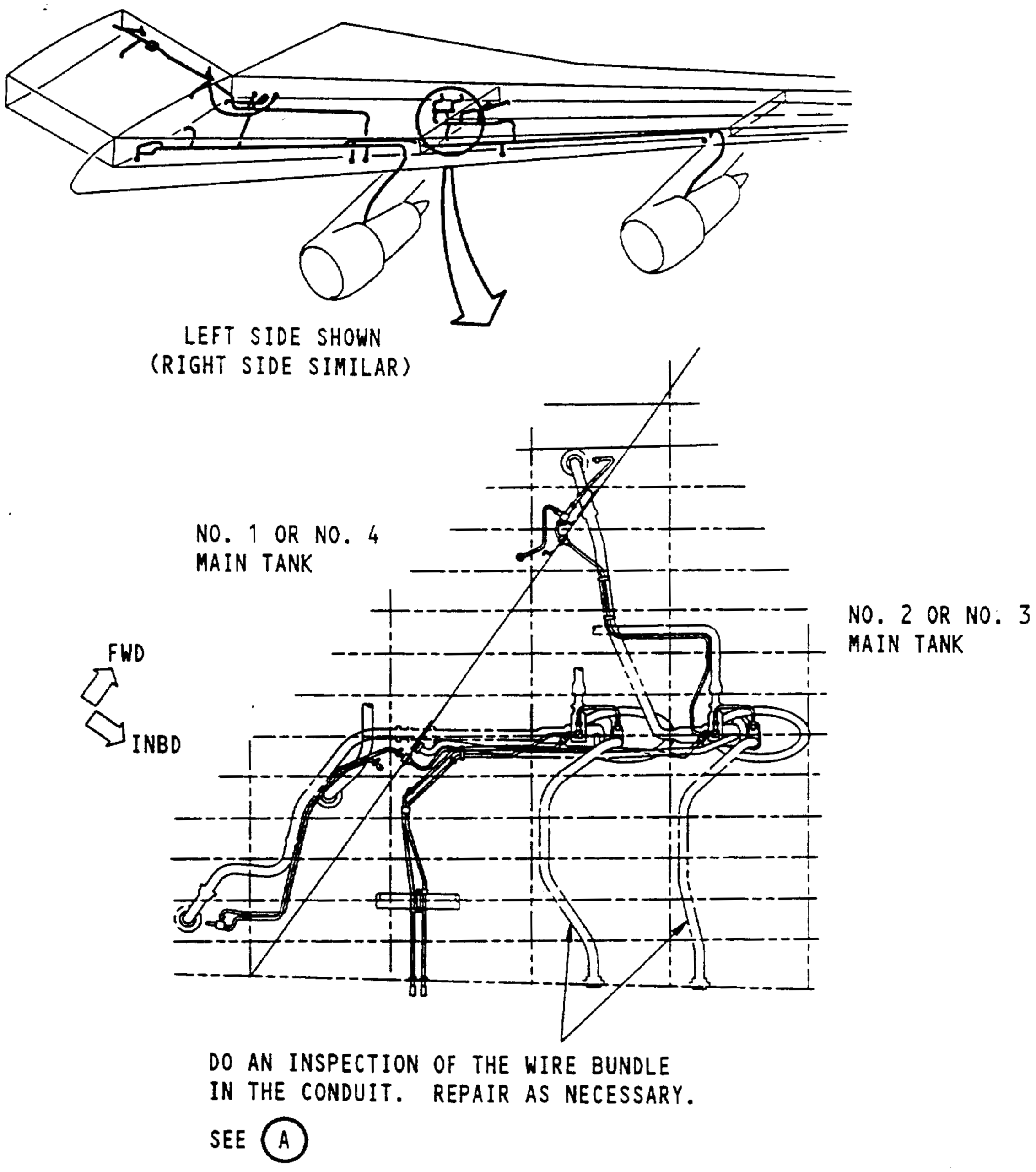


FIGURE 1. BOOST PUMP REFERENCE LOCATOR

ATA 28.22-00

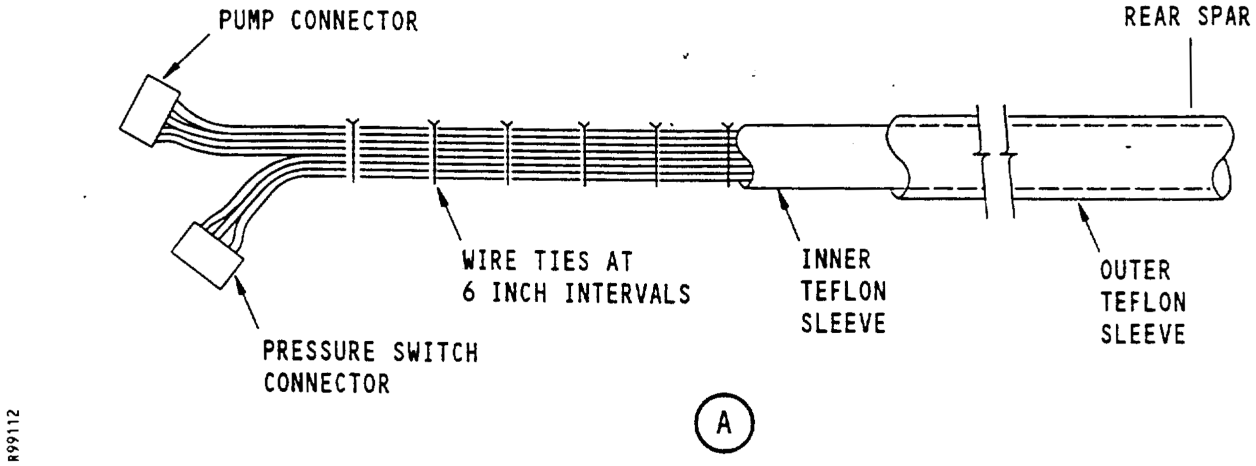
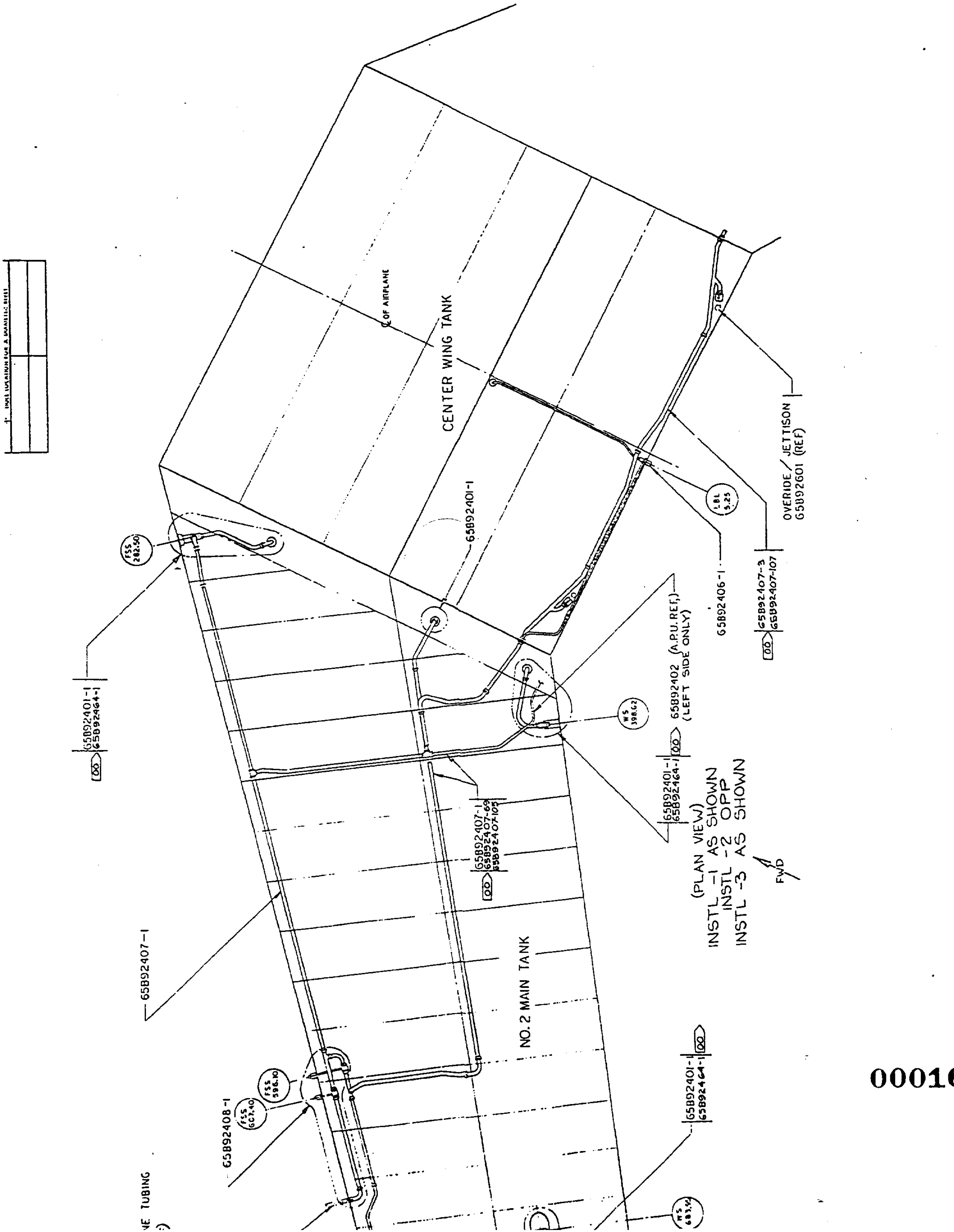


FIGURE 1. BOOST PUMP REFERENCE LOCATOR

SYSTEMS

28-22-07

65B00774



SEE SHEET 1 OR PL FOR L/A, USAGE AND NOTES

THE BOEING COMPANY
COMMERCIAL AIRPLANE DIVISION RENTON, WASH.

ENGINE FUEL FEED
SYSTEM INSTALLATION

CODE IDENT NO. 81205 | J | 65B00774

USED ON 747

CHANGE NO. PRR 9-1000

DWG ORIG BY (GROUP) FUEL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±2° DECIMALS ±.03

DRAWN AKEN
CHECKED SORENSEN
ENGR B. RYAN

000164

TWA PRESSURE CHECK OF FUEL TUBING & OF SEALING OF O-RINGS R Swain

SYSTEMS MANUAL MA 28-22-07

ATA ITEM DESCRIPTION	STK NBR	TASK CODE	MAX LIMIT	SCHED AT	WORK PAPER NUMBER	DESCRIPTION
(28) FUEL SYSTEMS						
				PS	M47-00-01	Drain fuel until clear bright fuel is obtained from each fuel sump
				AS	M47-00-A1/A6	Drain fuel until clear bright fuel is obtained from each fuel sump
				TCS	M47-00-03	Drain fuel until clear bright fuel is obtained from each fuel sump
				TCS	M47-00-03	Check APU fuel line shroud for accumulated fuel
				C	2140	Check APU Fuel line shroud for accumulated fuel
					2960	Drain fuel until clear bright fuel is obtained from each fuel sump
				OP 1	A/C F008	Check pressure decay of fuel feed system
					NET F008	Check pressure decay of fuel feed system
				OP 16	A/C EA31	Check APU fuel line shroud for accumulated fuel
				OP 16	AVN FA02,FA03	Following accomplishment of MO 97216, perform fuel sys qty calibration ck
					NET A402,M402	Open/close plates for center tank
					M47-57-01	Fuel tank entry record (Non-Routine)
1. Actr-APU Fuel S/O Vlv	288-8909	40C1		OP 16	AVN FA06	Op ck (See 28-2, 28-3, 28-4, 28-5, 28-6, 28-8)
2. Actr-Eng Fuel S/O Vlv	288-8909	40C1		OP 16	AVN FA06	Op ck (See 28-1, 28-3, 28-4, 28-5, 28-6, 28-8)
3. Actr-Fuel Crossfeed Vlv	288-8909	40C1		OP 16	AVN FA06	Op ck (See 28-1, 28-2, 28-4, 28-5, 28-6, 28-8)
4. Actr-Jettison Grav Xfer	288-8909	40C1		2/C	2965	Op ck (See 28-1, 28-2, 28-3, 28-5, 28-6, 28-8)
				OP 16	NET FA01	Op ck (See 28-1, 28-2, 28-3, 28-5, 28-6, 28-8)
5. Actr-Jettison S/O Vlv	288-8909	40C1		2/C	2965	Op ck (See 28-1, 28-2, 28-3, 28-4, 28-6, 28-8)
				OP 16	NET FA01	Op ck (See 28-1, 28-2, 28-3, 28-4, 28-6, 28-8)
6. Actr-Jettn Vlv Ctr Tank	288-8909	40C1		2/C	2965	Op ck (See 28-1, 28-2, 28-3, 28-4, 28-6, 28-8)
				OP 16	NET FA01	Op ck (See 28-1, 28-2, 28-3, 28-4, 28-5, 28-8)
7. Ctl-Press Fueling Vlv	288-8932	CM				
8. Actr-Reserve Xfer Vlv	288-8909	40C1		OP 16	AVN FA06	Op ck (See 28-1, 28-2, 28-3, 28-4, 28-5, 28-6)

SYSTEMS FACTUAL
ATA 28-22-07

```
AS02510     CHECK PRESSURE DECAY OF FUEL FEED SYST           747-100        10/16/96
                                                  AREA 400     SPEC.    MET
                                                               CARD NO. F008
              INSP.  MECH.                                       PAGE 1 OF 1
            01
            02              1. PERFORM PRESSURE DECAY OF ENTIRE FUEL FEED SYSTEM
            03                 PER MM 28-22-00 (METHOD B. USING AIR PRESSURE.)
            04
            05       ......    A. ENG 1 SYSTEM
            06
            07       ......    B. ENG 2 SYSTEM
            08
            09       ......    C. ENG 3 SYSTEM
            10
            11       ......    D. ENG 4 SYSTEM




                        OP. TYPE OP01    DWG.REF. A5836/B941110

            TWA FORM M-139-R-02  11-11-94    STD. HRS. 01 X   16.0

            FOOTNOTE: *** PRINT ONLY 10/16/96 ***

            ADDITIONAL DATA:  ATA CODE 2822  WORK BOOTH 0 CHECKPOINT 30  FACTOR 4

                        FILE ID 171 0000C     000 02 F008 1
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SYSTEMS MANUAL
ATA 28-22-07

Accident airplane

CHECK PRESSURE DECAY OF FUEL FEED SYST

AREA 400

A/C # 17115
SPEC. F/T
CARD # F008
PAGE 1 OF 1

INSP.	MECH.	
		01. PERFORM PRESSURE DECAY OF ENTIRE FUEL FEED SYSTEM PER MM 28-22-00 (METHOD B. USING AIR PRESSURE.)
	6186	A. ENG 1 SYSTEM
	6186	B. ENG 2 SYSTEM
	6186	C. ENG 3 SYSTEM
	6186	D. ENG 4 SYSTEM

DEC 09 1992

OP. TYPE OP01 DWG.REF. A5836

TWA FORM M-139-R-06 02-20-90 NO. MEN 01

SYSTEMS FACTUAL
ATA 28-22-07

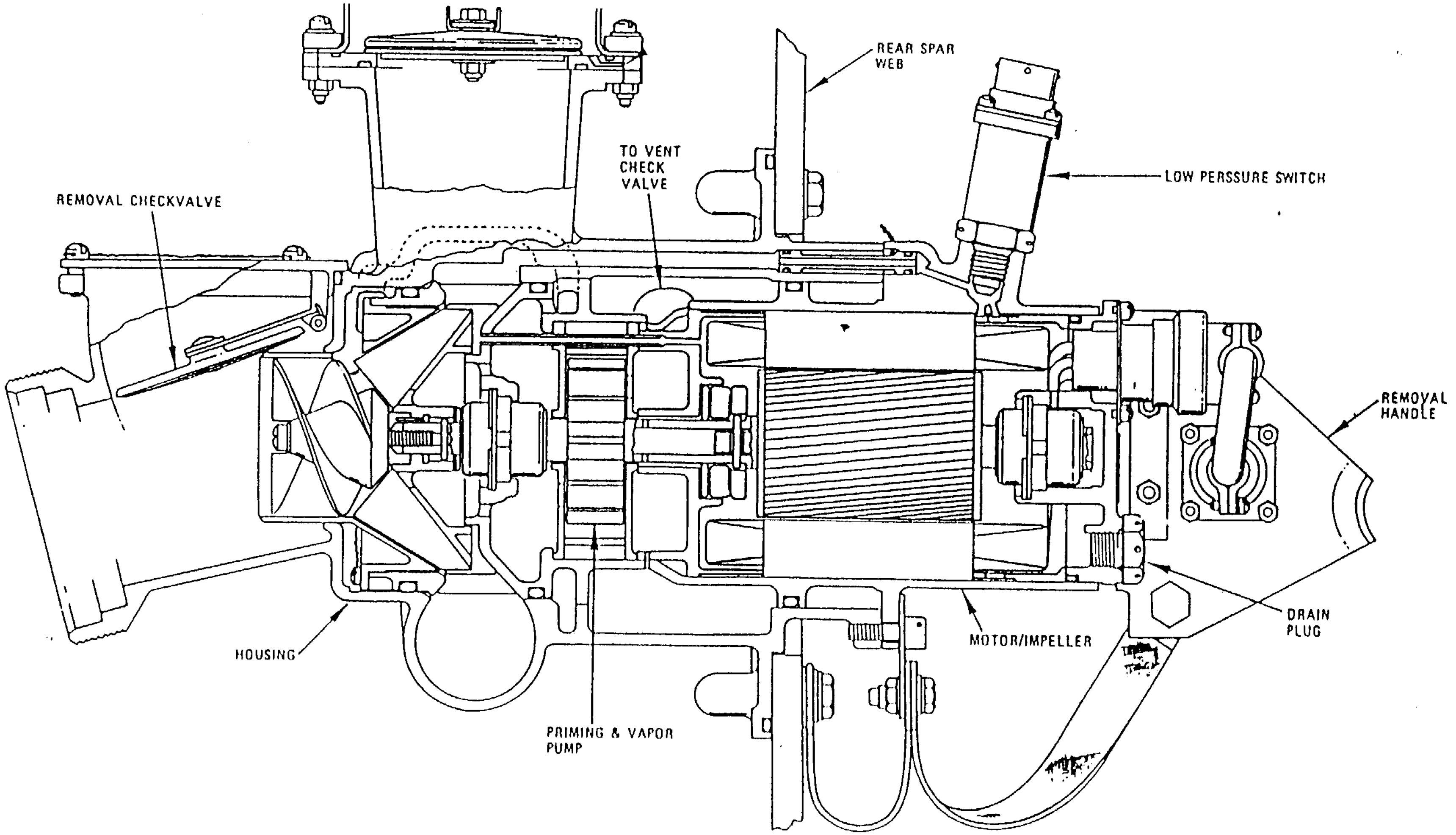
N93119 O-RING CRACKING
IN TUBE FROM ABOVE CWT
JETTISON/OVERRIDE PUMP

MAG ~~275~~ 3.75

SYSTEMS MANUAL

ATA 28-31-00

OVERRIDE/JETTISON PUMP



DESCRIPTION OF FUEL QUANTITY MEASURING SYSTEM.

The Basic System:

The following description is that of the fuel quantity system as applied to the 747-1XX aircraft. This system uses the following components.

Primary Indicator : JG603C__
Repeater Indicator : JG603C__
Totalizer : JG613C1
Tank Units : FG420A__

The full part numbers for indicators and repeaters depend on the full scale reading and therefore for which tank the indicator is used. For the tank units, the full part number defines a tank unit with a unique length and characterization for a specific location in the tanks. Figure 1 shows the elements of the fuel quantity system.

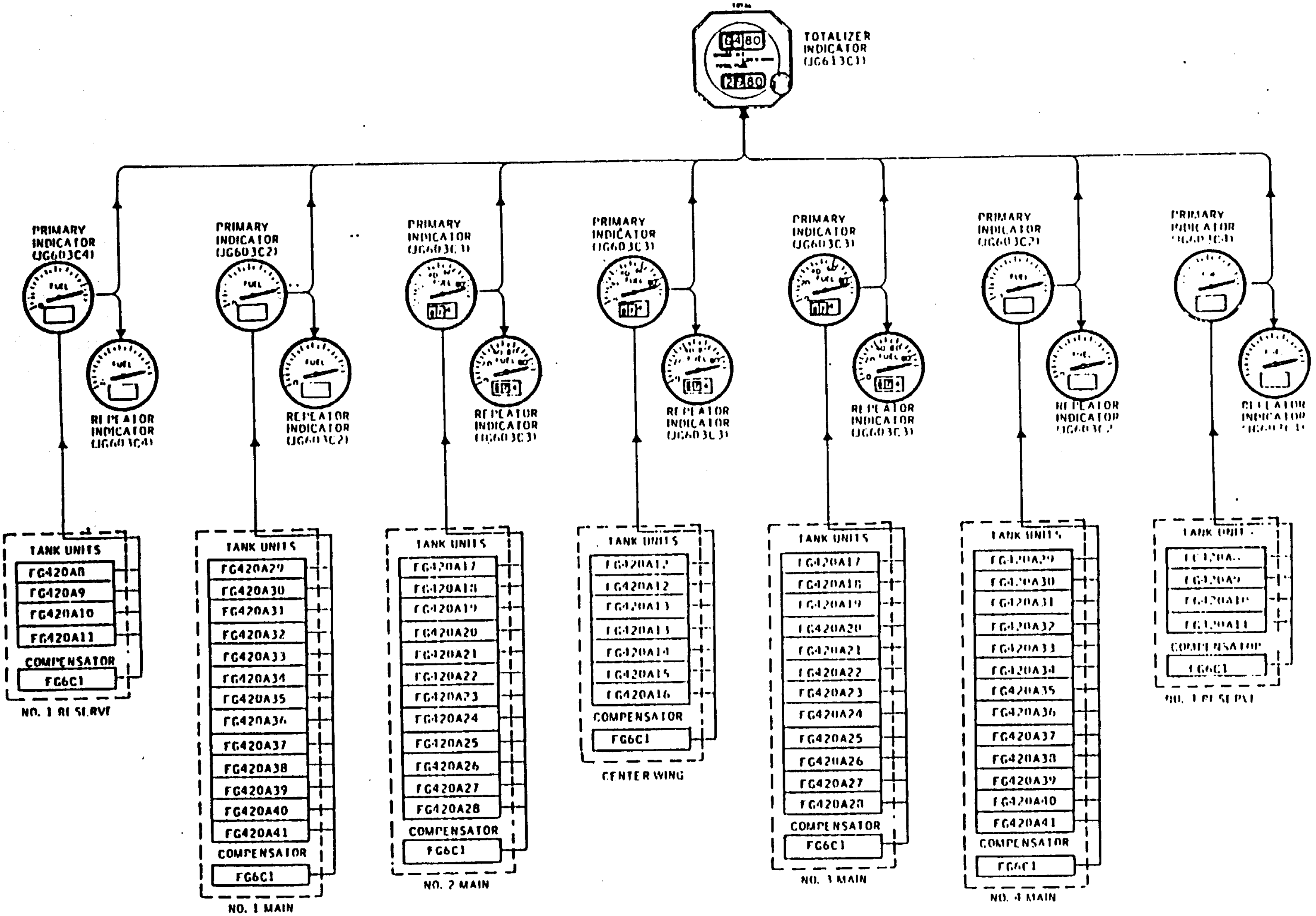
Fuel Quantity Measurement:

To determine the energy available for propulsion, the fuel quantity indicating system must measure the number of pounds of fuel carried. Therefore it must be both volume and density sensitive. The method of measurement used applies the principle of the capacitance bridge together with the operation of a closed-loop system. The system in essence is shown in Figure 2.

E_{FIXED} is a reference voltage of constant frequency. The variable capacitor represents the total variable capacitance developed by coaxial cylindrical capacitors placed in the fuel. See Figure 3. They are called Tank Units (T.U.). Because fuel has a different dielectric constant than air, about twice, changes in fuel quantity develop changes in the T.U. capacitance. For a single measurement system, such as a single fuel tank, there are usually several tank units connected in parallel. Because the capacitance value of capacitors connected in parallel is the sum of the individual values, the variable capacitor of Figure 2 represents all the variable capacitance values of the tank units of a single measurement system.

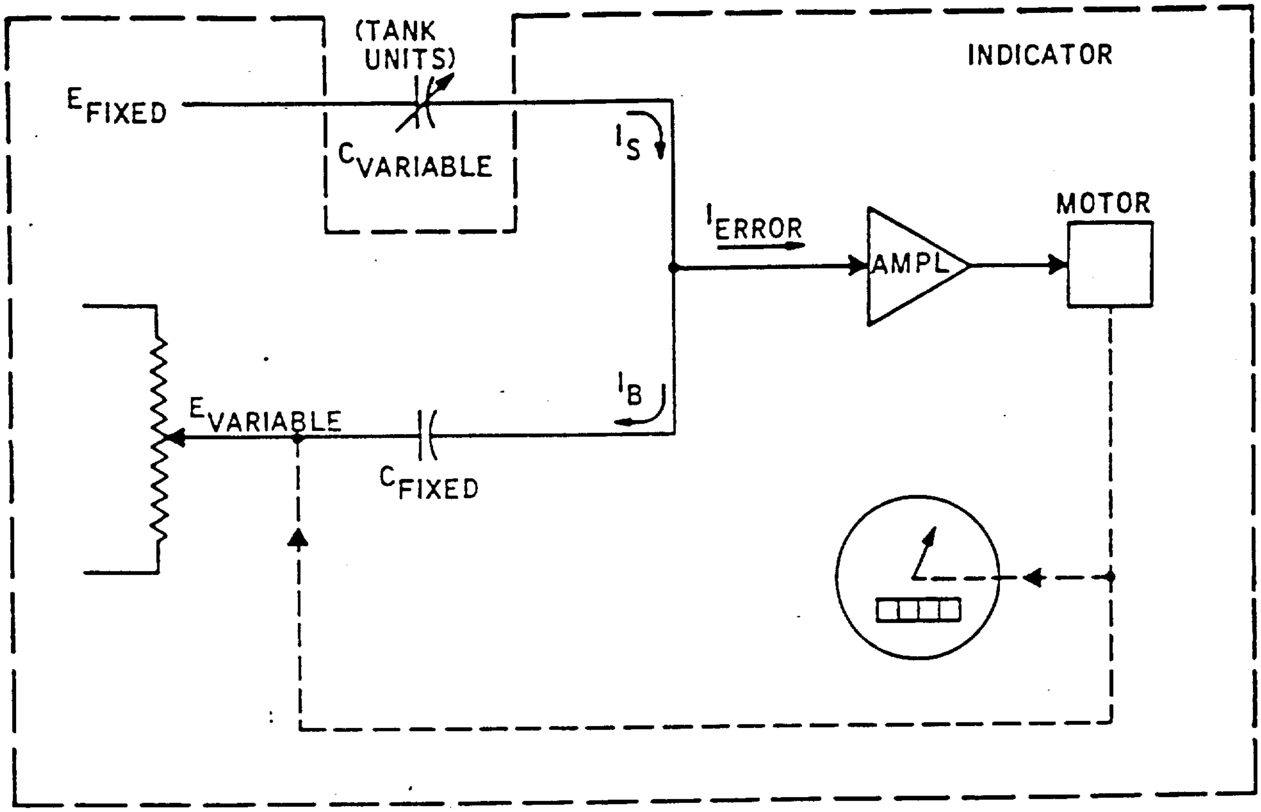
The combined result of E_{FIXED} and $C_{VARIABLE}$ is a variable AC current I_S, the amplitude of which is a function of fuel quantity. I_S signifies sensing current, this circuit being the sensing leg of a capacitance bridge.

The system of Figure 2 is also based on the principles of operation of the closed loop. That is, it is an "error actuated" system, the error in this case being the difference between the input current I_S and the oppositely phased feedback current, I_B. If I_B equals I_S in amplitude exactly there will be no I_{ERROR}. When a difference, or error, between I_S and I_B does exist, an I_{ERROR}, signal is generated. This I_{ERROR} signal, when amplified, produces motor rotation. Motor rotation, through a gear train, moves the potentiometer's wiper, changing the amplitude of I_B. The motor will cease when I_{ERROR} becomes exceedingly small. Such small input signals occur only in what is called the "threshold" or "dead spot" of the system; I_{ERROR} input signals outside the dead spot cause motor rotation. See Figure 4. Rotation continues until I_B is essentially equal to I_S.



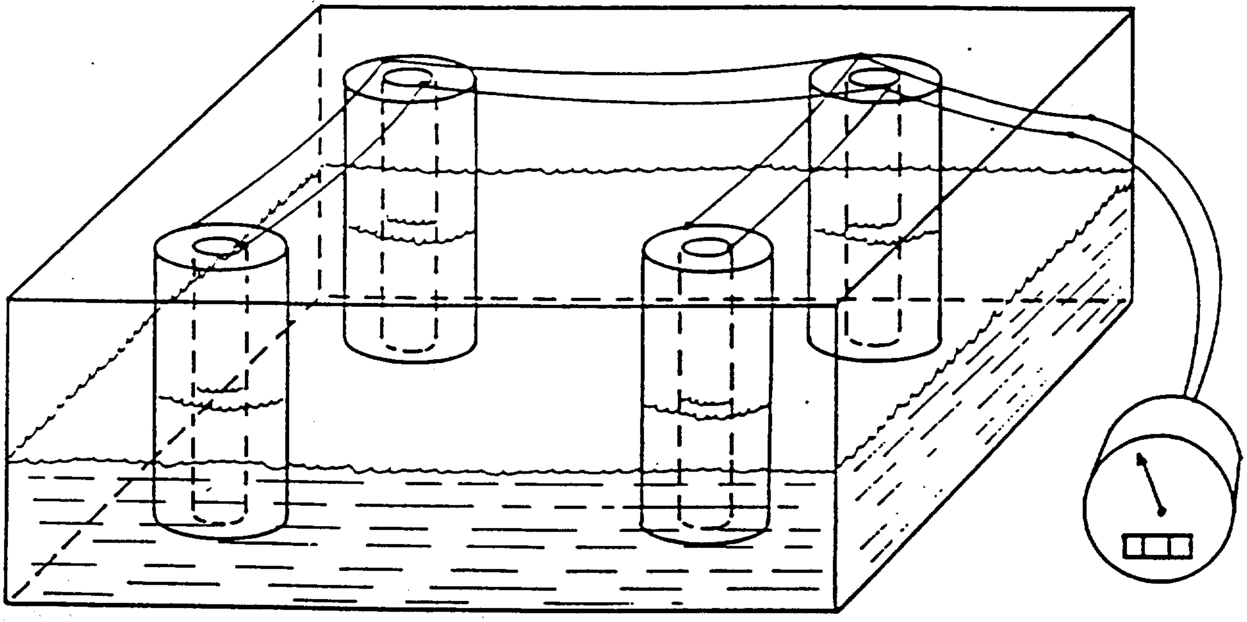
THE BOEING 747 FUEL QUANTITY INDICATING SYSTEM, YG597C1

FIGURE 1



BASIC ELEMENTS OF THE F.Q. INDICATING SYSTEM

FIGURE 2



THE PARALLEL CONFIGURATION OF TANK UNIT SENSORS

FIGURE 3

In order that the system be "closed-loop" the amplifier-motor combination is designed so that it can detect the phase of the error signal, either in-phase or out-of-phase, and drive the motor in the proper direction. Then the entire measurement loop is closed by properly phasing the mechanical connection to the wiper and the excitation of the potentiometer.

The operation of this "servoed" or "feedback" system is typical: the phasing of the system forces the input to the amplifier to become smaller. It does this by forcing the amplitude of I_B to become, practically speaking, the same as I_S.

Because of the amplitude to I_B is the direct result of $E_{VARIABLE}$ (E_B) fuel quantity readout is obtained by mechanically showing the position of the pot wiper.

Factors Determining Tank Unit Capacitance:

Capacitance exists when ever two conduction surfaces are separated by a non-conducting medium called the dielectric. Capacitance value is an expression of the electron storage ability This value is a function of the area of the surfaces, the distance between them, and the electrical characteristics of the dielectric.

The electrical characteristics of the medium are expressed in relation to the characteristics that exist when the medium is space only; a vacuum. The storage value using space is measured, and then the value using the particular dielectric. These values are then related as follows:

$$K = \frac{\text{Capacitance Value with Matter as Dielectric}}{\text{Capacitance value with Space as Dielectric}}$$

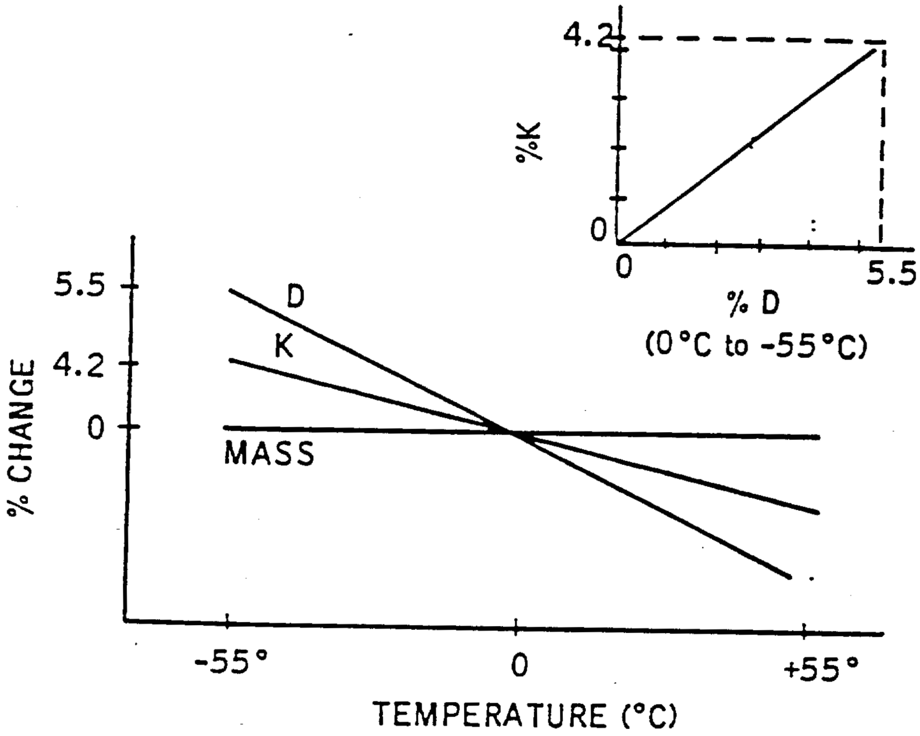
where K is specified as the dielectric constant of the matter.

It is instructive to understand why a dielectric such as petroleum fuel increases the electron-storage capacity of that part of the tank unit which is immersed.

First consider the results when only space separates the conductors. Current flows and the plates charge with electrons until the voltage across the capacitor equals the source voltage. There is a certain minimum capacitance of the tank unit when no fuel is present.

With fuel present between the elements of the tank unit, the atoms of the fuel become polarized and tend to reduce the voltage across the capacitor. More current will flow into the capacitor until its voltage is again the same as the source. Therefore the presence of fuel between the plates increased the stored energy and therefore the capacitance of the capacitor.

It should be realized that an increase in the density (D) of the fuel due to temperature changes, will in general be accompanied by an increase in its dielectric constant (K). Figure 4 illustrates the average changes of K and D due to temperature.



TYPICAL CHANGES IN K AND D WITH TEMPERATURE

FIGURE 4

It is beneficial to define basic capacitance factors and then develop the underlying relationships determining the total capacitance (C_T) of the sensing leg of the system. The manufactured T.U., with its construction and dimensions fixed, has a fixed minimum capacitance, its capacitance in air (C_A). Therefore, let

C_A = T.U. Capacitance in Air.

When the T.U., is immersed, totally or partially, fuel replaces air, the composite dielectric constant is increased and therefore the total capacitance, C_T is increased,. This increase in C_T is due to the presence of fuel. Let

C_F = The increase in capacitance due to the presence of fuel.

The relationship between C_T, C_A and C_F is

$$C_T = C_A + C_F$$

The capacitance change due to the presence of fuel is

$$C_F = C_T - C_A$$

From the definition for dielectric constant and letting the T.U. be totally immersed, K will be equal to

$$K = \frac{C_T}{C_A}$$

Substituting and factoring equations gives the expression when the T.U. is fully immersed

$$C_F = C_A (K-1)$$

The term (K-1) is the increase in dielectric constant due to the presence of fuel.

A generalized expression for the value of C_F for a linear (not characterized) T.U. and an area characterized T.U. wetted to any height is

$$C_F = C_A (K-1) a/A$$

Where A = Total Area
a = whetted area, directly proportional to actual fuel volume.

For the 747 the T. U is diameter characterized. the inner element is built having various diameters as well as areas throughout its wetted lengths. This equation cannot be applied to the T.U. as a whole. Further modification of the equation is needed to take into account the change in diameter of the inner element.

Bridge Design and Basic Relationships:

In figure 2 the basic measurement system was described. There is a desirable characteristic which that system will not produce. It is that the function of the E_B does not become zero when the useable fuel quantity is zero. I_S does not disappear with the disappearance of fuel as the T.U. still has it in-air capacitance. Therefore neither can balancing current, I_B go to zero. So also in the system of Figure 2 with zero fuel E_B cannot go to zero.

To allow E_B to go to zero two circuits are added: (See Figure 5).

1) An adjustable voltage (E_B') is applied to a fixed capacitor (C_R') such that the current it generates will equal and nullify I_S when the useable fuel is zero. An I_S - balancing current does not have to come from the feedback potentiometer and under empty conditions E_B can become zero.

2) The feedback pot is shunted by two resistors with their junction grounded, and their values chosen in size so that their ratio establishes a virtual or electrical signal ground on the feedback. pot at the point where, mechanically, the pot wiper voltage and the dial readout are both zero. Therefore E_B and I_B will be zero when the indicator reads zero.

Consequently with these two circuits applied, and assuming closed loop operation, the adjustable voltage (E_B') is set with empty fuel tank conditions so that the dial indication is zero. With zero fuel E_B will be made zero also.

By circuit design and by calibration at "empty", E_B' is adjusted so that by servo action $E_B = 0$ and therefore $I_B = 0$. E_B' is set by the "empty" adjustment.

I_S is increased above its empty value as a function of the added capacity C_F. Because I_B' has been fixed, by "empty" calibration, the bridge will be unbalanced until, by servo action, I_B nullifies the increase in I_S. Therefore with fuel

$$E_B = E_S \times \frac{C_F}{C_R}$$

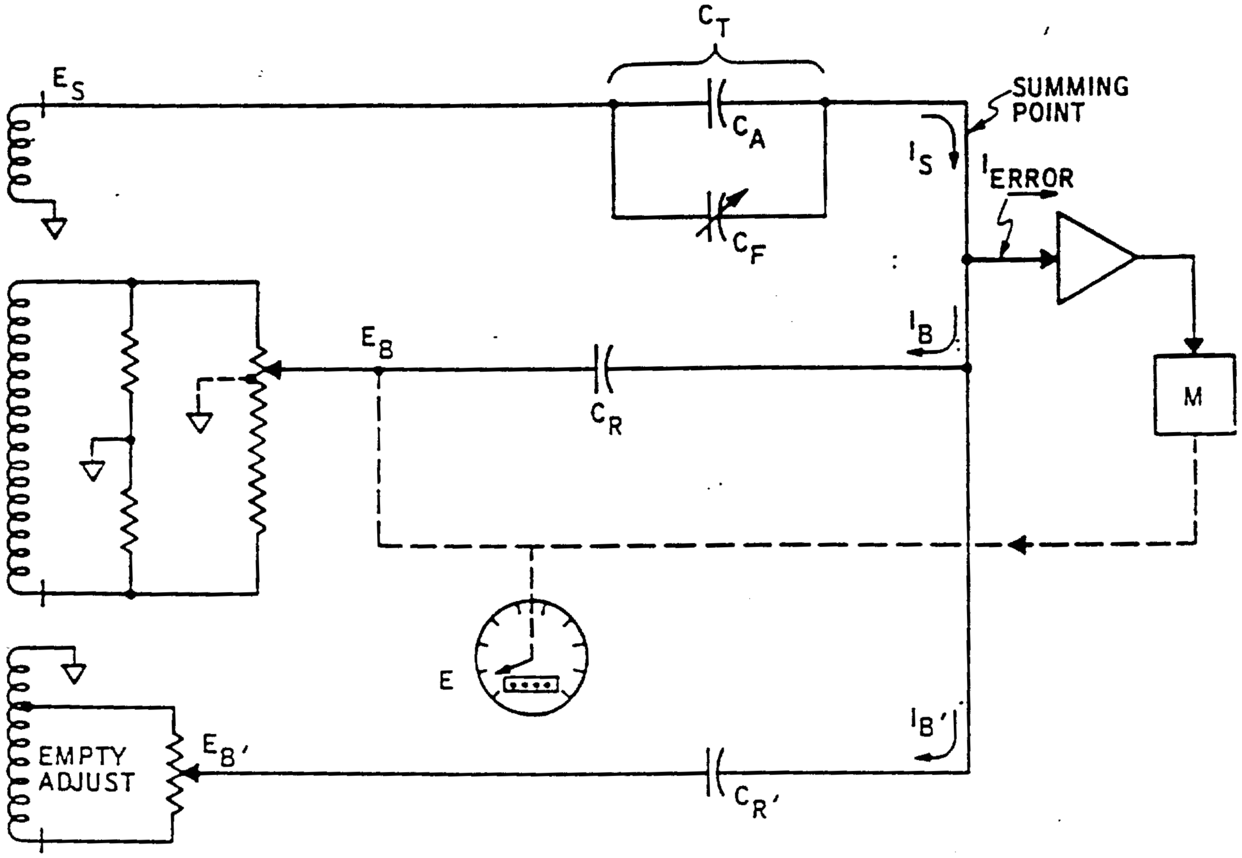
By circuit design and with E_S and C_R fixed, E_B is a direct and linear function of the added capacity due to the presence of fuel C_F.

"Full" Adjustment:

To make the pot wiper position, along with the indicator reading and its voltage correspond to the correct value of fuel a second adjustment must be made. By enabling the voltage across the feedback pot to be varied as shown in Figure 6, the voltage drop per unit distance of the wiper can be changed. The full adjustment is made when the precise added capacity applied corresponds to some top-scale exact dial readout. By applying across R6 and R7 (and the signal ground tap) the same adjustable voltage applied to the feedback. pot, any previously made "empty" adjustments will not be altered when the "full" adjustment is made.

Tank Unit Characterization:

Characterization of the 747's T.U. is accomplished by keeping the diameter of the outer tube constant while changing the diameter of the inner tube. See Figure 7. If it is desired to have at a certain height, small changes in capacitance per unit change in wetted length, the diameter of the inner element is made small, keeping the distance in that region large; if it is desired to have at another height large changes in capacitance per unit change in wetted length the diameter is made large. Thus the dimensions of the inner element are controlled in such a manner that the capacitance generated by the presence of fuel corresponds to that particular volume of that fuel.

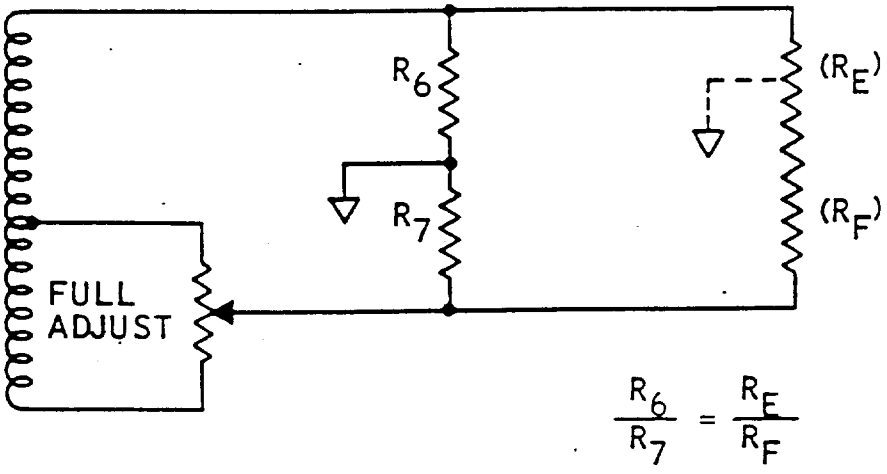


TWO CIRCUIT ADDITIONS TO THE BASIC BRIDGE

FIGURE 5

Definitions:

E_S = fixed sensing voltage
C_A = T.U. capacitance in air
C_F = T.U. added capacitance due to presence of fuel
C_T = total T.U. capacitance
I_S = sensing current
E_B = feedback balancing voltage
I_B = F.B. balancing current
C_R = fixed reference capacitor
E_B' = adjustable bias balancing voltage
I_B' = adjustable bias balancing current
C_R' = fixed reference capacitor
I_{ERROR} = difference between I_S and $(I_B + I_B')$



$$\frac{R_6}{R_7} = \frac{R_E}{R_F}$$

THE FULL ADJUST CIRCUIT

FIGURE 6

The characterizing of the added capacitance, C_F, is accomplished by the combination of the step-changes in capacitance of the several T.U.'s working together. See figure 7 for the 747 T.U. patterns. The profiles shown for both length and diameter are not to scale.

Bridge Compensation:

Gage accuracy is a function of the accuracy at empty, reading only C_A, and also a function of the response of the electrical capacitance of the fuel, i.e. the C_F response. We have seen that C_F is determined by the dielectric factor (K-1) and by the wetted length. But the apparent wetted length is indirectly affected by density, D.

Define the term capacitive index

$$\text{Capacitive Index} = \frac{(K-1)}{D}$$

Assume that our measuring system, gaging nominal fuel with nominal K and density D, is calibrated to read accurately the quantity in a partially filled tank. Assume that this fuel is replaced to the same height with a fuel having a higher density. The resultant increase in weight will be indicated accurately on the dial only if the percentage increase in (K-1) is the same as the percentage increase in D. Generally this is not the case.

An analysis of fuel data shows that the (K-1) change is almost always greater than the D change and that the variation in the capacitive index

$$\frac{(K-1)}{D}$$

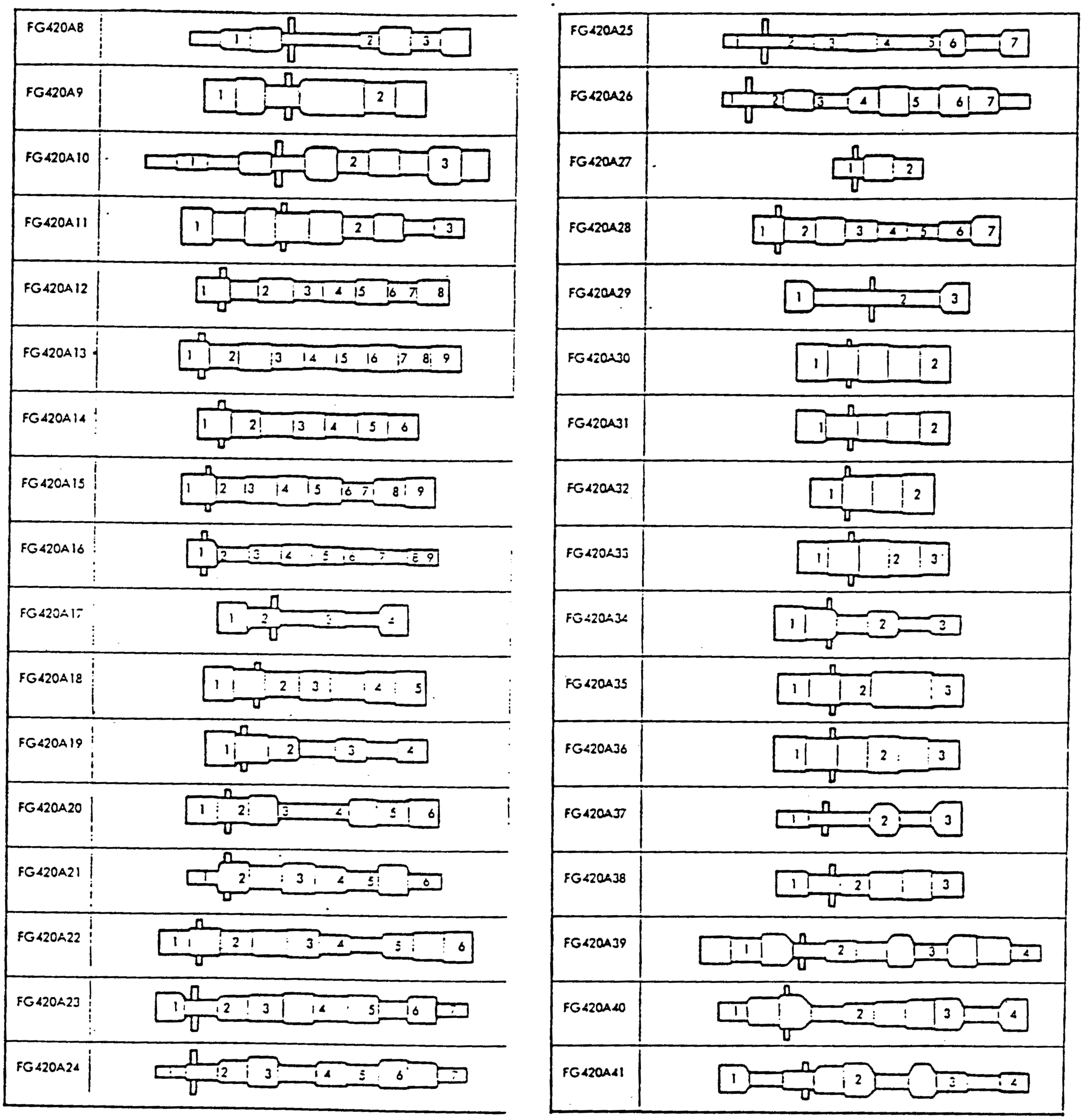
also tends to follow variations in the dielectric constant factor (K-1) with good correlation. These facts allow simple compensating circuitry that produces a cancellation or reduction of the gaging errors due to

$$\frac{(K-1)}{D}$$

deviations. With bridge "compensation", nominal deviations of capacitance index will not cause gage error and the errors associated with non-nominal deviations will be reduced.

Compensation Circuitry:

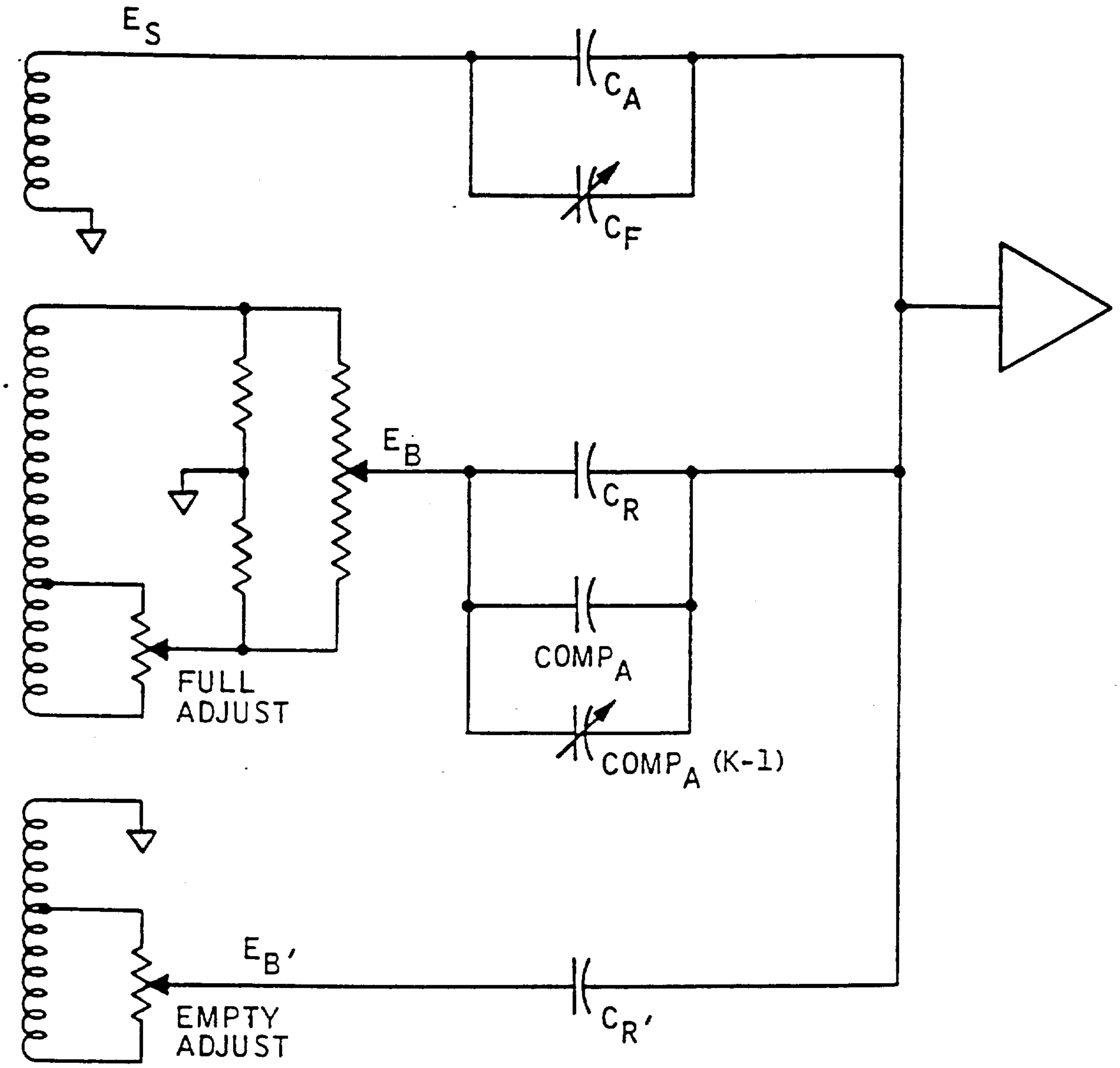
To the system of figure 5 a variable capacitor is added to the balancing leg of the bridge, a capacitor whose capacitance value will be only a function of the dielectric constant of the fuel, not the volume of the fuel. See Figure 8. This is accomplished by placing a tank unit type capacitor, called a compensator, in the tank in a position where it is essentially always immersed in fuel.



NOTE: The numbers indicate inner electrode spacer positions.

747 TANK UNIT CHARACTERIZATION PATTERNS

FIGURE 7



THE COMPENSATED FUEL QUANTITY BRIDGE

FIGURE 8

Now immersed, the compensator's total capacitance value will be

$$Comp_T = K\ Comp_A$$

or

$$Comp_T = Comp_A + Comp_F$$

and

$$Comp_F = Comp_A\ (K-1)$$

Note that the variations in compensator capacitance are not a function of the volume of the fuel as it always fully immersed, but only of the (K-1) factor. The compensated system then becomes that of Figure 8.

The essence of compensation is simple: variations in T.U. current from nominal due to the

$$\frac{(K-1)}{D}$$

deviations are canceled by essentially the same current changes in the compensator due to its (k-1) deviations.

But for optimum "compensation" the relative magnitude of the compensator's current must be carefully established,. The level of authority of this canceling current is determined by the ratio of $Comp_A$ (K-1) to the total capacitance in the variable feedback leg, $C_R + Comp_A + Comp_A\ (K-1)$. This level of authority is specified by the term "percentage of compensation"

$$\%\ \text{of compensation} = \frac{Comp_A\ (K-1)}{C_R + Comp_A + Comp_A\ (K-1)} \quad X\ 100$$

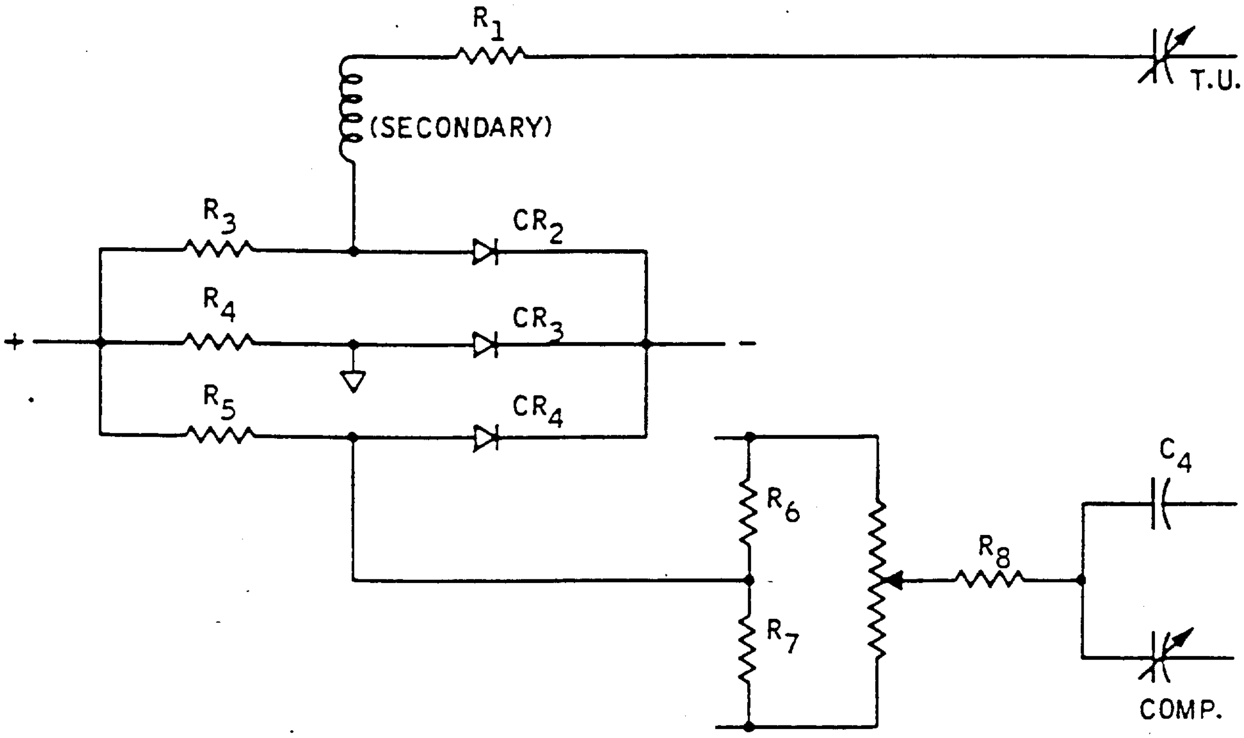
For the fuel type to be used on the 747 ($K_N = 2.133$, $D_N = 6.763$) and with its dry compensator value of 52.64 pF the percentage of compensation chosen as the optimum compromise is 24.6 %.

Push To Test:

Grounding the T.U. unshielded lead by switching provides a convenient means of exercising the system to test it. That is, grounding the lead reduces I_S to zero and the system then tries to reduce $I_B + I_B'$ to zero, therefore causing the indication to run downscale. Removing the ground allows the system to rebalance itself in its normal manner. The downscale response will result regardless of the initial conditions.

Current Limiting:

The bridge is designed so that should a short circuit occur in the tank unit circuit or compensator circuit, either from the unshielded lead to ground or between the two leads, the resulting current would be less than 0.01 amps. This limiting is accomplished by a diode-resistor biasing network. See Figure 9.



SENSOR CURRENT LIMITING

FIGURE 9

In normal (no failure) operation the biasing voltage forward biases CR2, CR3 and CR4. Because the anode of CR3 is physically grounded the anodes of CR2 and CR4 will also be at electrical ground potential due to the identical drops across the diodes.

The normal electrical grounds are supplied to:

1) the transformer secondary developing E_s and

2) the ground for the R6 -R7 voltage divider.

CR2 and CR3 being oppositely connected produce an open circuit for instantaneous secondary voltages greater than 0.6 V, the voltage drop on the forward biased diode. Then the load for the secondary consists of R3 and R4 in series.

Should failures occur in this normal current limiting circuit, the "back-up resistor in the T.U. and feedback Compensator low impedance leads, R1 and R8 respectively, will limit current to less than 0.15 amps.

Repeater Operation:

The design and layout of the indicator's bridge circuitry is such that, by the proper connections at the connector, an indicator can be used either as the primary fuel quantity indicator or as a repeater of a primary indicator. Figure 10 shows the configuration of the repeater.

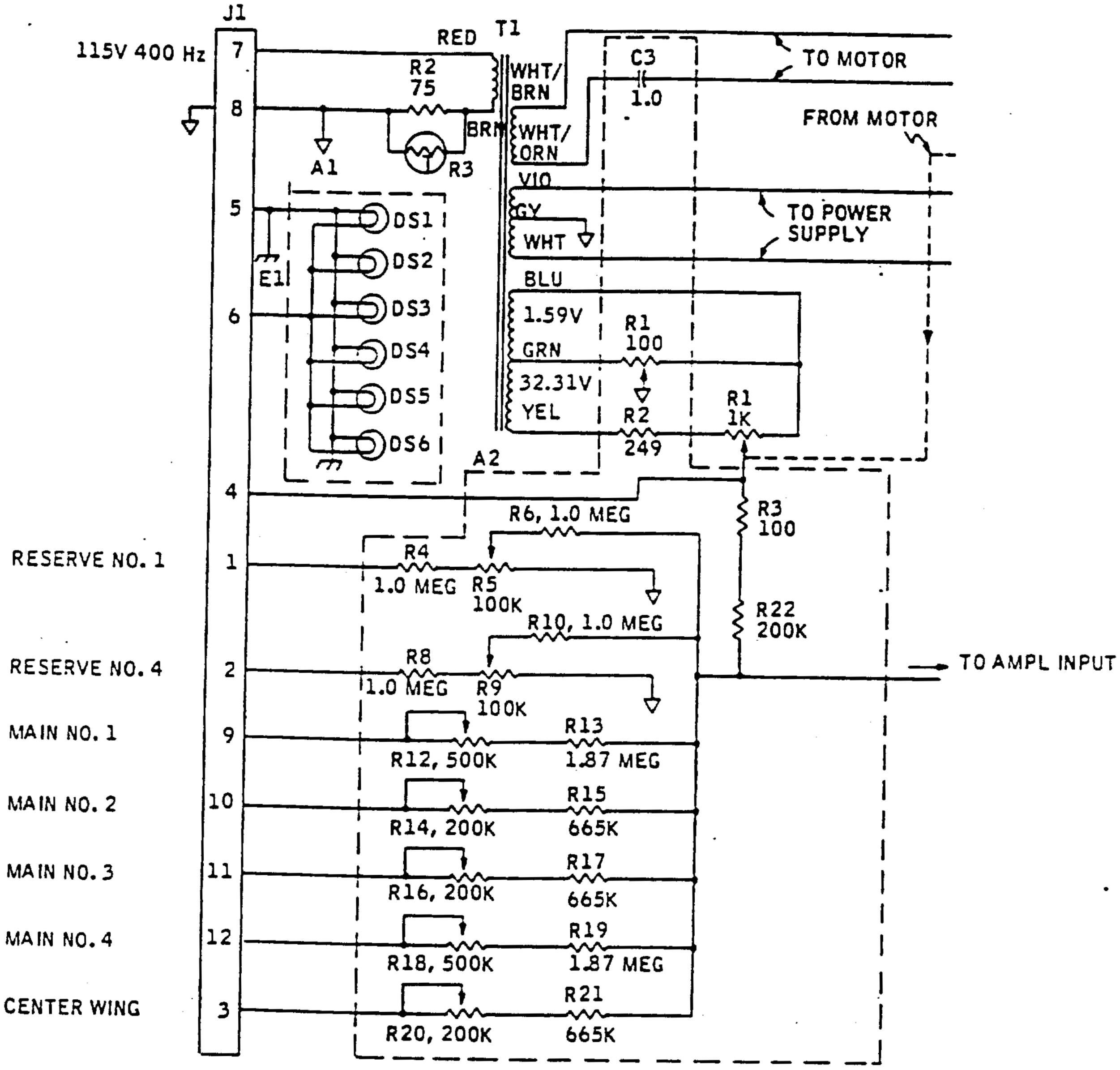
Repeater push-to-test is accomplished by grounding pin 2 of the indicator. With the push-to-test switch closed, the otherwise opened transformer secondary (connected to the push-to-test switch) now applies a voltage to the current limiting circuit adding a voltage to the otherwise signal ground on the wire between R6 and R7. This causes the feedback voltage to be too high, causing the system to reduce that voltage to its original value driving the pot wiper down scale.

Totalization:

Totalization of the individual indications developed by the various primary indication systems is usually accomplished by a signal summing servo indicating system.

Each primary indicator feeds to the totalizing indicator, the voltage E_B, developed as a function of the mechanical deflection of its individual feedback potentiometer. Because the various primary indicators and their feedback potentiometers and pot excitation values are essentially identical, identical mechanical positions produce identical E_B voltages. But, identical E_B values generally represent different quantities of fuel.

It is necessary to modify individual E_B values to develop signals proportional to the individual indicators fuel quantity value in the totalizing indicator, (see Figure 11)



JG613C BRIDGE ASSEMBLY

FIGURE 11

The operation of each leg of the resistive network is to develop a current proportional to the quantity being monitored by that leg. This is accomplished either simply by the resistance value in series with the particular E_B or by a voltage divider and current controlling series resistance network. In order to read this total current value, a servo indication system with a potentiometer feedback is used. The totalizing feedback voltage generates an out-of-phase current which, by servo action, becomes equal to the sum of the input currents. The mechanical deflection associated with the feedback voltage and current is measured and represents the total fuel of all the primary indicators.

FUEL PROBE & COMPENSATOR LOCATIONS FOR REFERENCE

INSULATION RESISTANCE TABLE III

60B92010

SH 49

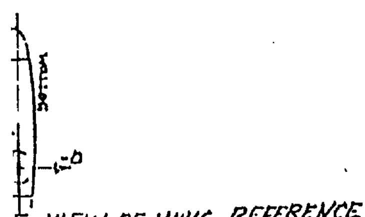
SIZE A

CODE IDENT NO. 81205

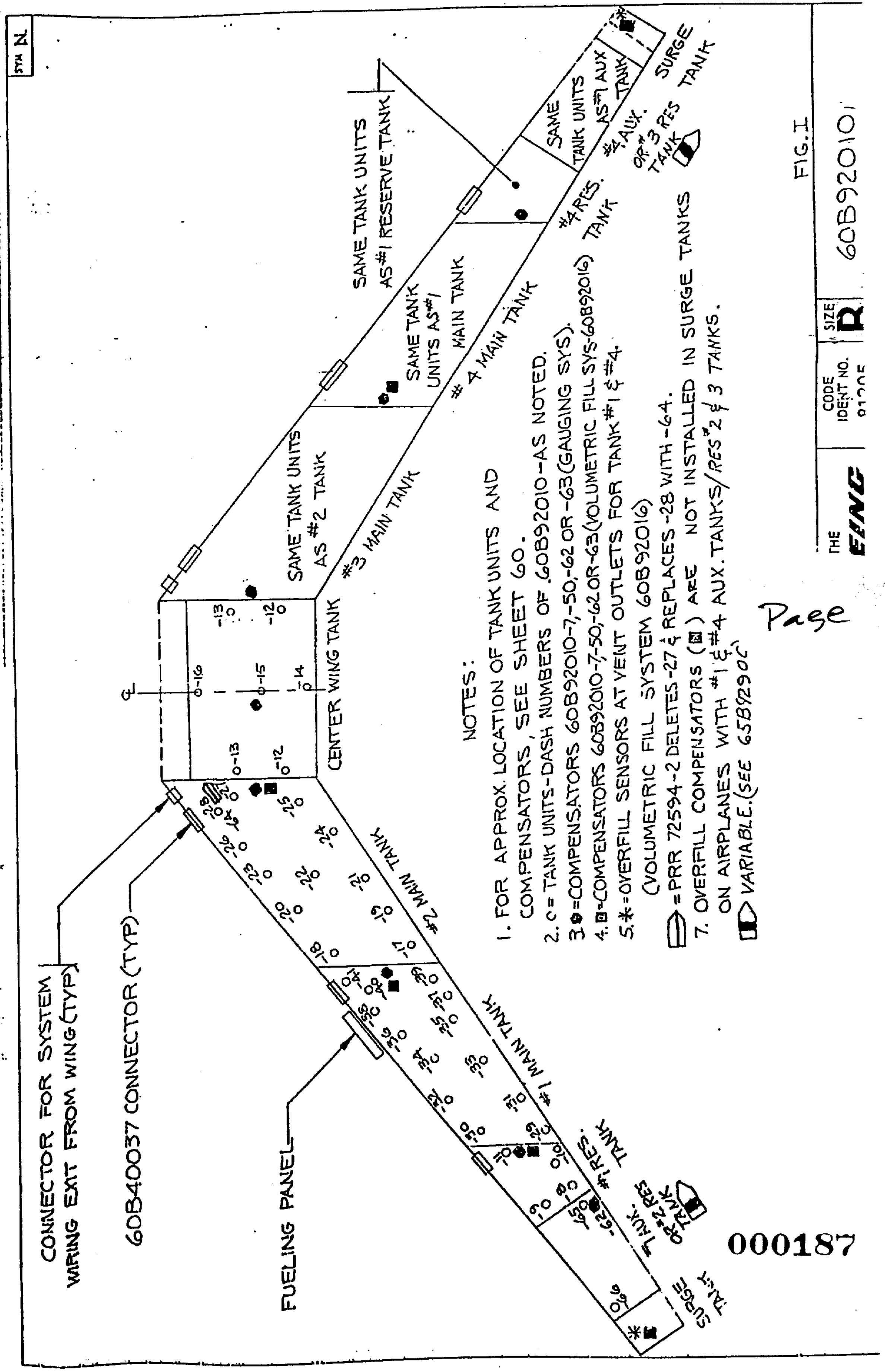
SCALE

THE BOEING COMPANY

	C	
D FULL	FLIGHT (MEAN)	
INCHES'D'	DEGREES'T'	INCHES'D'
.0.00	0	0
- 0.24	-0.10	+ 0.35
- 0.93	-0.29	+ 1.40
- 2.57	-0.58	+ 4.01
- 5.26	-0.97	+ 8.42
- 9.06	-1.40	+ 15.06
-13.78	-1.85	+ 24.02
-17.20	-	-
-18.95	-2.31	+ 35.43
-24.37	-2.65	+ 49.08
-30.00	-2.84	+ 64.36
-32.80	-2.90	+ 72.50



VIEW OF WING REFERENCE
- SHOWING PARAMETERS
ABLE II



NOTES:

1. FOR APPROX. LOCATION OF TANK UNITS AND COMPENSATORS, SEE SHEET 60.
2. c = TANK UNITS-DASH NUMBERS OF 60B92010-AS NOTED.
3. ● = COMPENSATORS 60B92010-7,-50,-62 OR -63 (GAUGING SYS).
4. ▣ = COMPENSATORS 60B92010-7,-50,-62 OR -63 (VOLUMETRIC FILL SYS-60B92016)
5. ✱ = OVERFILL SENSORS AT VENT OUTLETS FOR TANK #1 & #4.
(VOLUMETRIC FILL SYSTEM 60B92016)

⬠ = PRR 72594-2 DELETES -27 & REPLACES -28 WITH -64.

7. OVERFILL COMPENSATORS (▣) ARE NOT INSTALLED IN SURGE TANKS ON AIRPLANES WITH #1 & #4 AUX. TANKS/RES #2 & 3 TANKS.

⬠ VARIABLE. (SEE 65B92900)

FIG. I

60B92010

SIZE B

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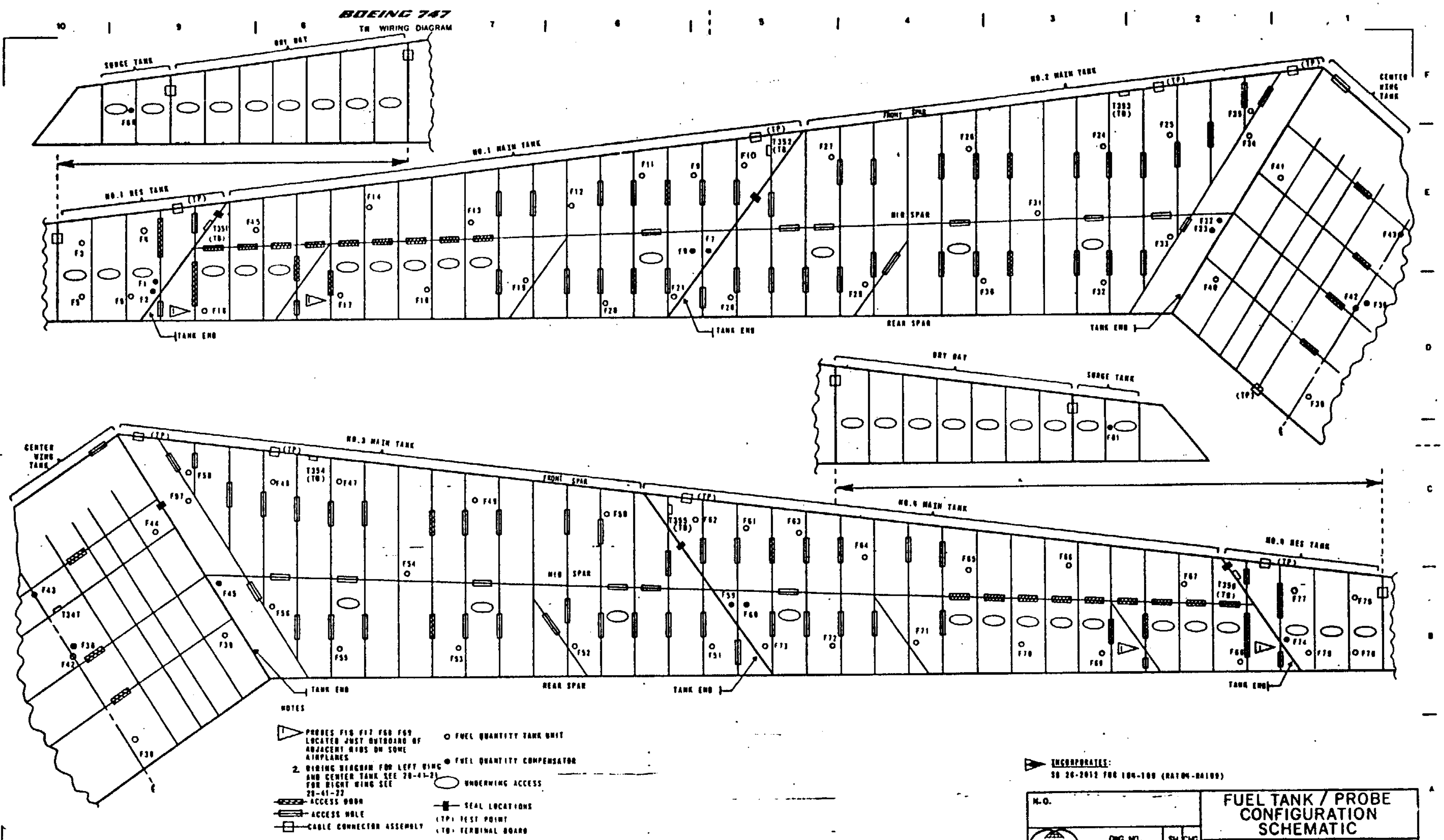
BOEING 747

TW WIRING DIAGRAM



NOTES

1. PROBES F15 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 104-109 (RA104-RA109)

N.O.			FUEL TANK / PROBE CONFIGURATION SCHEMATIC
TWA DWG NO. 1-84263	SH 1	CHG	EFFECTIVITY 104-109

RA104-RA109

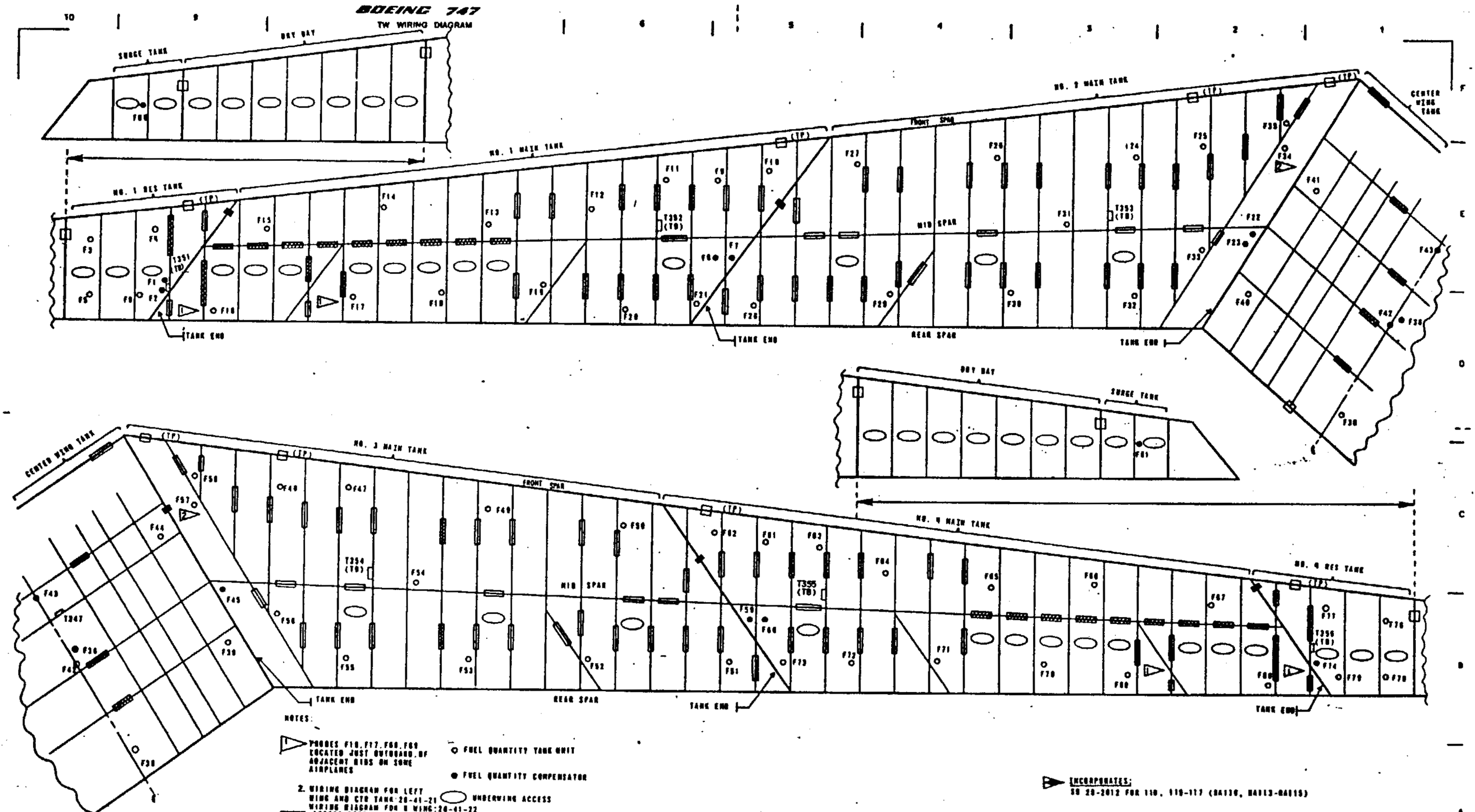
DRAWN: Ford 6/1/7
CHECKED: Mi... 9/1/77
SYS APVD: 9/1/77

1A DRAWING NO. 61B74702
PAGE DATE: SEP 27/77

BCN V
CHANGE: ABCN 6045

FACTUAL
ATA 28-40-00

SYSTEMS FACTUAL
ATA 28-41-01



NOTES:

1 PROBES F10, F17, F68, F69 LOCATED JUST OUTBOARD OF ADJACENT RIBS ON SOME AIRPLANES

2. WIRING DIAGRAM FOR LEFT WING AND CTR TANK: 28-41-21
WIRING DIAGRAM FOR R WING: 28-41-22

ACCESS DOOR
ACCESS HOLE
CABLE CONNECTOR ASSEMBLY
3 EFF FOR 110, 115-117, 119 (RA110, RA113-RA115, RA164)

○ FUEL QUANTITY TANK UNIT
● FUEL QUANTITY COMPENSATOR
UNDERWING ACCESS
SEAL LOCATIONS
(TP) TEST POINT
(TB) TERMINAL BOARD

INCORPORATES:
SB 28-2012 FOR 110, 115-117 (RA110, RA113-RA115)

DRAWN:
CHECKED:
SYS. APVD:

2A DRAWING NO. 61B74702
PAGE DATE: SEP 27/77

ECN:U
CHANGE: ADCN 6950

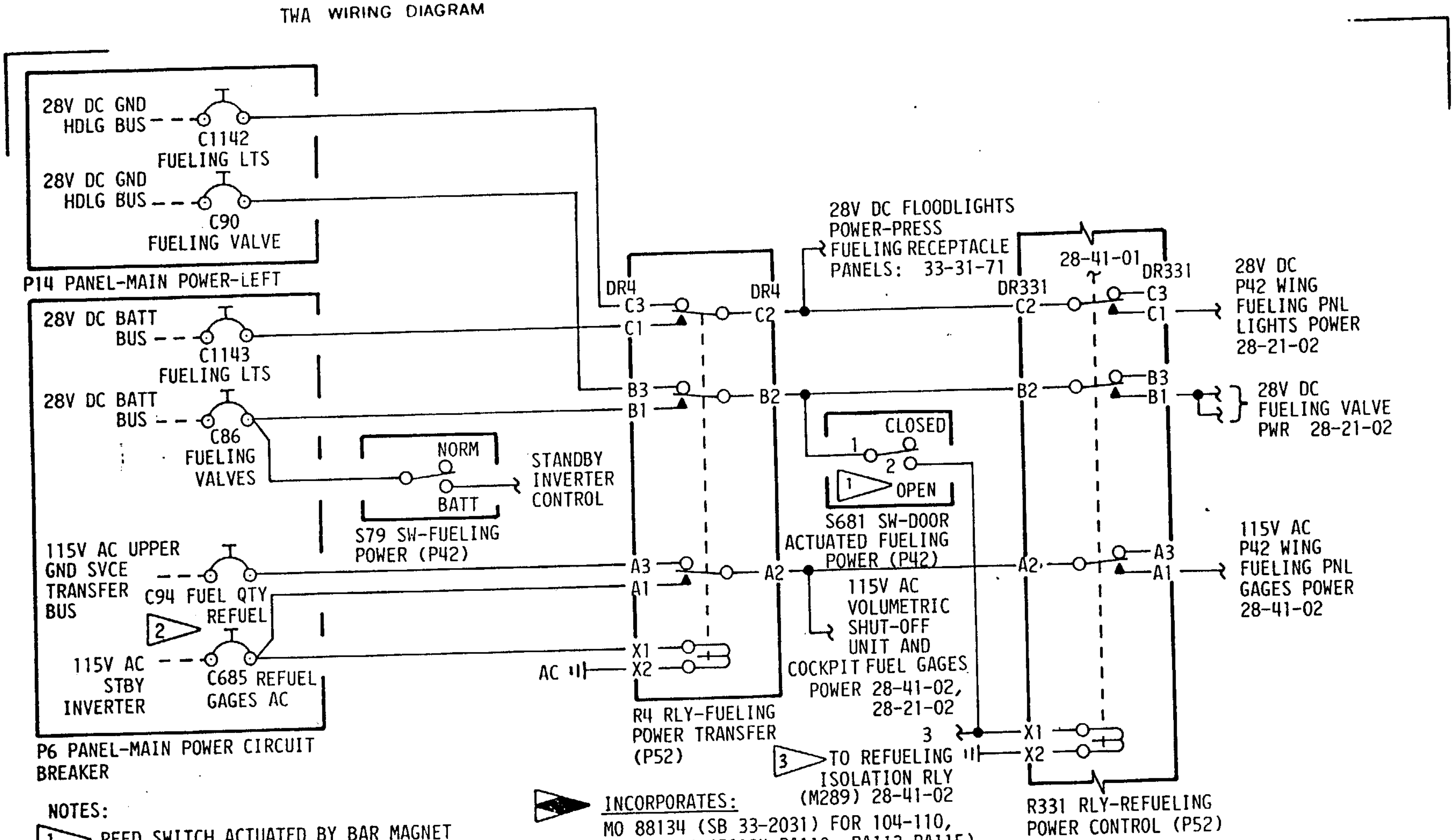
M.O.			FUEL TANK/ PROBE CONFIGURATION SCHEMATIC
TWA DWG. NO. 1-09263	SHT 2	CHG	EFFECTIVITY: 110, 115-117, 119

RA110
RA113-RA115
RA164

AM 28-4000

BOEING 747

TWA WIRING DIAGRAM



INCORPORATES:

MO 88134 (SB 33-2031) FOR 104-110,
115-117 (RA104-RA110, RA113-RA115)

MO 97718 (SB 28-2054R1)
MO 97158 (SB 28-2069R1)
MO 97159

NOTES:

1 REED SWITCH ACTUATED BY BAR MAGNET

2 ØB FOR 104-110, 115-117 (RA104-RA110, RA113-RA115) AFTER INC OF SB 28-2054R1

3 104-110, 115-117 (RA104-RA110, RA113-RA115) AFTER INC OF SB 28-2069R1

DRAFTED BY:
CHECKED BY:

DRAWING NO. 61B74702
PAGE DATE OCT 1/80

DCN V
CHANGE SB

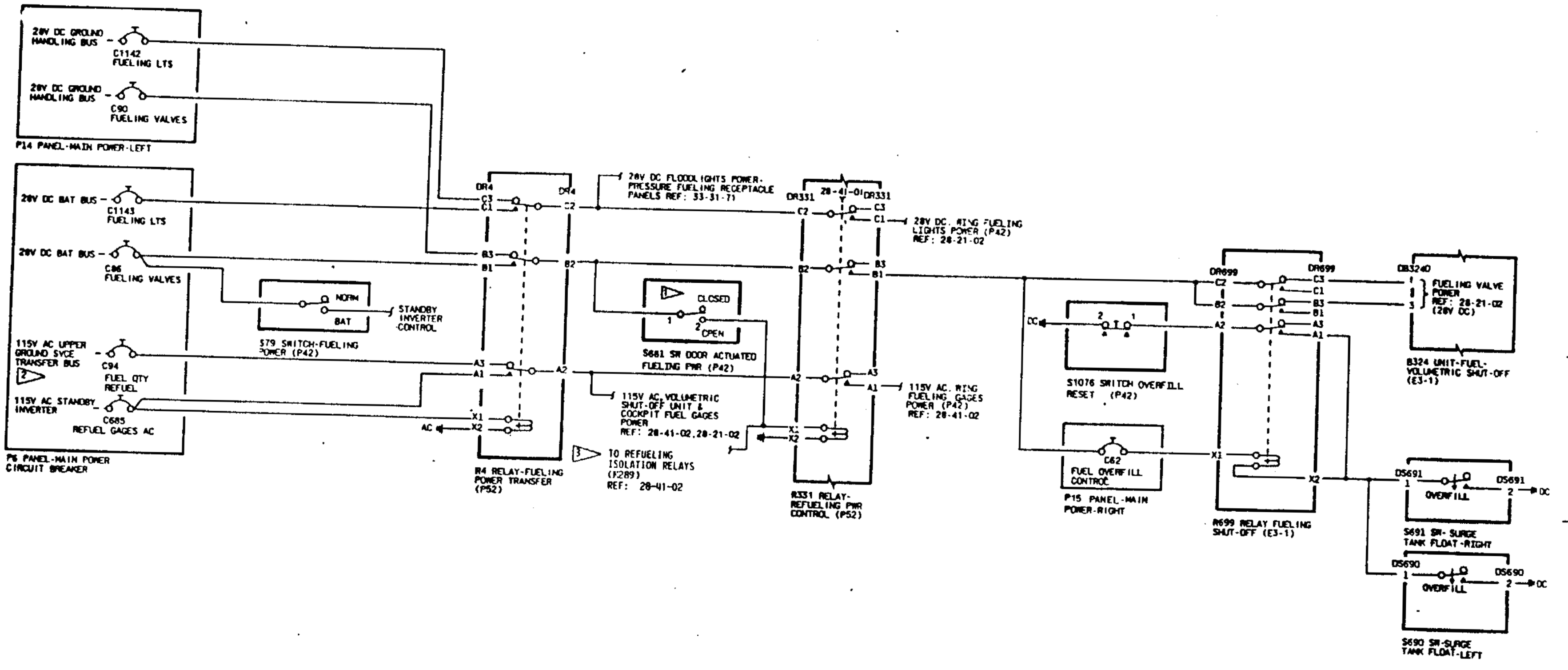
MO 88134
97718

FUEL QUANTITY SYSTEM
AC & DC POWER-
SCHEMATIC

DWG NO. 1-84797
SHT 1

EFFECTIVITY:
104-110, 115-117

RA104-RA110
RA113-RA115



NOTES

1 REED SWITCH ACTUATED BY BAR MAGNET

2 B AFTER INCORP S/B 28-2054R1 FOR 119 (RA164)

3 119 (RA164) AFTER INCORPORATION OF SB 28-2069R1

INCORPORATES:
PO 8813- (SB 33-2031) FOR 119 (RA164)
PO 97715 (SB 28-2054P1)
SB 28-2069R1

DRAWN:
CHECKED:
SYS APVD:

5A DRAWING NO. 61874702
PAGE DATE: OCT 1/60

DCN: V
CHANGE: 58

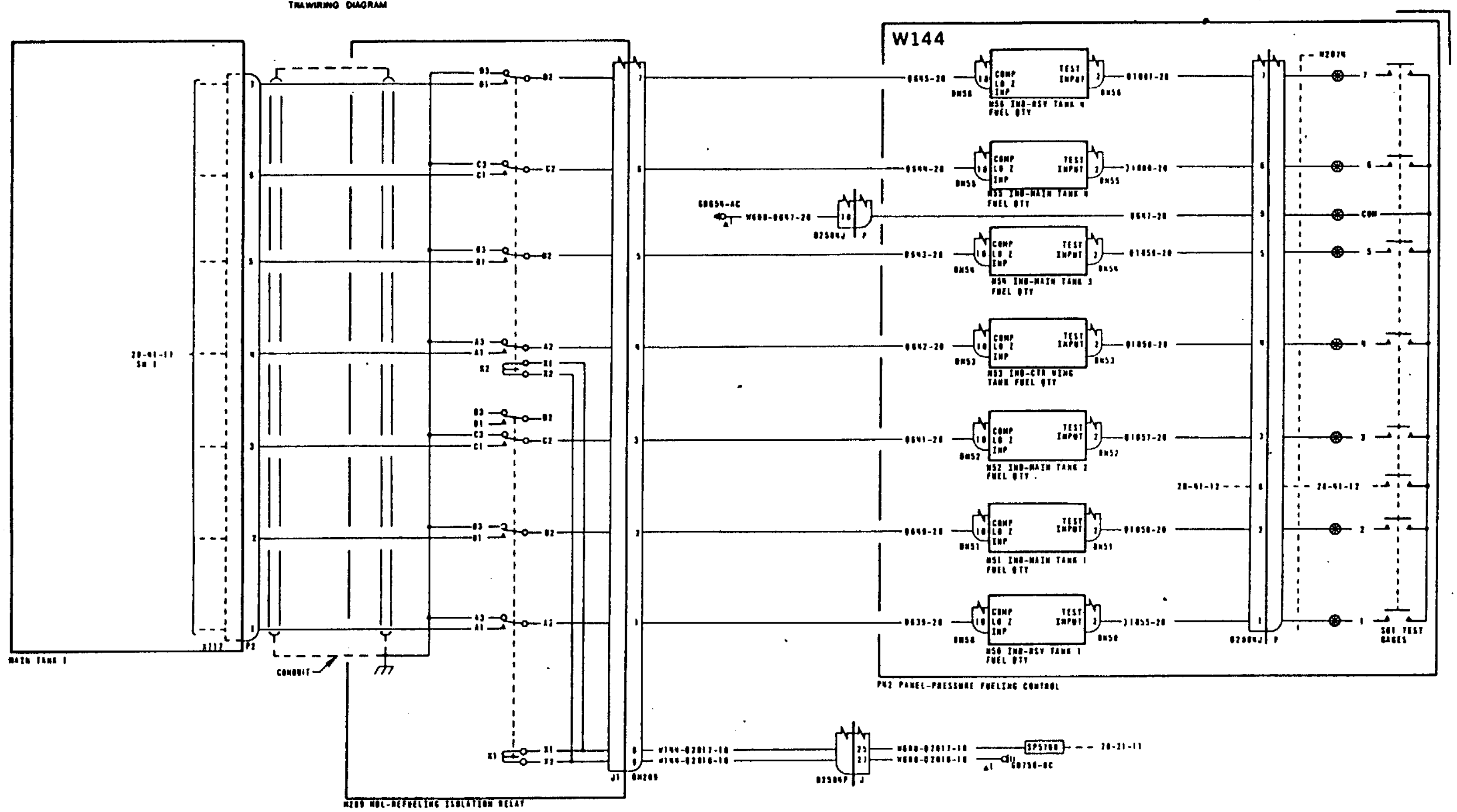
M.O. 88134 97718			FUEL QUANTITY SYSTEM-AC AND DC POWER-SCHEMATIC
TWA DWG. NO. 1-84797	SHT 2	CHG	EFFECTIVITY: 119

RA164

ATA 28 40.00

FACUAL

ATA 28-40.00



INCORPORATES:
SB 28-2064 (R1) FOR 116-117, 119 (RA114-RA115, RA164)

H.O.		FUEL QUANTITY GAGES- SIGNAL 1	
TWA	DWG NO 1-EHALH	SHT 3	CHG
		EFFECTIVITY 116-117, 119	

RA114 - RA115
RA164

DRAFTED BY Cuane K
CHECKED BY Jr.

DRAWING NO. 6187Y702
PAGE DATE OCT 1/80

DCN V
CHANGE 5B

28-41-11
SH 2 PAGE 6

SYSTEMS MANUAL
ATA 28-40-00

BOEING 747
TW WIRING DIAGRAM

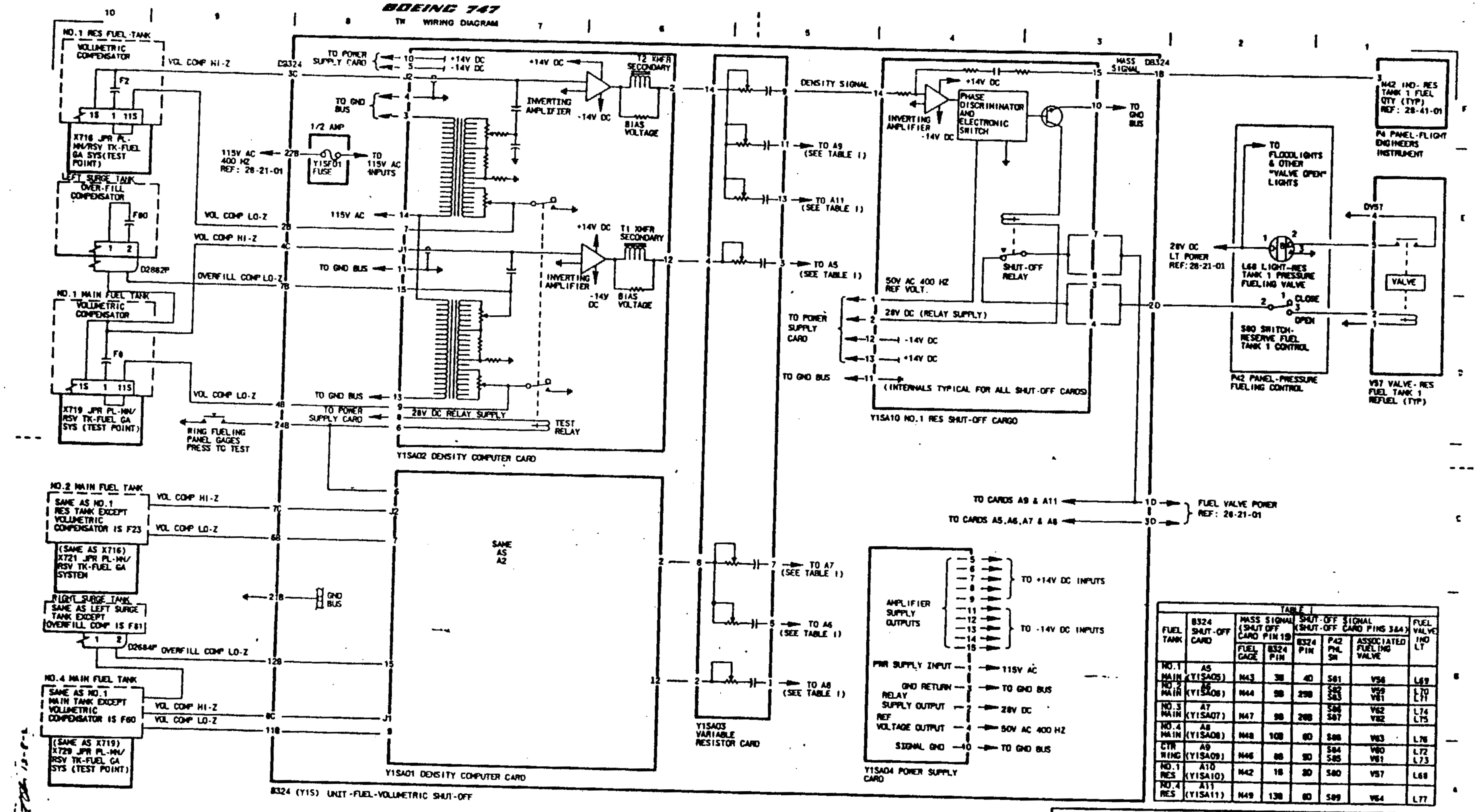


TABLE 1

FUEL TANK	B324 SHUT-OFF CARD	MASS SIGNAL (SHUT OFF CARD PIN 19)		SHUT-OFF SIGNAL (SHUT-OFF CARD PINS 3&4)			FUEL VALVE IND LT
		FUEL GAGE	B324 PIN	B324 PIN	P42 PNL SW	ASSOCIATED FUELING VALVE	
NO.1 MAIN	A5 (Y1SA05)	N43	3B	4D	S81	V58	L69
NO.2 MAIN	A6 (Y1SA06)	N44	9B	29B	S82 S83	V59 V61	L70 L71
NO.3 MAIN	A7 (Y1SA07)	N47	9B	28B	S86 S87	V62 V82	L74 L75
NO.4 MAIN	A8 (Y1SA08)	N48	10B	6D	S88	V63	L76
CTR WING	A9 (Y1SA09)	N46	8B	5D	S84 S85	V60 V61	L72 L73
NO.1 RES	A10 (Y1SA10)	N42	1B	2D	S80	V57	L68
NO.4 RES	A11 (Y1SA11)	N49	13B	6D	S89	V64	L77

N.O.

TWA
DWG NO.- 1-04700
SH 1
CHG
RA104-RA110 RA113-RA115 RA104

FUEL VOLUMETRIC SHUT-OFF SCHEMATIC

EFFECTIVITY ALL

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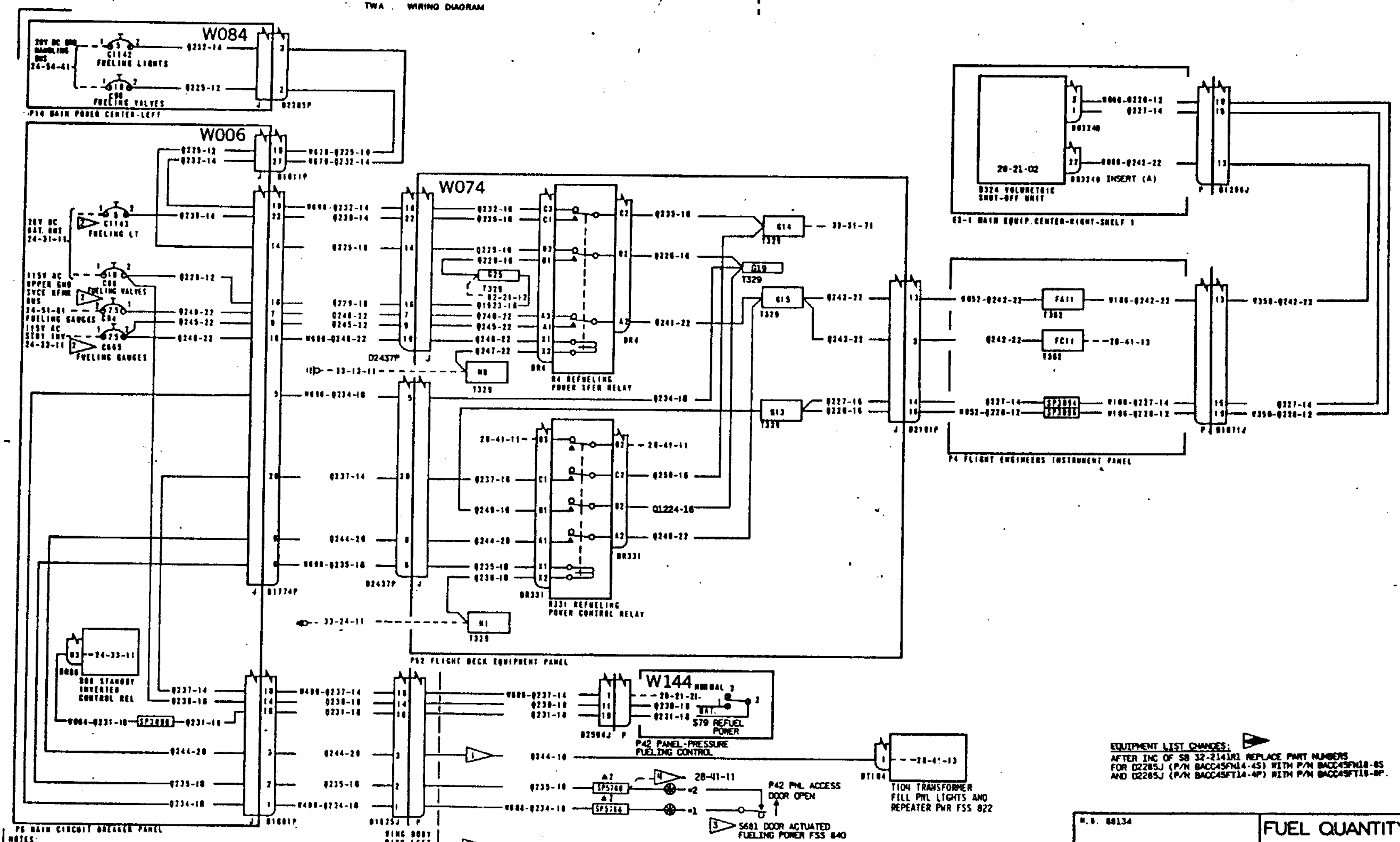
CHECKED:
SYS APVD: 12-8-81
DRAWING NO. 61874702
PAGE DATE: SEP 27/77

DCN:U
CHANGE:

SYSTEMS FACTUAL
ATA 28 40.00

BOEING 747
TWA WIRING DIAGRAM



DRAFTED BY dk
CHECKED BY Pam

NOTES:

1 20 GAUGE ACCEPTABLE FOR 102-109 (RA102-RA109)

2 3 AMP FOR 101-106 (RA101-RA106)

3 BAR MAGNET ACTUATED
REED PROXIMITY SWITCH.

W/B PRESS. SEAL

4 104-110, 115-117 (RA104-RA110, RA113-RA115)
AFTER INC OF SB 28-2068R1

INCORPORATES:
M.O. 88134 (SB 33-2031) 101-117 (RA101-RA115
SB 32-2141R1 RA161-RA162)

SB 28-2069R1 FOR 101-110, 115-117
(RA101-PA110, RA113-RA115)

EQUIPMENT LIST CHANGES:
AFTER INC OF SB 32-2141R1 REPLACE PART NUMBERS
FOR D2285J (P/N BACC45FN14-4S) WITH P/N BACC45FN18-8S
AND D2285J (P/N BACC45FT14-4P) WITH P/N BACC45FT18-8P.

DRAWING NO: 61874702
PAGE DATE: MAR 1/81

ECN V
CHANGE: SB

M.O. 88134

TWA

DWG NO.
1-84253

SHT	CHG
1	

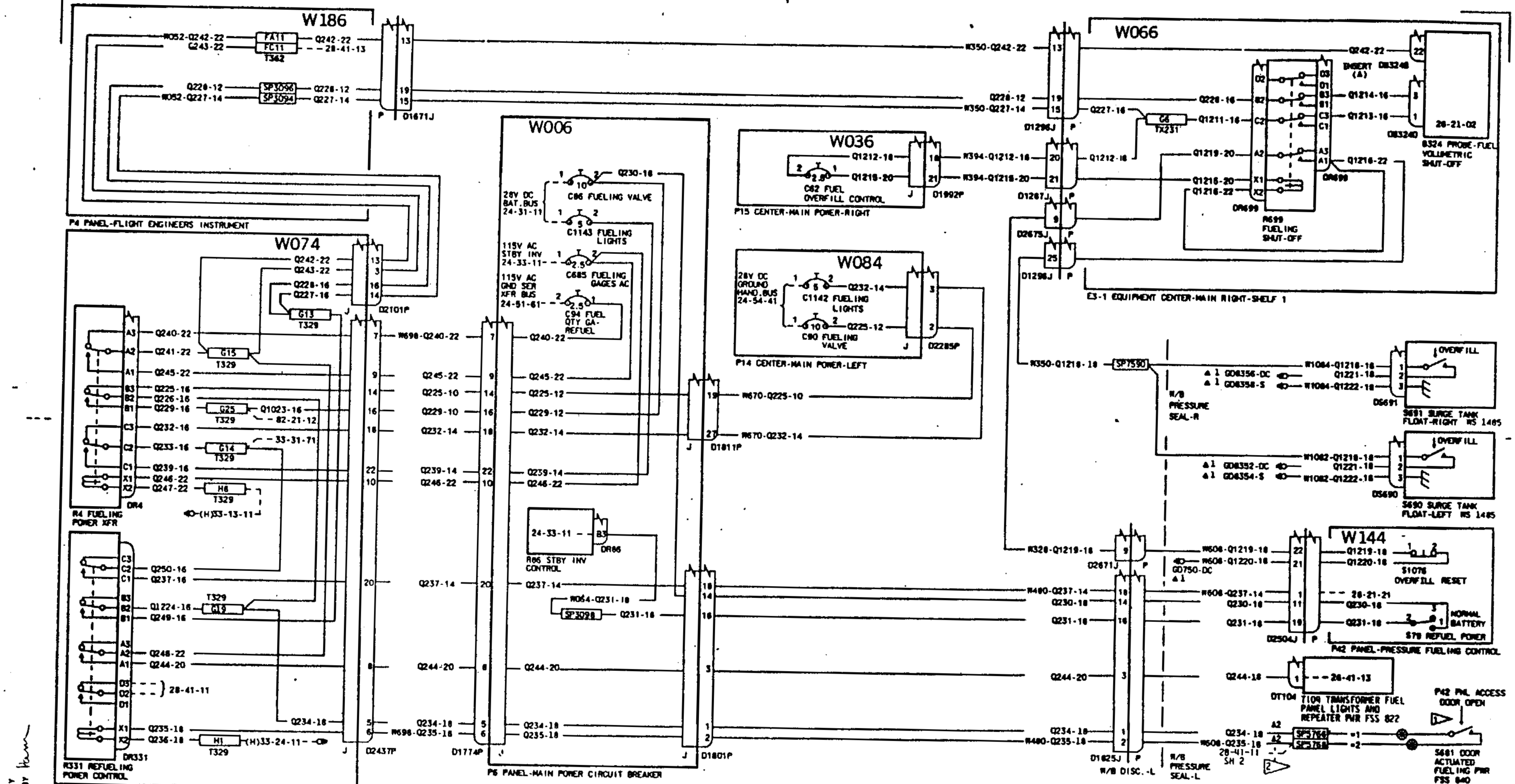
FUEL QUANTITY - AC AND DC POWER

EFFECTIVITY
101-117

RA101-RA115
RA161-RA162

BOEING 747

TWA WIRING DIAGRAM



P52 PANEL-FLIGHT DECK EQUIPMENT-RIGHT

NOTES:

1 BAR MAGNET ACTUATED REED PROXIMITY SWITCH.

2 119 (RA164) AFTER INC. OF SB 28-2069 (R1).

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.

INCORPORATES:

MO 88134 (SB 33-2031) 118-119 (RA163-RA164)
SB 32-2141R1

SB 28-2069 (R1) FOR 119 (RA164)

DRAFTED BY
CHECKED BY

DRAWING NO. 61874702
PAGE DATE: MAR 1/81

DCN:V
CHANGE:

M.O. 88134			FUEL QUANTITY- AC AND DC POWER
TWA DWG NO. 1-84253	SHT 3	CHG	EFFECTIVITY 118-119

RA163 -RA164

FAC UAC

ATA 28 40 00

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SYSTEMS FACTUAL
28-41-00

BOEING COMMERCIAL AIRPLANE GROUP

AIR SAFETY INVESTIGATION

FAX COVER SHEET

TO: >>>>>	Bob Swaim	From:	Dennis Rodrigues
FAX:	(202) 314-6349	Fax:	(206) 237-8188
PHONE:	(202) 314-6394	Phone:	(206) 237-8301
	Pages: L + 0	Date: April 11, 1997	Time: 10:30AM

Subject: Fuel Probe to Ground Impedance

I understand that you requested the subject information from Tom Peacock. In response, the impedance between the probe and ground under steady state DC conditions is as follows:

Between Hi-Z and ground the impedance is 39 Ohms +/- 5 % and between Lo-Z and ground it is 6.8K Ohms +/- 5 %.

If you have any additional questions, feel free to call at any time.

Regards;

Dennis 4/10/97

Dennis Rodrigues

28-41-00

TWA Wiring Investigation Summary
Fuel Tank Wire Routing
Center Tank FQIS Component Test

TWA (RA164) Fuel Tank Wire Routing Analysis

Front Spar - Main Tanks

The FQIS wiring exits the in-board front spar at approximately FSSI 261 and penetrates the wing leading edge cavity at the wing root at approximately STA 986 on both the left and right wing. There is also a penetration near the refueling panel (FSSI 820) to provide fuel quantity data to the panel. Boeing Service Bulletin 747-28-2069 and the subsequent AD 79-20-11, added a "Zipper Tube" overall lightning shield to the inboard front spar wiring which provides additional protection against incidental contact and shorting to any other wire harness. The Service Bulletin also adds an Isolation Relay Module to the Refuel Panel Wiring that disconnects and grounds the wiring from the Refuel Panel to the tank when the Refuel Panel Door is closed.

Wheel Well - Rear Spar - Center Tank

FQIS Wire Bundle W480 penetrates the Center Tank Rear Spar in the Wheel Well at approximately STA 1230 LBL 100. W480 is routed along the spar up along the upper part of the wheel well and penetrates the floor into the pressurized area of the airplane at approximately STA 1270 LBL 60 (See Figure 1). The length of this run is approximately 10 feet. W480 is routed with the power wires noted in Table 1. This wire bundle does not have an overall lightning shield because of the inherent lightning protection provided by the wheel well, it is not in a lightning zone.

W480 consists of one shielded and jacketed wire and two unshielded twisted and jacketed wires. The conductor and insulation of these wires are constructed per MIL-W-16878, Type EE, 200°C rated, 20 AWG, with extruded Teflon insulation. The jacket over the shielded wire is composed of TFE Teflon. The overall jacket is a lacquered nylon braid (See Figure 2).

In order for an outside power source to get into the tank a wire-to-wire short would have to occur. In the case of the shielded FQIS wire, the nylon braid, the outer jacket, the shield and the inner insulation would have to be penetrated in addition to the insulation on the outside source wire. Also, the shield on the FQIS shielded wire would provide a shorting path to ground until it was abraded significantly. For the twisted wires, the nylon braid and the insulation on at least one of the two wires would have to be penetrated in addition to the insulation on the outside source wire. 115VAC power applied to these wires would also result in immediate damage to, or erroneous indication on, the Flight Deck Indicator.

If power from an outside source penetrated the FQIS wiring, a fault internal to the tank is still required in order to initiate an ignition of fuel or fuel vapor. The FQIS probes are capped on both ends with plastic covers to prevent contact with structure. The cylinders of the capacitive probes are also coated with a non-conductive varnish. The fuel tank structure is treated with a non-conductive protective coating in addition to joints and penetrations being coated with sealant. A surface on the probe and an adjacent surface in the tank would have to be abraded to expose bare metal to provide the necessary spark gap or conductive path that could cause fuel vapor ignition. Note that any wiring or probe short to structure in the tank would result in an erroneous indication on the Flight Deck Indicator.

28-41-00

Center Tank FQIS Component Test

A set of Center Tank Fuel Quantity probes and the associated production in-tank wire harnesses were assembled and installed in an altitude chamber. The purpose of the test was to determine the insulation resistance and dielectric withstanding capability of the entire Center Tank FQIS assembly. See Figure 3 for a schematic of the test setup. The following series of tests were conducted:

Altitude	Test Voltage (1)	Evaluation Criteria (2)	Results
Sea Level	115VAC	>25mA	Less than <3.0µA
up to 50,000'	115VAC	>25mA	<3.0µA
Sea Level	500VDC Insulation Resistance	<100 Mohm	∞
	1500 VAC Dielectric Withstanding	>40mA	<1.3mA
	500 VDC Insulation Resistance	<100 Mohm	∞
up to 50,000'	1500 VAC Dielectric Withstanding	>40mA	(3)
Sea Level	1500 VAC Dielectric Withstanding	>40mA	<1.3mA
	600 VDC Insulation Resistance	<100 Mohm	∞
Sea Level	Dielectric Withstanding Limit Test	>40mA	<1.3mA 3300VAC (4)

Note (1): For the 115VAC tests , the test voltage was applied between Hi-Z to Lo-Z, Hi-Z shield to Lo-Z and Hi-Z shield to Hi-Z wires. For the Dielectric Withstanding tests and the Insulation Resistance tests the test voltage was applied between the Hi-Z and Lo-Z wires.

Note (2): The evaluation criterion for the 115 VAC and Dielectric Withstanding test (>40mA) is an arbitrary value chosen to allow measurement of currents up to that value and does not reflect the current limit requirement for the FQIS.

Note (3): The leakage current stayed constant at <1.3mA from sea level to approximately 25,000'. Between 25,000' and 30,000' the overcurrent detector, set at 40mA, on the Hi-Pot tester would trip off as the test voltage approached 1500VAC. From 25,000' to 50,000' a linear reduction in voltage was set from 1500VAC down to 840VAC while maintaining <40mA leakage current.

Note (4): The voltage was increased until breakdown occurred. The breakdown occurred at the top end of the fuel probes between the edges of the Hi-Z and Lo-Z concentric cylinders.

These results show that the insulation resistance of the FQIS Center Tank assembly did not degrade during this test demonstrating the assembly is impervious to the 28VDC routed with the Center Tank FQIS Wire Bundle.

The dielectric withstanding capability did decrease with altitude but this is a normal result of the reduced dielectric of atmosphere at higher altitudes and the increase in the corona effect. The results show that the voltage required to generate enough current in an intact Center Tank FQIS assembly is well in excess of 115VAC, the highest voltage routed with the Center Tank FQIS Wire Harness, even at 50,000'. The results also show that below 25,000' the Center Tank FQIS assembly maintains full 1500VAC Dielectric Withstanding capability.

28-41-00

Additional Information Regarding Wiring Integrity and Center Tank Components

The inspection of the Center Tank Fuel Quantity Gauge revealed no evidence of damage as a result of an extraneous voltage being applied to the wiring of the Center Tank.

The Center Tank FQIS Wire Bundle W480 was intact on the RA164 and showed no evidence of insulation breakdown or abrasion. The overall jacket was torn but showed no evidence of abrasion or burn through. The insulation on the twisted wires and the outer jacket on the shielded wire showed no evidence of abrasion or burn through.

The Override/Boost Pump switches on the Flight Engineers Fuel Panel were in their OFF position and the Scavenge Pump switch was in its OFF position indicating there was no 115VAC power on these wires.

SYSTEMS FACTUAL
28-41.00

BOEING COMMERCIAL AIRPLANE GROUP

AIR SAFETY INVESTIGATION

FAX COVER SHEET

* * *

TO: >>>>>	Bob Swaim	**From**:	Dennis Rodrigues
FAX:	(202) 314-6349	**Fax**:	(206) 237-8188
PHONE:	(202) 314-6394	**Phone**:	(206) 237-8301

Pages: 2 Date: April 1, 1997 Time:

* * *

Subject: TWA 800 Fuel System Questions

Reference: Your e-mail to Kevin, dated 3/25/97

Here are some additional answers to your questions in reference, using the same question numbers:

6. Do the vents in the 747-SP wing tips both face fore or aft? Do they provide a forced flow of ventilation?

They face forward. The 747 fleet has flush vents (a round hole in the lower surface) up to airplane line position 205, and NACA ram scoops (forward facing) from line 205 and on. The first 747SP was line 265. The purpose of the ram vent scoop is to provide a slight positive pressure in the tanks for improved fuel feed (especially boost off) performance. This makes the airplane more tolerant to fuel mismanagement; inadvertently put on suction feed. Although not the specific purpose, both types of vents will produce a crossflow of air through the center tank as slight pressure variations exist between wing tips.

7. Has Boeing certified a nitrogen inerting system in any commercial airplane?

No.

8. What test results does Boeing have to show accuracy of the center wing tank fuel quantity indication system at fuel levels, including 300# and 640#?

Ground and flight calibrations of fuel gages are done on a first-of-a-model basis. Ground calibration: The airplane that was calibrated demonstrated slight overreading in the range of interest; +0.15 to +0.25 percent of full scale, that is 143 to 238 pounds gage high.

Flight calibration: At the unusable fuel level (end of scavenge) the gage read 260 pounds in level flight.

SYSTEMS FACTUAL
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9. At what fuel quantity is the center wing tank quantity system unreliable at the 3.5 degree body angle seen at the end of the FDR?

The gage will read as long as there is fuel on any probe. At 3.5 degrees nose up, it takes 180 pounds to touch the first probe.

Ramp and flight conditions have been estimated by computer model as follows:

<u>Ground</u>: Gate 27 JFK (1 degree nose up airplane pitch)

	Probe		submerged length at	
			350#	640#
	-14		0	0.37 inch
	-12		0	0.20 inch
Flight:		Pitch		
	-14	+2	0.41	1.17 inch
		+3.5	0.887	1.65 inch
		+5	0.932	1.98 inch

Note: The -14 probe is the aftmost probe at BL 0 rib. The -12 is the two aft side-of-body rib probes.

We will provide answers to the other questions as soon as they are available.

Regards;

4/1/97

Dennis Rodrigues

SYSTEMS
FACTUAL
[illegible]

BOEING COMMERCIAL AIRPLANE GROUP

AIR SAFETY INVESTIGATION

FAX COVER SHEET

TO: >>>>>	Bob Swalm	From:	Dennis Rodrigues
FAX:	(202) 314-6349	Fax:	(206) 237-8188
PHONE:	(202) 314-6394	Phone:	(206) 237-8301
	Pages: 2	Date: April 10, 1997	Time: 2:30 pm

Subject: TWA 800 Fuel System Questions

Reference: Your fax to Dennis Rodrigues, dated 4/2/97

In your reference fax you raised some additional questions relative to our answers to your original questions 8 and 9. Following are responses to reference:

1. On the ground, what's the minimum fuel required to touch any probe?

At the Gate 27 ramp angle, 390 lbs would be required to just touch the aft-most (-14) probe.

2. In flight, with fuel touching the probes (for example, in the 640# case), is there much/any change in reading that comes from attitude change?

Honeywell expects to have an answer next week. We have provided the submerged probe depths to Honeywell.

3. If the fuel is less than what's required to touch the probes, will the gage go to zero?

The gage will read it's zero-adjusted reading which will be at or very near zero. Adjustment is made by substituting the tank empty capacitance and turning the empty-adjust screw on the gage until it reads zero. Stiction in the gage gear train produces minor repeatability tolerance.

4. At what pitch does 300# and 640# submerge the aft (-14) probe to 3.75 inches?

It takes at least 148 gallons (1000#) to reach 3.75 inches at any pitch attitude. Some examples of the relation are:

Pitch	Gallons
14	148
8	160
5	210
3	290
1	625

If you have any additional question, feel free to call at any time. We will respond to the remaining questions as soon as possible.

Regards:

Dennis 4/10/97

Dennis Rodrigues

28-41-01

FG420A
FUEL QUANTITY TANK UNIT

1. DESCRIPTION AND OPERATION. Paragraphs 1A to 1C.

A. Description.

(1) The FG420A Fuel Quantity Tank Unit is a sensing element in a capacitance-type fuel quantity indicating system. The tank unit consists primarily of two concentric tubes (electrodes) and a terminal block. The concentric tubes consist of an aluminum outer electrode and a nickel inner electrode, which form the plates of a capacitor. The tubes are spaced and insulated from each other at intervals throughout their lengths by Teflon spacers. The terminal block contains three terminals for connecting the tank unit to the aircraft wiring. The tank units are mounted in the fuel tanks by means of mounting brackets attached to the outer electrode.

(2) Leading particulars and specifications are listed in table 1.

B. Operation in System. The height and dielectric constant of fuel between the electrodes determine the capacitance of the tank unit. The diameter of the inner electrode for each tank unit varies along the length of the unit to conform to the shape of the fuel tank, resulting in the tank unit capacitance changing linearly with the fuel quantity. Within a fuel tank, several tank units are connected in parallel so that the total capacitance of the tank units varies linearly with the fuel quantity in the tank. The tank units for the fuel tank connect into the sensing leg of a rebalancing bridge circuit within a fuel quantity indicator. Changes in quantity of fuel vary the capacitance of the tank units and cause an unbalance in the bridge circuit. This unbalance initiates indicator operation and results in a dial presentation of measured fuel quantity expressed in either pounds or kilograms, depending upon the dial calibration of the indicator.

C. Series Data. Series numbers, stamped on the identification plate, identify forward-production changes to the tank units. This manual covers all existing series of tank units as listed in table 2.

Table 1. Leading Particulars and Specifications

PART NO.	CAPACITANCE (UUF)*	LENGTH (INCHES)	WEIGHT (POUNDS)
FG420A8	26.84	15.61	0.474
FG420A9	78.40	16.80	0.492
FG420A10	43.46	16.14	0.482
FG420A11	54.86	17.64	0.504
FG420A12	115.50	58.11	1.161
FG420A13	184.13	72.16	1.397
FG420A14	138.70	50.43	1.046
FG420A15	178.86	66.00	1.280
FG420A16	119.68	72.61	1.404
FG420A17	52.10	24.89	0.613
FG420A18	96.79	28.37	0.666
FG420A19	73.35	29.48	0.682
FG420A20	84.33	35.74	0.801
FG420A21	81.17	34.97	0.780
FG420A22	102.91	44.30	0.931

Table 1. Leading Particulars and Specifications (Cont)

PART NO.	CAPACITANCE (UUF)*	LENGTH (INCHES)	WEIGHT (POUNDS)
FG420A23	115.41	47.14	0.972
FG420A24	92.00	44.88	0.938
FG420A25	75.67	52.68	1.080
FG420A26	116.96	56.06	1.131
FG420A27	23.93	14.81	0.462
FG420A28	116.82	58.27	1.164
FG420A29	38.11	15.04	0.466
FG420A30	97.16	18.20	0.513
FG420A31	56.89	17.63	0.504
FG420A32	88.19	18.68	0.520
FG420A33	101.78	19.84	0.532
FG420A34	53.24	21.27	0.559
FG420A35	98.67	22.13	0.572
FG420A36	104.88	22.96	0.584
FG420A37	49.38	20.82	0.552
FG420A38	60.55	22.37	0.572
FG420A39	55.08	21.69	0.565
FG420A40	68.92	24.57	0.609
FG420A41	57.78	22.75	0.581
FG420A64	140.75	66.67	1.300
FG420A65	44.11	14.50	0.460
FG420A66	42.84	13.50	0.460
FG420A72	146.48	58.76	1.170

* Capacitance tolerance is ±1.0% or ±0.50 uuf, whichever is greater.

Table 2. Series Differences

TANK UNIT	SERIES NO.	SERIES CHANGES
FG420A8 thru FG420A11, FG420A17 thru FG420A21, FG420A27, and FG420A29 thru FG420A41	1	Original production unit
	2	Same as series 1. Series number advanced upon completion of qualification testing
	3	Bracket (27, figure 101) changed from part number 10022195-106 to 1026353-101 to provide stronger part

SYSTEMS FACTUAL
28-41-01

Honeywell

OVERHAUL MANUAL

PART NO. FG420A8 THRU FG420A41,
FG420A64 THRU FG420A66,
FG420A72

FUEL QUANTITY TANK UNIT

COMPONENT OF HONEYWELL FUEL QUANTITY INDICATING SYSTEM

Note: 95-4879C, 95-4879C-1, and 95-4879C-2 have been incorporated to make this a complete issue.

REVISION NOTICE: LATEST REVISED PAGES SUPERSEDE THE SAME PAGES OF PREVIOUS DATE. INSERT REVISED PAGES INTO BASIC PUBLICATION. DESTROY SUPERSEDED PAGES.

28-40-12
1 MAY 1971

REVISED 1 JUNE 1977

95-4879C-3 (Supplements 95-4879C, 95-4879C-1, and 95-4879C-2) Printed in U.S.A.

28-41-01

Table 2. Series Differences (Cont)

TANK UNIT	SERIES NO.	SERIES CHANGES
	4	Same as series 3, except a new terminal block (20A, figure 101) with new terminal assemblies (5A, 10A, 14A, figure 101) added. Associated with these improvements to the terminal block are differences in other related parts
	5	Same as series 4, except adds selected tuning washer (7, figure 101) to provide for empty fuel tank capacitance adjustments. Associated with this improvement are differences in other related parts
FG420A8, FG420A10, FG420A17, FG420A20, FG420A21, FG420A29, FG420A39, FG420A41	6	Same as series 5, except incorporates style 2 spacer (33A, figure 101) and spacer pin (33B, figure 101)
FG420A9, FG420A11, FG420A12, FG420A13, FG420A14, FG420A15, FG420A18, FG420A19, FG420A22, FG420A27, FG420A30 thru FG420A38, FG420A40	6	Same as series 5, except that Honeywell specification MC8223-01 Varnish replaces specification MC7755-01 for coating inner electrode
	7	Same as series 6, except for minor change to terminals 5A, 10A, 14A, figure 101 (part numbers unchanged)
FG420A12 thru FG420A16, FG420A22 thru FG420A26, and FG420A28	1	Original production unit
	2	Bracket (27, figure 101) changed from part number 10022195-106 to 10026353-101 to provide stronger part
	3	Same as series 2. Series number advanced upon completion of qualification testing
	4	Same as series 3, except a new terminal block (20A, figure 101) with new terminal assemblies (5A, 10A, 14A, figure 101) added. Associated with these improvements to the terminal block are differences in other related parts

28-41-01

2. DISASSEMBLY.

Index to Figure 101

-1	Fuel quantity tank unit [items 1A thru 34]
1A	Protective cap [series 4 and up]
1B	Protective cap (2) [series 4 and up]
1C	Protective cap [series 4 and up]
2	Identification plate
3*	Strap assy
4	Strap assy [FG420A27, FG420A29, FG420A65, and FG420A66 Fuel Quantity Tank Units only]
5	Terminal assy [series 1, 2, and 3 only]
5A	Terminal assy [series 4 and up]
6*	Machine screw
7*	Tuning washer
8*	Lock washer
9*	Hexagon nut
10	Terminal assy [series 1, 2, and 3 only]
10A	Terminal assy [series 4 and up]
11*	Machine screw
12*	Lock washer
13*	Hexagon nut
14	Terminal assy [series 1, 2, and 3 only]
14A	Terminal assy [series 4 and up]
15*	Hexagon nut
16*	Lock washer
17	Leadwire clamp [series 1, 2, and 3 only]
18*	Machine screw [series 1, 2, and 3 only]
19*	Hexagon nut [series 1, 2, and 3 only]
19A	Machine screw [series 4 and up]
20	Terminal block [series 1, 2, and 3 only]
20A	Terminal block [series 4 and up]
21	Terminal insulator
22	Insulator
23	Electrostatic shield
24	Spacer
25	Terminal sleeve
26	Insulator
26A	Terminal sleeve [series 5 and up]
27	Mounting bracket
28*	Rivet
29	Mounting bracket
30*	Rivet
31	End cap
31A	Closed end cap (used on tank units manufactured after November 1972, and on units modified per Service Bulletin FG420A-28-1)
31A	End cap (identical to item 31 - used on tank units manufactured prior to November 1972 which have not been modified per Service Bulletin FG420A-28-1
32	Outer electrode
33**	Spacer style 1
33A**	Spacer style 2
33B**	Spacer pin
34	Inner electrode

NOTES:

- Indicates item not illustrated.

* Indicates attaching part for immediately preceding unasterisked item.

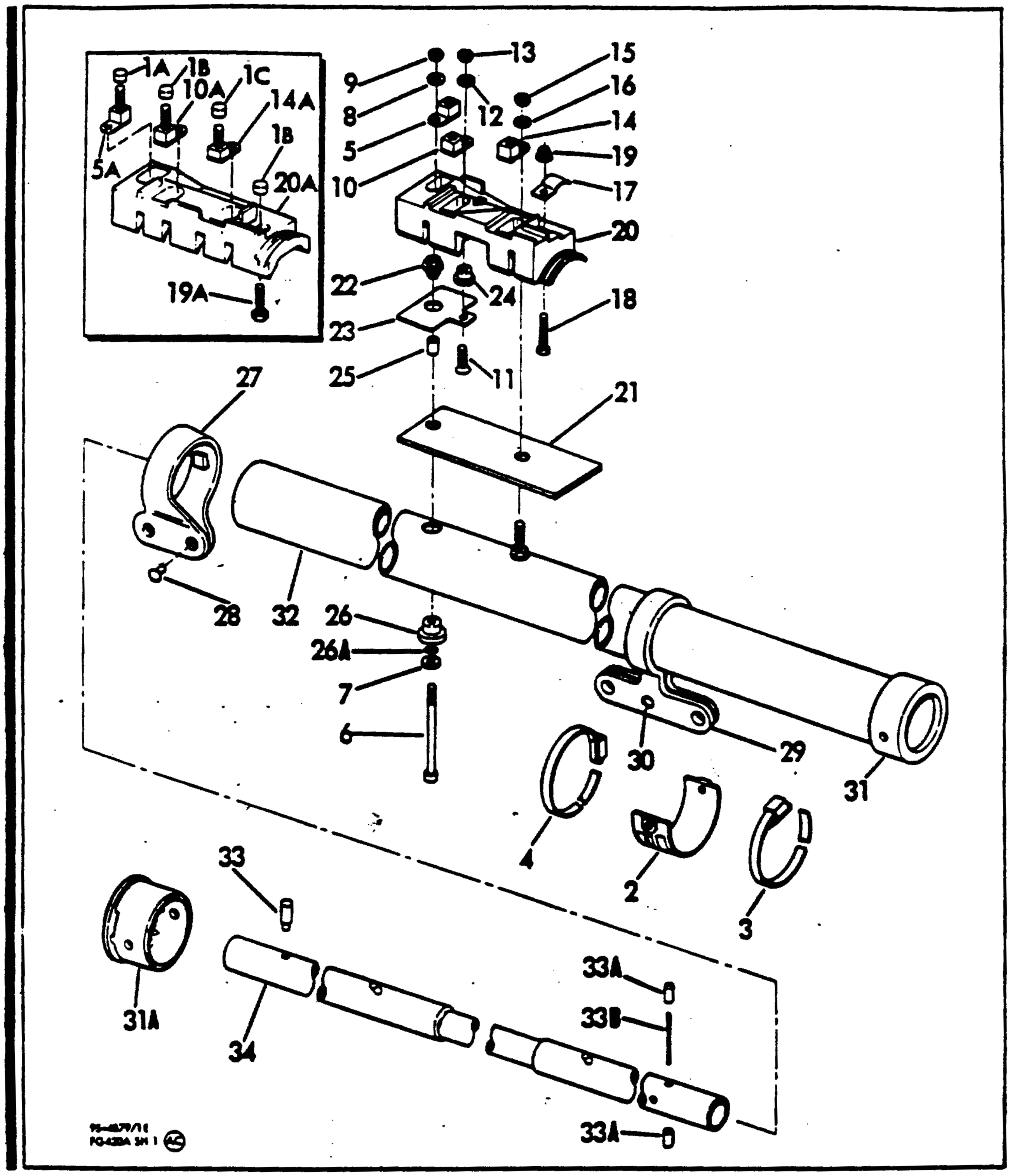
( ) Indicates quantity other than one.

** Indicates that quantity and usage shall be as specified in the detailed parts list, paragraph 12.

Items specified as applicable on Series 4 and up are also used on models FG420A64, and up.

28-41-01

2. DISASSEMBLY.



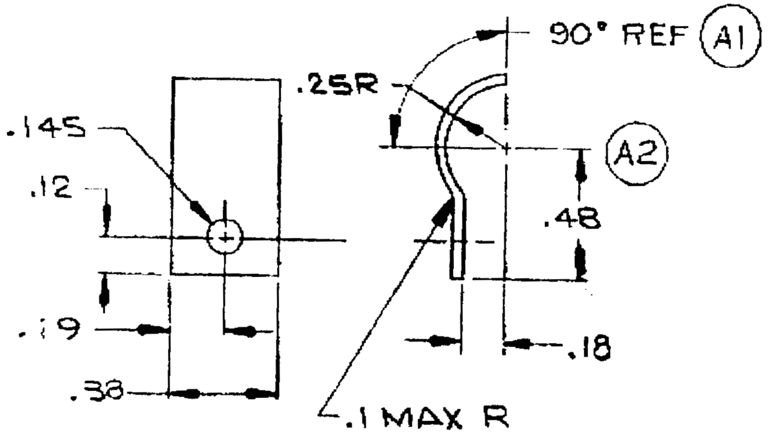
FG420A Fuel Quantity Tank Unit - Exploded View
Figure 101

SYSTEMS
FACTUAL
28-41-01

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	–	CONTROLLED DRAWING	10-29-67	FG420A
	A	ADD (1) ; (2) WAS ".75"	12-4-67	67-1707

DIMENSIONING AND TOLERANCING PER MIL-STD-8
INTERPRET DRAWING IN ACCORDANCE WITH
MIL-D-1000, FORM 2

HONEYWELL
PART NO.
10022188-101



3 - BREAK ALL CORNERS TO REMOVE SHARP EDGES

2 - PASSIVATE PER SPEC 4834

⚠1 - MATL .040 CRES PER QQ-S-766 TYPE 302 OR 304 (MATL SPEC 6537)

FG420A	FG420A
FG6C	FG6C
NEXT ASSY	USED ON
APPLICATION	

TOLERANCES UNLESS NOTED OTHERWISE	
X ±.02 XX ±.01 XXX ±.005	90° FORMED ANGLES +2° −1°
DEV 3036-05	
SUPSD	
FINISH - SEE NOTE 2	
GOVT MATL SPEC	⚠1
REF MATL (SPEC ⚠1)	

DRAFTSMAN		10-13-67
CHECK		
MATL & FIN		11-21-67
APPL ENGR		
DEV ENGR		10-11-67
PROJ ENGR		
PROD ENGR		10-25-67
RELIABILITY		

HONEYWELL INC. MILITARY PRODUCTS GROUP
■ AERO MPLS. ☐ ORDNANCE ORD. ☐ AERO ST. PETERSBURG
☐ ORDC ☐ SOL ORD SEATTLE ☐ BOSTON RADIATION CENTER

CLAMP, LEADWIRE

SIZE	CODE IDENT NO.	DRAWING NO.
B	94580	10022188
SCALE 2/1	WT	SHEET

SERIES 1-3 TERMINAL BLOCKS USE THIS CLAMP TO SECURE WIRING.
R Swain

SYSTEMS FACTUAL
28-41-[redacted]01

Fax Transmittal

Date: 12 NOV 1997

Time: 9:30 CST

TO: Fax Number 202-314-6349

Name Bob Swaim

Company NTSB

City/State/Country Washington D.C.

Phone Number/Mail Station for Pickup 314-6394

cc:

Total Number of Pages: Cover + 4

Message

Bob, - here is info we talked about on phone

pg 1) change directed by Boeing to improve wire connections

pg 2) Para 3.5.2 mounting requirement for compensator requires withstand 50 lb pull on the airplane wires

pg 3) Para 3.6.2 same requirement for tank units

pg 4) Terminal block - top of page shows block with threaded holes and strain relief clamp as being optional - bottom part of sheet shows terminal block with studs.

FROM: Name Lou Taylor

Mail Station MN51-1610

Phone 612-957-4279

Honeywell Inc.
Commercial Flight Systems
8840 Evergreen Boulevard
Minneapolis, MN 55433
Fax Number 612-957-4080

If you did not receive all pages or if document is illegible, please contact sender immediately.

CFS-157 Rev 12/91

28-41-01

ML.18.69 [illegible] 5558

REVISIONS

SYM J

SYM	DESCRIPTION	DATE	APPROVAL
D	PRR 94000 Incorporated ADCN 2, 3, 4, 5 & 6 CHG. EFF: R0001 - R9995 PIN: 17-762000	5/28/69	R.K Ryan
	PRR 95000 REASON: Drafting Error. (To complete accuracy requirem'ts.) CHG. EFF: R0001 - R9995 PROD. INFO: Drawing clarification only, airplane parts not affected. Coordinated with Supplier.	6-5-69	J. NEWMAN E-5500
	Priority: None REQUESTED BY: N. S. Ruder E-8450 Page 11 Para. 3.1.4.8 added reference to deviation Page 19 Para. 3.2.8.1 added reference to deviation.. Page 20 Para. 3.2.11.2, accuracy degradation extended to include High temp., EMI & power variation, from .4% to .5%. Page 24 Para. 3.3.11.2, environmental tolerance degradation requirements was .10 for Low temp. only. Page 28 Para. 3.5.3.5 deleted. Page 32.1 Para. 3.7.2.1, added continuous rotation knob and positive knob retention. Para. 3.7.2.2, added second test capability. Page 32.2 Para. 3.7.2.11, functional changed to qualification testing. Page 44 Para. 4.4.2, 4.4.3 and 4.4.4 added. Page 52 Added reference to deviation. Page 63 Added test - pin 14., Dial graduations changed.	5-28-9	PDS-LR-R8
	PRR 72594 REASON: To incorporate committed change. (To improve integrity of wire connections.) CHG. EFF: R0001 - R9995 PROD. INFO: Rework or replace existing parts and/or assemblies. Outside production item. Page 5.2 Added -50. Page 6 Para. 1.4 added -50. Page 50 Deleted reference to -7.	5/28/69	H.H.Dowen
	Page 54 Added View A-A for -7 and -50.	5/29/9	[illegible]
	Page 55 View A-A altered to add stud terminals. Detail I added. Page 60 Added -50.	6/11/9	C. COOK E5100

THE **BOEING** COMPANY	CODE IDENT NO. 81205	SIZE A	60B92010	000212
	SCALE			SH 205

6

SYM J

3.5 Specific Requirements For Design Of Compensator Units

[illegible] -7 - [illegible]

3.5.1 The compensator unit shall be an electrical device which senses fuel density as a function of device capacitance versus fuel dielectric constant.

3.5.1.1 The unit shall contain:

a) All metal electrodes, mount supports and wire strain relief

b) Electrical terminals

3.5.1.2 Unit markings and critical outline dimensions shall be in accordance with Figure V.

3.5.2 Mounting

3.5.2.1 The unit shall be designed for internal tank mounting.

3.5.2.2 The unit when mounted shall be capable of withstanding without damage a force of fifty (50) pounds applied from any direction including a direct pull on the airplane wiring when the wiring is clamped in the wire strain relief support.

3.5.2.3 The unit shall be of sturdy construction to preclude premature failure as a result of installation, maintenance and sloshing of fuel.

3.5.3 Electrical

3.5.3.1 The unit shall consist of a suitable arrangement of all metal conductors which are electrically insulated and isolated from each other, have positive (no pockets or traps wherein water or sediment can accumulate) drainage and which will preclude water, deposits and sediments across or between the electrically insulated and isolated component parts, which affect accuracy or operation of the system.

3.5.3.2 The unit shall be unaffected by micro-organisms and their by-products. A suitable coating shall be applied to the plates to preclude water adhesion as much as possible to provide [illegible] corrosion protection and electrical insulation. For -63 and subsequent compensator units the minimum spacing between all electrical parts shall be .25 inches.

3.6 Specific Requirements for Design of Tank Units

3.6.1 The tank unit shall be an electrical device which senses fuel level as a function of device capacitance versus device immersion.

3.6.1.1 The unit shall contain:

a) All metal electrodes, mount supports and wire strain relief

b) Electrical terminals

3.6.1.2 Unit markings and critical outline dimensions shall be in accordance with Figure VI.

3.6.2 Mounting

3.6.2.1 The unit shall be designed for internal tank mounting.

3.6.2.2 The unit when mounted shall be capable of withstanding without damage a force of fifty (50) pounds applied from any direction including a direct pull on the airplane wiring when the wiring is clamped in the wire strain relief support.

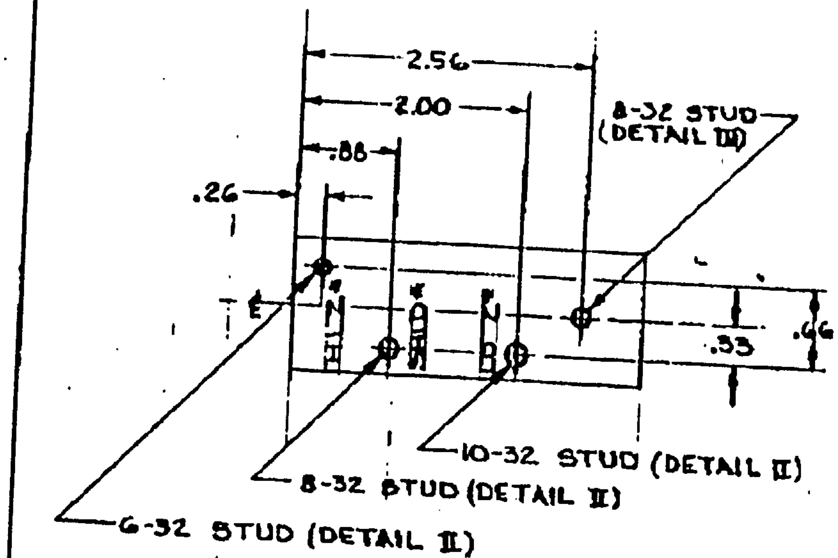
3.6.2.3 The unit shall be of sturdy construction to preclude premature failure as a result of installation, maintenance and sloshing of fuel.

3.6.3 Electrical

3.6.3.1 The unit shall consist of a suitable arrangement of all metal conductors which are electrically insulated and isolated from each other, have positive (no pockets or traps wherein water or sediment can accumulate) drainage and which will preclude water absorbtion and the formation of and bridging by water, deposits and sediments across or between the electrically insulated and isolated component parts, which affect accuracy or operation of the system.

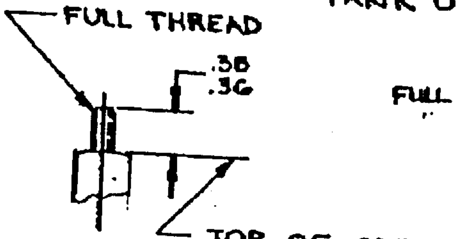
3.6.3.2 The unit shall be unaffected by micro-organisms and their by-products.

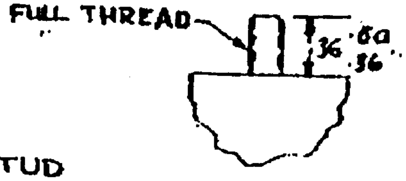
3.6.3.3 The unit shall be designed for a fluid level rate of change of ten (10) inches per minute and during this rate of change the fluid shall be at its natural level freely, completely and homogeneously between and outside the conductors.



DETAIL I

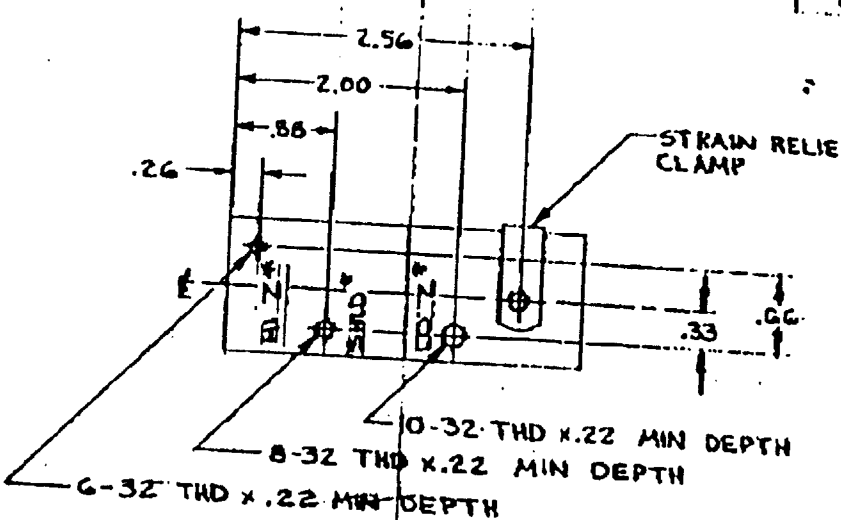
-62,-50 COMPENSATOR UNIT ONLY
TANK UNITS ☒ (EXCEPT -72)





DETAIL II

DETAIL III



DETAIL I (OPTIONAL)

-7 COMPENSATOR UNIT ONLY
TANK UNITS ☒ (EXCEPT -72)

* TERMINAL IDENTIFICATION, ~~.12~~ .20 HIGH
LETTERING, WHITE, PERMANENT,
FUEL RESISTANT.

☒ SEE INSTALLATION 65B00776
FOR APPLICABILITY (REFERENCE).
(NOTE: ALL -7 UNITS HAVE BEEN REWORKED TO 69B92008-1 PRIOR TO ASTE)

THE
BOEING
COMPANY

CODE IDENT NO. 81205

SIZE B 60B92010

SCALE NONE

SH 65.1

[redacted] 69 15826

ENGINEERING CHANGE ORDER

FORM A SHEET 1 OF 5

E.C.O. DATE DEC 9 1969

E.C.O. NO. 69 15826

ADM - 1601

REV. 11/66

IMPLEMENTED BOEING PRR 72594 OF 5-28-69. R Swain

SYSTEMS FACTUAL 28-41-01

CCB IDENT. NO. EF46-FC-L120

ECP NO. E-5651-4-9861

SCN NO.

PROJECT NO./ACCT. NO. C1438-1

TOTAL NO. OF ENG. DOCUMENTS TO BE CHANGED BY THIS ECO. PACKAGE 2

ANA 445 OR CONTRACT CLASS OF CHANGE

CLASS I ☒ CLASS II ☐

NOT APPLICABLE ☐

	YES	NO
ADVANCE SERIES	☒	☐
CUSTOMER APPROVAL REQUIRED	☒	☐
UPDATE OF DOCUMENT REQ. IMMEDIATELY	☒	☐
INACTIVATION	☐	☒

PURCHASED PART ☐

NEW RELEASE ☐

	YES	NO
REWORK PERMITTED	☒	☐
REWORK REQUIRED	☐	☒
INTERIM CONFIGURATION	☐	☒
REACTIVATION	☐	☒

ADVANCE PRINT AVAILABLE ☐

STATEMENT OF THE PROBLEM

FG 420A Terminal Block Change

DOCUMENT NO. & NAME	DASH NO.	REV. LET.	PROJECTED REV. LTR.	SHEETS REVISED
FG 420A Tank Unit	ALL	L	M	1, 2, 4, 6, 7 9, 10

DESCRIPTION OF CHANGE AND SPECIAL INSTRUCTIONS

Sheet 1 & Sh 2: Replace old Prints with new prints attached

Sheet 4 & 7: Change Item ④ to NAS 1291C04 ~~4-40~~ UNJC-3B

Add △11 to: Item ⑥, ⑦, ⑧, ⑨, ⑩, ⑪, ⑫

Change Item ⑮ To: 955652-37

Sheet 6 & 9: Change per Sh 2 & 3 of this E.O.

Sheet 10: Change per Sh 4 of this E.O.

REASON FOR

Series Advance & "Revised Terminal Block incorporating threaded stud type terminals"

EFFECTIVITY:

Effective as soon as new terminal Blocks are available

	11/24
	11-24
R. A. [illegible]	11-24-69
OTHER SIGNATURES	11-24
REQUESTER Budo	11/21/69
EXT. 9098 M.S A3614	DATE

ORIGIN

NEXT. ASSY	DEVICE	CCB CHAIRMAN	DATE	CONTROL CHANGE IN ITEM	AT SERIAL NOS.	F/V	ON-OR-BEFORE DATE OR S.N.
	FG 420A	R B Lee	11/25/69	FG 420A ALL			Special

USAGE

APPLICATIONS

EFFECTIVITY ☒ OR RECORDS CHANGE ☐

EF46-FG420
CONT ON 6A

C	ADD ITEM 131	[illegible]	68-14782
K	ADD ITEM 132; QTY OF ITEM 98 FOR A27 WAS "3"	9-25-68	68-18365
L	ITEM 132 PN WAS 1990327-3	10-4-68	68-18569

REVISIONS

SYM	DESCRIPTION	DATE	APPROVAL
—	CONTROLLED DRAWING	12-6-67	[illegible]
A	ITEM 98 ADD QTY 3 FOR FG420A22 & A27; ITEM 102 ADD 3 FOR A27 & REM 3 FOR A22; ITEM 103 REM 3 FOR A27; ITEM 105 ADD 3 FOR		

A31	A30	A29	A28	A27	A26	A25	A24	A23	A22	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	QTY	ITEM	PART NO.	DESCRIPTION	REMARKS
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		137	449304-26	Screw Hex Head	8-32UNC2A △12
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		136	10034323-103	Stud Assy	△12 6-32
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		135	10034323-102	Stud Assy	△12 8-32
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		134	10034323-101	Stud Assy	△12 10-32
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		133	10032447	Block, terminal	△12
				3																					132	1990427-3	SPACER	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	✓	131	10026353-101	BRACKET, MOUNTING	
				1																				✓	130	10022195-114	BRACKET, MOUNTING	
																								✓	129	1990427-5	SPACER	
																								✓	128	1990427-29	SPACER	
																								✓	127	1990427-28	SPACER	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	✓	126	10022197-102	INSULATOR, TERMINAL	
																									~~125~~	~~10022195-109~~	~~BRACKET, MOUNTING~~	
																									~~124~~	~~10022195-110~~	~~BRACKET, MOUNTING~~	
		3	3		9	16	6	3		3	6			3	3										123	1990427-32	SPACER	
										3											3		3		122	-31		
	6	3																		3	3				121	-30		
												3	3												120	-27		
		3																				3			119	-26		
3																						3			118	-25		
							3						3	3											117	-24		
3					3					3															116	-23		
			3					3					3			6	3								115	-22		
							3						3	3				3							114	-21		
								3		3						3	3								113	-20		
								6								3	3	3							112	-19		
					3			3	3		6				3						3				111	-18		
			3		3			3	3			3				3	6	3							110	-17		
									3	3	3					3									109	-16		
						3	3		3				3					6							108	-15		
					3				3		3	3						3	9						107	-14		
						3												3		3					106	-13		
			3									3				3	3								105	-12		
							3												3						104	-11		
																		6							103	-10		
				3															3						102	-9		
															6										101	-8		
														3					9	3					100	-7		
										3					3								3		99	-6		
			3				3		3							6									98	-4		
																							3		97	1990427-2		
			6												12										96	1990427-1	SPACER	
																									95	10022199-134	ELECTRODE, OUTER ASSY	
																									94	-133		
																									93	-132		
																									92	-131		
																									91	-130		
																									90	-129		
																									89	10022199-128	ELECTRODE, OUTER ASSY	

69 15826

E.O. # 69 15826
SH. 2 OF
DOC. # FG420A
SH. # 6 REV. ✓
ZONE
ADM 1942

000217

LIST OF MATERIALS

HONEYWELL MILITARY PRODUCTS GROUP ☒ AERO MPLS ☐ AERO ST. PETERSBURG ☐ SEL and SEATTLE	CODE IDENT NO 94580	SIZE C	DRAWING NO. FG420A
	SCALE NONE	WT	SHEET 6

FG420A L

EF46- FG-420

28-41-01

REVISIONS

SYM	DESCRIPTION	DATE	APPROVAL
—	CONTROLLED DRAWING	[illegible]	[illegible]
A	ADD ITEM 130	[illegible]	[illegible]
B	ITEM 97 PN WAS "1990427-3"	311-68	68-11542
C	ADD ITEM 131	6-27-68	68-14636
[illegible]	~~ADD ITEM 132~~	[illegible]	68-14782

	QTY A41	QTY A40	QTY A39	QTY A38	QTY A37	QTY A36	QTY A35	QTY A34	QTY A33	QTY A32	ITEM	PART NO.	DESCRIPTION	REMARKS
	1	1	1	1	1	1	1	1	1	1	137	41-9304-26	Screw Hex Head 8-32UNC-2A △12	
	1	1	1	1	1	1	1	1	1	1	136	10034323-103	STUD ASSY △12	6-32
	1	1	1	1	1	1	1	1	1	1	135	10034323-102	Stud Assy △12	8-32
	1	1	1	1	1	1	1	1	1	1	134	10034323-101	Stud Assy △12	10-32
	1	1	1	1	1	1	1	1	1	1	133	10032447	Block, Terminal	△12
											132	1990427-3	SPACER	
✓	1	1	1	1	1	1	1	1	1	1	131	10026353-101	BRACKET, MOUNTING	
✓											130	10022195-114	BRACKET, MOUNTING	
✓		3									129	1990427-5	SPACER	
✓	3					3					128	1990427-29	SPACER	
✓					3				3		127	1990427-28	SPACER	
✓	1	1	1	1	1	1	1	1	1	1	126	10022197-102	INSULATOR, TERMINAL	
											~~125~~	~~10022195-109~~	~~BRACKET, MOUNTING~~	
											~~124~~	~~10022195-110~~	~~BRACKET, MOUNTING~~	
	3		6								123	1990427-32	SPACER	
											122	-31		
		3				3			3	3	121	-30		
							3		3		120	-27		
											119	-26		
					3			3			118	-25		
							3				117	-24		
											116	-23		
		3									115	-22		
											114	-21		
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	3							3			98	-4		
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											96	1990427-1	SPACER	
	1										95	10022199-134	ELECTRODE, OUTER ASSY	
		1									94	-133		
			1								93	-132		
				1							92	-131		
					1						91	-130		
						1					90	-129		
							1				89	10022199-128	ELECTRODE, OUTER ASSY	

E.O. # 69 15820

SH. 3 OF

DOC. # FG-420A

SH. # 9 REV. ✓

ZONE

ADM 1942

HONEYWELL MILITARY PRODUCTS GROUP

● AERO MPLS ☐ HOPKINS GRD
☐ AERO ST PETERSBURG ☐ AERO BOSTON
☐ MIL GRD SEATTLE ☐

LIST OF MATERIALS

CODE IDENT NO	SIZE	DRAWING NO.
94580	C	FG420A
SCALE NONE	WT	SHEET 4

L FG420A

EF 111 - FG-420

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	—	CONTROLLED DRAWING	12-6-67	FG 420 A
	A	DELETE NOTE 1 & ADD NOTE 7	3-6-68	68-11542
	B	DELETE NOTE 4	3-21-68	68-12209
	C	ADD NOTE 8	5-20-68	68-15815
	D	ADD NOTE 9	9-12-68	68-15564
	E	NOTE 9 WAS " SPACERS - - - SUBSTITUTED	8-22-68	68-18035

1 - ~~INDENT OUTER ELECTRODE INTO END GAP HOLES FOR RETENTION UNDER FORCE OF 50 LBS. SHAPE OF INDENTATION OPTIONAL~~

2 - SELECT RIVETS PER SPEC 4196

3 - TIGHTEN NUTS ITEM 4 REF 3 PLACES TO MIN TORQUE OF 5.0 IN. LBS

4 - ~~UPSET THDS ON ITEM 10 REF TO PREVENT NUT (ITEM 11) FROM BACKING OFF~~

5 - SEE INNER ELECTRODE ASSY DRAWING FOR PROPER SPACER LOCATION

6 - CAPACITANCE AND CONFORMANCE LISTED ON APPLICABLE INNER ELECTRODE DRAWING

7 - ON FG420A27 ITEM 14 SHALL BE INSTALLED IN ALTERNATE POSITION SHOWN AND ITEM 130 SHALL BE INSTALLED WITH MOUNTING HOLES ORIENTED AS SHOWN

8 - ON FG420A29 ITEM 14 SHALL BE INSTALLED IN ALTERNATE POSITION SHOWN

9 - SPACERS 1990427-TAB. SHALL BE USED AS SHOWN WHEREVER POSSIBLE. WHEN EXTREMES OF TIGHTNESS OR LOOSENESS OCCUR, DUE TO TOLERANCE VARIATIONS, THE NEXT SIZE SPACER TABULATION MAY BE SUBSTITUTED. SPACERS SELECTED MAY RESULT IN A GAP BETWEEN THE OUTER ELECTRODE AND SPACER CORNERS. THE MAXIMUM GAP PERMISSABLE FROM THE SPACER CORNERS WHEN THE OTHER TWO SPACERS OF THE SAME SET ARE PRESSED AGAINST THE OUTER ELECTRODE IS .035

10 .12 to .20 ~~High Lettering~~ Spec 13205 TYPE I
Apply MATL ~~SPEC~~ MC8030-02 white Epoxy
~~approx as shown~~

11 Series 1-3

12 Series 4

10 - .12 TO .20 HIGH LETTERING
PER MIL-STD-130 MARK
(SPEC 13205 TYPE I) WITH
MC8030-02 WHITE INK RETMA
Approx AS SHOWN

E.O. # 69 15826
SH. 4 OF
DOC. # FG420A
SH. # 10 REV. E
ZONE
ADM 1942

C
B
A

FG420A | E |

28-44-01

HONEYWELL INC.
MILITARY PRODUCTS GROUP

SIZE	CODE IDENT. NO.	DRAWING NO.
C	94580	FG420A
SCALE NONE	WT	SHEET 10

28-41-01

[redacted] 69 15826

ENGINEERING CHANGE ORDER

FORM A SHEET 5 OF 5

E.C.O. DATE DEC 9 1969

E.C.O. NO. 69 15826

ADM - 1601 REV. 11/66

CCB IDENT. NO. EF46-FG420

ECP NO. Sec Sh 1

SCN NO.

PROJECT NO./ACCT. NO. 21438-1

TOTAL NO. OF ENG. DOCUMENTS TO BE CHANGED BY THIS ECO. PACKAGE

ANA 445 OR CONTRACT CLASS OF CHANGE

CLASS I ☒ CLASS II ☐

NOT APPLICABLE ☐

	YES	NO
ADVANCE SERIES	☒	☐
CUSTOMER APPROVAL REQUIRED	☒	☐
UPDATE OF DOCUMENT REQ. IMMEDIATELY	☒	☐
INACTIVATION	☐	☒

PURCHASED PART ☐

NEW RELEASE ☐

	YES	NO
REWORK PERMITTED	☒	☐
REWORK REQUIRED	☐	☒
INTERIM CONFIGURATION	☐	☒
REACTIVATION	☐	☒

ADVANCE PRINT AVAILABLE ☐

STATEMENT OF THE PROBLEM

Stud length too long for new FG420 Terminal block

DOCUMENT NO. & NAME ① 10022199 Electrode Assy, outer

DASH NO. —

REV. LET. C

PROJECTED REV. LTR. D

SHEETS REVISED 1, 2

DESCRIPTION OF CHANGE AND SPECIAL INSTRUCTIONS

Sheet 1 : Delete item E

Sheet 2 : Delete item E
Change item F to: 10022201-103

Effectivity: All series 4 to have new parts

000220

OTHER SIGNATURES

REQUESTER Burda

EXT. 4048 M.S. A3619

DATE 11/24/69

ORIGIN

NEXT. ASSY

USAGE

DEVICE FG420A

APPLICATIONS

CCB CHAIRMAN RB Lee

DATE 11/25/69

CONTROL CHANGE IN ITEM FG420A

AT SERIAL NOS.

F/V

ON-OR-BEFORE DATE OR S.N. Special

EFFECTIVITY ☒ OR RECORDS CHANGE ☐

CCB IDENT. NO. EF46- FC-420

ENGINEERING CHANGE ANALYSIS FORM C SHEET 1 OF 1

ADM-1602, REV. 6/66

E.C.O. NO. 69 15826

DEVICE	DOCUMENT NO.	REVISION LETTER	DASH NUMBERS
FG420A	FG420A	L	
	10072199	C	
	~~955652~~	~~C~~	

1. New Terminal Block
18. Revise dwg for new terminal Block
26. Manuals to include new terminal Block & changes
27. New parts added

EXPLAIN IMPACT OF PROPOSED CHANGE. EACH CHECK MARK BELOW MUST BE REFERENCED AND EXPLAINED.

000221

THIS CHANGE AFFECTS: RECORDS ONLY ☐ OR FACTORS CHECKED BELOW

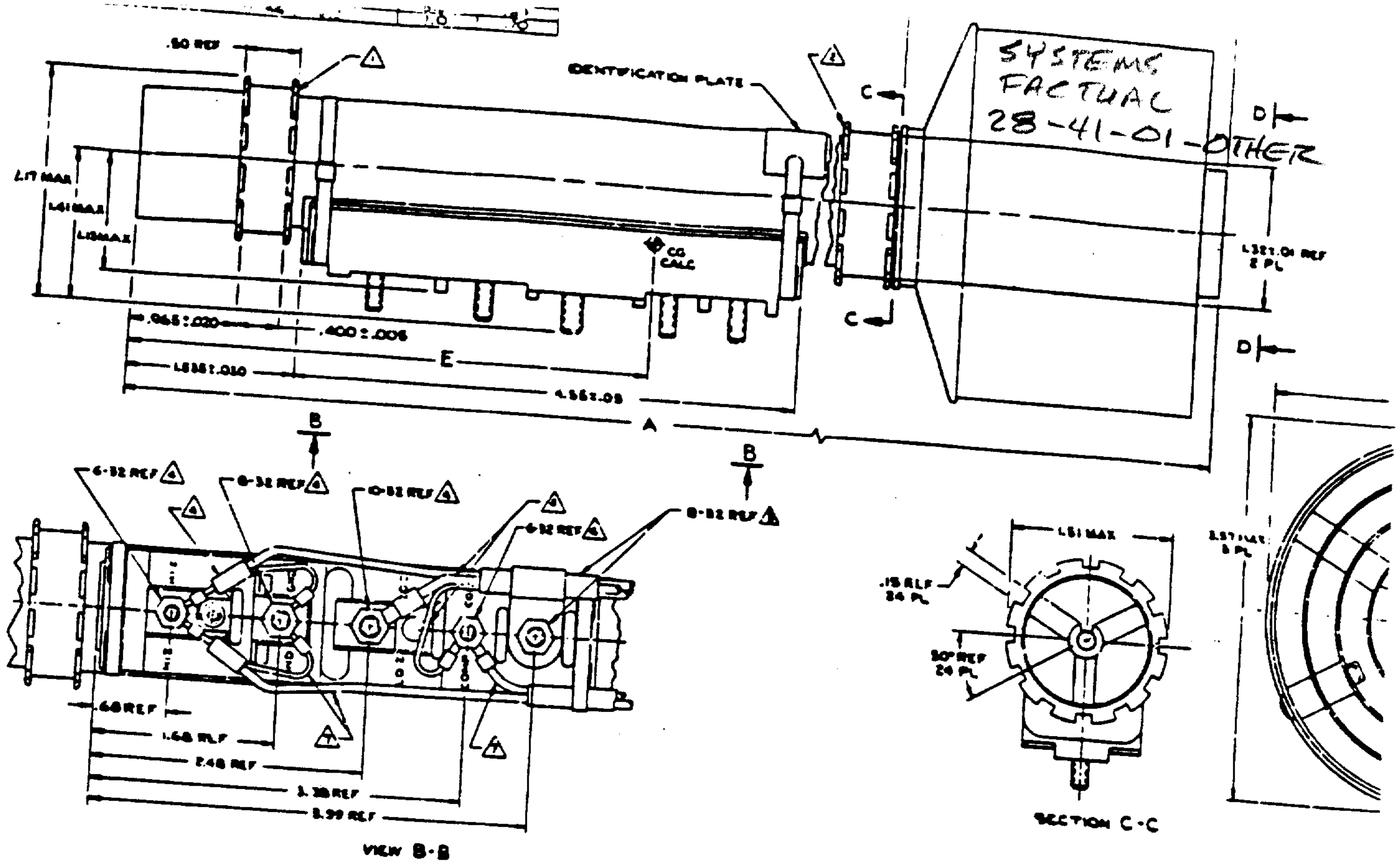
1. COST-ADDED	X	13. EVALUATION TEST STATUS		25. MAINTAINABILITY	
2. COST-SAVINGS		14. CONTRACT CHANGE IN SCOPE		26. TECHNICAL PUBLICATIONS	X
3. DELIVERY SCHEDULE		15. SUGGESTED EFFECTIVITY		27. SPARES PROVISIONING LISTS	X
4. INTERNAL SCHEDULE		16. RETROFIT RECOMMENDED		28. HIGHER ASSEMBLIES CONTAIN OLD STYLE PARTS	
5. RELIABILITY		17. PROPRIETARY DATA		29. INSPECTION INSTRUCTION CHANGE REQUIRED	
6. WEIGHT		18. INSTALLATION DRAWING	X	30. SPECIAL PURPOSE INSTRUMENTATION	
7. INTERFACE		19. SPECIAL ANALYSIS FORM ATTACHED		31.	
8. SCRAP		20. CONFIGURATION LISTS		32.	
9. RAW MATERIAL		21. SPECIFICATIONS ES MS RE-D ETC.		33.	
10. SYSTEMS CABLING		22. ENGINEERING TECHNICAL SERVICES		34.	
11. TOOLING		23. CLASSIFICATION OF CHARACTERISTICS		35.	
12. SUPPORT EQUIPMENT		24. SCHEMATICS (DEVICE-SYSTEM-SUBASSEMBLY)		36.	

CCB MEMBERS

TITLE	*	SIGNATURE	DATE	EXT.	M.S.
DEV. ENG.					
PROD. ENG.					
REL. ENG.					
PROD. CONT.					
QUALITY					
SPARES SUPP.					
TECH. PUB.					
MAINTAINABILITY					
CAYE	✓	D. Larson	11Nov	1431	[illegible] 86

28-41-01

SYSTEMS FACTUAL 28-41-01-OTHER



DEVICE NO: FG450A51-53 NAME Fuel Tank Unit-Compensator

WHERE USED LOCKHEED C-130E

RELEASE DATE: August 1976 CUSTOMER SPEC GELAC 695799

E.S. 25473-01 SCHEMATIC NONE

SYSTEM # H4947-41

TECH MANUALS

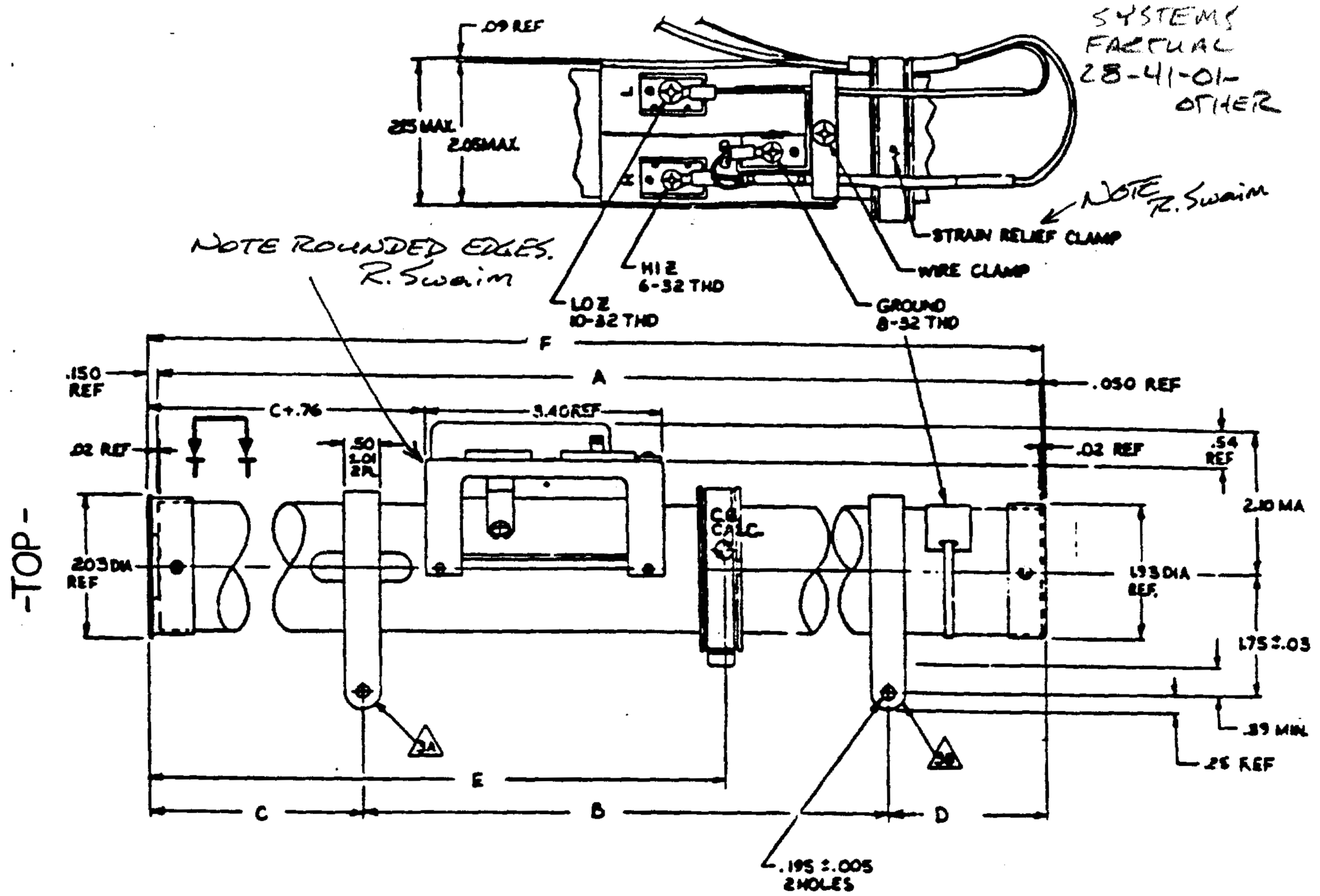
FUNCTION:

These units are the same as the FG430A tank units except that a compensator is mounted concentrically on one end of the tank unit and some units use stainless steel inner electrodes. The compensator assembly consists of four concentric aluminum tubes separated and insulated from each other by teflon spacers. Electrical connections to the compesnator electrode are made by leadwires which are connected to the tank unit terminal block.

The FG450A devices replace FG250A devices having the same dash number. Compensator electrode spacing is 0.250 inch minimum and it has a nominal dry capacitance of 30.3 ± 0.5 pf.

(Referenced in Systems Factual Report as having features similar to the fuel probes used in the B-747. R Swain)

SYSTEMS FACTUAL 28-41-01- OTHER



NOTE R. Swaim

NOTE ROUNDED EDGES. R. Swaim

DEVICE NO: FG1006AA01-64 NAME Fuel Tank Unit

WHERE USED Boeing 767 and 757

RELEASE DATE: August 1980 CUSTOMER SPEC BAC S345T002

E.S. 28144-01 SCHEMATIC

SYSTEM # YG1767A01 and YG1757A01

TECH MANUALS 95-8000

FUNCTION:

The tank unit assembly consists of two concentric aluminum tubes separated and insulated by teflon spacers. The unit shall be mounted inside the tank such that it may be immersed by usable fuel. Electrical connections to the tank unit electrodes are made by lead wires which are connected to the tank unit terminal block. Nominal spacing between electrodes is 0.40 inch. The basic function of the tank units in the FQIS Systems are to provide a means to determine the depth of the fuel at each tank unit location. This fuel depth is computed in the Processor Unit of the System from the measured capacitance of each tank unit and the measured value of fuel dielectric constant provided by the compensator unit in each tank.

In order for the system to compute fuel depth, the wetted sensing length (WSL) of the tank unit must be calculated. An accurate calcuation of WSL depends on two basic factors:

1) The change in tank unit capacitance must be linear with WSL.
2) The fuel dielectric constant sensed by the compensator must be identical to that at the tank unit.

USAF FUEL PROBES
SYSTEMS FACTUAL
28-41-01-OTHER

Analysis Of An Aircraft Fuel Probe

4 January 1990

PURPOSE

Determine the cause of the submitted fuel probe failure and if there is evidence of electrical arcing in the assembly.

FACTUAL DATA

An aircraft fuel probe was submitted for analysis. The probe was removed during the troubleshooting of a varying fuel quantity problem. A black residue was also reported on the wall of the fuel tank in contact with the fuel probe wiring.

The fuel probe received for analysis is shown in Figures 1 and 2. The entire length of the electrical cable was blackened. Black residues were also noted at the entrance of the cable into the connector and on the outer electrode of the assembly.

NSN: 6680-00-526-7388
MFRS: FG120L2
Series: 4
Serial No. L-142
TANK UNIT, FUEL QUANTITY, USA

The fuel probe determines fuel quantity by measuring the capacitance of fuel between the outer and inner electrodes. The capacitance value is a function of the dielectric constant which varies with the volume of fuel and air between the electrodes. The tubular inner electrode has two electrically isolated conductive patterns. One pattern (smaller) is used as an input guard and the other is used as the sense side of the capacitor or active pattern. The wire connected to the sense side is also shielded. A 24 volt 400 Hertz excitation signal is applied to the outer electrode. A schematic of the probe is given in Figure 3.

The capacitance of the fuel probe was measured as 148pf @ 400 Hertz. The specification value is 148.4pf in air. Insulation resistance was measured between the input, output, and shield. All values were in the range of 1 X 10^{11} ohms at 50 VDC. A continuity check of the 13-foot cable did not identify opens or shorts between conductors. The surface of the outer insulation was, however, found to be slightly conductive. The value would fluctuate with the bending of the cable. A minimum value of 250 kilohms/foot was obtained using an ohmmeter.

The cable connector was disassembled for inspection. Apparently the cable wires had been twisted and pulled out of the connector during the removal of the fuel probe. A black residue was noted in the potting material adjacent to the wiring (Figures 4 and 5). The copper wiring did not exhibit melting or other evidence of electrical arcing. The ends of the conductors were necked down to a small diameter. Infrared spectrometry identified the potting material as a polysulfide rubber. Elemental X-ray analysis of the black residue identified the following elements: silica (Si), sulfur (S), aluminum (Al), magnesium (Mg), calcium (Ca), barium (Ba), lead (Pb), iron (Fe), nickel (Ni), and copper (Cu) (Figure 6).

The probe was disassembled for inspection and material analysis. The clamp retaining the wire cable was removed from the outer electrode. The outer cable insulation was blackened except for the material underneath the clamp (Figure 7). A chemical analysis was conducted on the cable materials (Figure 8). The results are given in Table I. The shield cable was heavily oxidized as shown in Figure 8. X-ray elemental analysis detected only copper. Analysis of several shield samples detected silver on some of the copper conductors. The primary insulation and conductors did not exhibit anomalies. X-ray elemental analysis determined the conductors were silver plated, copper wiring. The black residue on the outer fuel probe electrode (Figure 9) and on the outer cable insulation was analyzed with X-ray elemental analysis (Figure 10). Analyses found that sulfur, silver, and copper were associated with the black residues. X-ray diffraction pattern analysis on the black residue from the outer electrode identified a copper sulfide (CuS) compound. The black residue on the outer electrode was found to be conductive when probed with an insulation resistance meter. Probing with an ohmmeter resulted in a value between 1 and 5 kilohms.

The strain relief cable housing at the top of the probe exhibited black deposits at the cable entrance (Figure 11). The cable housing was removed and inspected. The cable housing was chemically analyzed and identified as nylon. During the removal process, debris was removed from beneath the plastic clamps. X-ray elemental analysis identified the following elements: Al, Si, Ca, Fe, chlorine (Cl), cadmium (Cd), phosphorous (P), and Mg. A black deposit was noted where the cable came in contact with the housing (Figure 12). The black deposit was found to be conductive when probed with an ohmmeter (1 to 5 kilohms). X-ray elemental analysis of the black deposit is shown in Figure 13. The analyses identified S, silver (Ag), Fe and Cu. The wiring associated with the cable housing is shown in Figure 14. The blackened outer cable insulation was found to be slightly conductive. X-ray elemental analysis of the outer cable insulation is shown in Figure 15. The analysis detected S, Ag, and Cu. A black residue was also noted on the inner electrode of the probe (Figure 16). The area was found to be conductive and X-ray analysis identified S, Ag, and Cu. The area was found to be conductive and X-ray analysis identified S, Ag, and Cu (Figure 17). The terminals used to connect the outer and inner electrode to the cable wiring were also blackened and corroded (Figures 18 and 19). There was no evidence of electrical arcing in this area. A four point probe measurement was made on the outer electrode terminal. A value of 300 milliohms was obtained. The inner electrode was removed and examined for evidence of electrical arcing. The inner electrode appeared to be a Fiberglas material. The electrode was coated with a conductive film which, using X-ray elemental analysis, was identified as silver. The silver was protected with a phenolic coating. The edges of the electrode and other areas where the phenolic coating was damaged were blackened. The outer electrode was determined to be aluminum with an epoxy and iron oxide paint. The surface was nonconductive except where the black residue was previously noted.

DISCUSSION:

There was no direct evidence of electrical arcing in the fuel probe assembly.

The submitted fuel probe did not exhibit an electrical short in air and met the specification for capacitance in air.

The black residue reported by field personnel and documented in this report is most likely due to a chemical degradation or corrosion process. The silver plating and exposed copper from the shield conductor has been silver plating and exposed copper from the shield conductor has been transferred to the outer cable insulation and adjacent structures. It is postulated that sulfur in the aircraft fuel has reacted with the silver plating and copper conductor. The fuel was able to permeate through the outer cable insulation and come in direct contact with the shield conductor. Chemical analysis identified copper sulfide and silver compounds in the residues examined. Copper and silver sulfides are black or grayish-black compounds that are insoluble in water. These compounds would not be expected to be highly conductive. However, the black residues were found to be conductive in the range of 1 to 5 kilohms at 1.5 volts and a distance of 0.25 inches between electrical probes. This is most likely due to the presence of carbon and possibly metallic copper and silver in the residue.

The residues found on the outer cable insulation and cable housing could produce a low resistance path between the electrically isolated probe wiring. A low resistance path would most likely develop between the wiring of the outer electrode and shield wiring. The distance between the connections has been reduced by the presence of a black residue. The residue, in combination with fuel and aircraft vibration could produce a variable capacitance output which would result in erroneous fuel quantity readings.

A reduction of the distance between electrically isolated probe wiring could make the assembly more susceptible to electrical arcing from lightning strikes or static discharges. Charge build-up in the fuel could be shunted through the conductive surface of the probe cable and result in arcing between the probe wiring. Build-up of static charges on the connector housing and cable wiring may also accelerate the corrosion reaction between the shield wiring and the fuel. A discharge could ignite fuel under certain conditions. The excitation voltage applied to the active electrode is not sufficient to arc between the probe electrodes or wiring. A conductive path would have to be formed to have an electrical short between the wiring or probe electrodes. In the event of an electrical short, a properly designed fuel probe system would not provide sufficient energy to ignite fuel. This would have to be confirmed with a more detailed analysis of the fuel measurement system.

PREPARED BY:

George Slenski

GEORGE SLENSKI, Team Lead
Materials Integrity Branch
Systems Support Division
Materials Directorate

Analysis of Transport Fuel Probe Electrical Cables

28 October 1993

PURPOSE

Determine the cause of a low insulation resistance in the submitted splices.

FACTUAL DATA

Two fuel quantity measurement system cable splices were submitted for analysis. It was reported the resistance between the ground shield and center conductor was below 30 megaohms (the minimum specification requirement) near a splice connection. Field personnel have reported a large number of fuel quantity system failures are related to low resistances in the cable splice area. During the course of the MLSA analysis, a complete cable harness was submitted which was removed during troubleshooting a malfunctioning fuel quantity system. All cables were received from Altus Air Force Base, Oklahoma and have been immersed in jet fuel (JP-4) for over 10 years.

Cable splices received for analysis are shown in Figures 1 and 2. The terminal is connected to the fuel probe capacitor element (high-Z or high impedance signal). Several probes are parallel connected by placing two shielded signal wires in each high-Z terminal. The shields of each high-Z wire are connected to ground (black wire) by a solder splice approximately 8 to 8.5 mm from the terminal (Figures 1 and 2). A description of the received cables is given below:

Sample Number	Aircraft Number	Description	Location	Field Problem
1	453	Loose splice, two shielded wires	Aux. tank #3 Probe 2	Low resistance (330K)
2	453	Loose splice, one shielded wire	Aux. tank #3 Probe 3	None, good splice
3A-3D	454	Complete harness, four high-Z terminals	Main tank #3 four splices	Low resistance in cable

Visual inspection of the splices identified a brown-black residue on the exposed conductor strands and insulation near the splice area (Figures 2, 3, and 4). Residues are associated with exposed copper (Figure 3) and in between the two signal wires (Figure 4). Sample one was examined with real-time radiography to locate shorts in the wiring. No anomalies were found in the radiography inspection.

The splice insulation resistance between the terminal and ground was measured with a HP329A High Insulation Resistance Meter at 50 volts dc and evaluated with a Tektronics 576 Curve Tracer. Results are given below at 43 percent relative humidity and a room temperature of 23°C:

Sample Number	Insulation Resistance (Ω) 50 vdc after 1 minute	Curve Tracer Results
1	$1.5x10^7$	70nA @ 1v=14MΩ,unstable 100nA @ 1v=100MΩ,unstable 100A @ 50=7MW,unstable
2	$1x10^{12}-2x10^{14}$	1nA @ $50=50x10^{12}$Ω,stable

Sample Number	Insulation Resistance of Cable (terminal to ground) 50 vdc after 1 minute (Ω)		
	Intact Cable	Splice 3C removed	Splice 3B removed
3A	350K*	4M,stable	$5x10^{10}$, stable
3B	350K*	4M, unstable	5M, unstable separated from the cable
3C	350K* unstable	275K* separated from the cable	----
3D	350K*	$1x10^{11}$, stable	$1.5x10^{11}$, stable

*measured with an ohmmeter due to the low resistance.

Splices 1, 3B, and 3C were below the minimum specification requirement of 30MΩ. Low resistance connections were unstable and would change value if moved. Humid air applied to low resistance splices reduced the resistance by an order of magnitude with a 10 vdc potential. Terminals with only one signal wire (samples 2 and 3D) were well above the 30MΩ minimum and stable measurements produced.

The insulation tubing covering the solder splice of sample one was removed (Figure 5). Black residues were noted on exposed copper areas. Solder was partially dewetted and a blue-green material was found on the splice connection (Figure 5). Separation of the two signal wires increased the insulation resistance to $4x10^{13}$Ω at 50 vdc. Removal of the crimped terminal connection and separation of the two signal wires showed a continuous residue path on the insulation between signal conductors and the exposed shield conductors (Figures 4 and 6). Note the brown-black residue streak along the inside of the two wires. The residue was not dissolved by water, isopropyl alcohol, ammonia hydroxide, or acetone. Removal was possible by using a dry cotton swab.

Materials associated with the splice were analyzed using Fourier transform infrared spectrometry (FTIR) to identify composition. The results below agree with the submitted specification sheet material description (MIL-C-27500/22ML1T08). No solder flux residues or sulfur containing materials were found using X-ray fluorescence and mass spectroscopy.

	Identified Compounds
Splice shrink tubing Figure 2	polyvinylidenefluoride, no sulfur
Blue-green material Figure 5	polyvinylidenefluoride, no abietic acid (solder flux)
Wire insulation over the shield	polyvinylidenefluoride
Clear insulation on the primary wire insulation	polyvinylidenefluoride
White wire insulation Figure 6	polyethylene based material
Black wire insulation Figure 2	polyethylene based material

Splice sample one was examined using a scanning electron microscope (SEM) with elemental X-ray analysis. A SEM backscatter micrograph of the residue streak on the wire insulation is shown in Figure 7. In backscatter mode the higher the atomic weight, the lighter the image. The residue streak appears white in Figure 7 since the residue materials are a higher atomic weight than the insulation material. Two elemental X-ray maps of the residue streak are shown in Figures 8 and 9. The X-ray maps identify the residue as a copper and sulfur compound and show its distribution across the wire insulation surface. The highest concentration of copper and sulfur coincides with the residue streak (Figure 9). A close-up of the residue is shown in Figure 10. Note the residue is an irregularly deposited thin film. An elemental X-ray spectrum of the residue identified copper and sulfur and is shown in Figure 11. Elemental X-ray analysis identified the shield and primary conductor as tin coated copper. Tin coating on the terminal crimp wiring has cracked and exposed the copper substrate as shown in Figure 12. The exposed copper contained high levels of sulfur.

A 50ml sample of JP-4 submitted by the customer was chemically analyzed and found to contain 277 ppm of sulfur. For JP-4 the maximum sulfur level is 4000 ppm.

DISCUSSION

Three of the six inspected splices exhibited insulation resistances below 30M between the high-Z connection (terminal) and ground (shield). Low insulation resistances are due to the formation of a copper-sulfur compound between the splice and terminal connections. Two-wire splices are more susceptible since the conductive residue can be trapped in between the signal wires.

The copper-sulfur residues found on the wire insulation and exposed copper surfaces are the result of a time dependent materials degradation process. Chemical analysis of materials associated with the splice did not detect sulfur containing products. The sulfur is most likely being supplied by JP-4 or other type of commonly used jet fuel. Fuel is able to come into direct contact with the shield braid in the solder splice and in the crimp terminal. Both areas exhibited exposed copper. An electric field between the connections most likely accelerates the formation of the residue. MLSA has conducted several fuel probe failure analysis reports and concluded copper sulfide was responsible for a low resistance path between normally electrically isolated connections (Reference WL/MLS reports 90-1, 90-25, and 92-47).

The possibility of replacing low resistance splices on existing cables was explored. The shield insulation was removed and solder was applied to the conductor braid. Due to oxidation and fuel contamination, proper wetting of the solder could only be obtained with an RMA solder flux. Residues on the insulation could only be removed with a mechanical process.

The copper sulfide thin film residue is a semiconductive material that can be made highly conductive if moisture is applied to the film. Cables that appear to heal themselves, or are intermittent, may be due to varying levels of moisture in the fuel tanks.

PREPARED BY:

GEORGE SLENSKI, Team Lead
Materials Integrity Branch
Systems Support Division
Materials Directorate

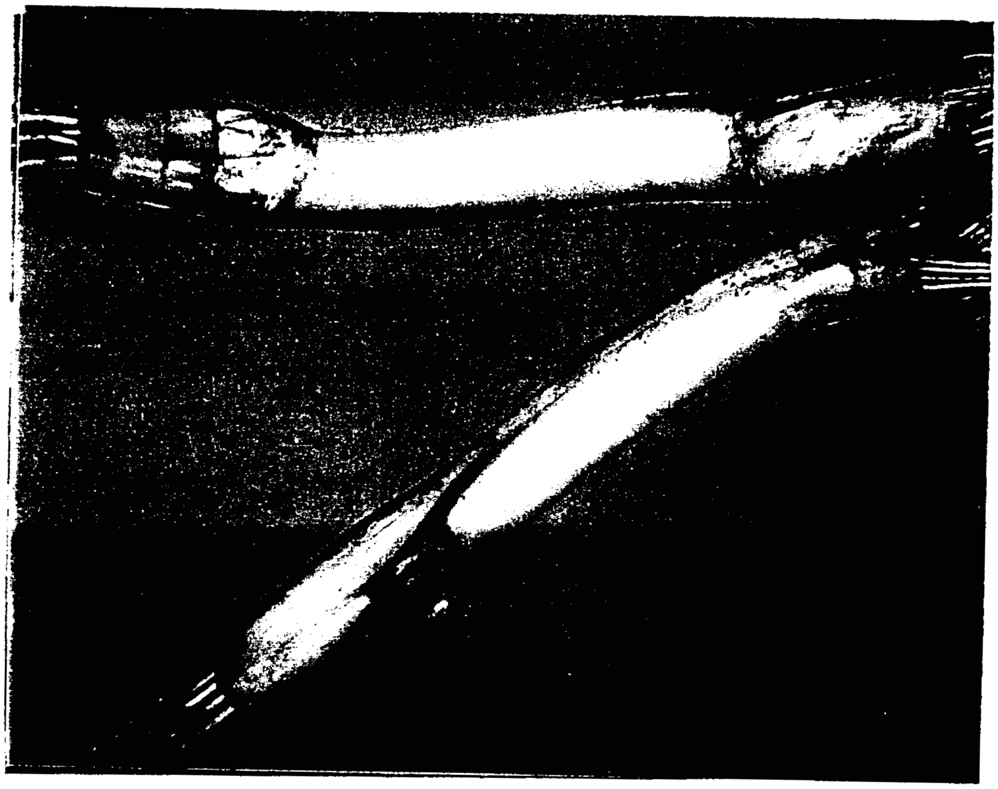


Figure 6. Sample one with high-Z wires separated. Note brown-black residues on the insulation. The residue forms a conductive path between the shield and signal wiring.

Mag: 7.8X

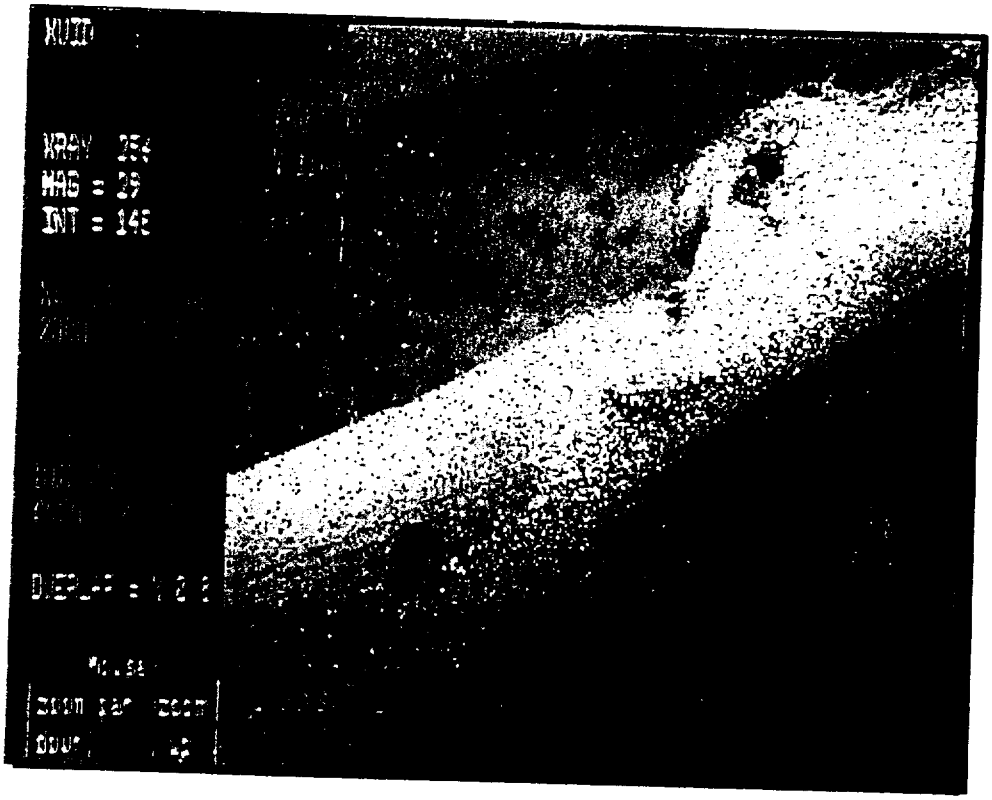


Figure 9. SEM back-scatter micrograph of the residue streak on the wiring showing the elemental distribution of copper (red) and sulfur (yellow). Note that the highest levels of the copper and sulfur coincide with the residue streak.

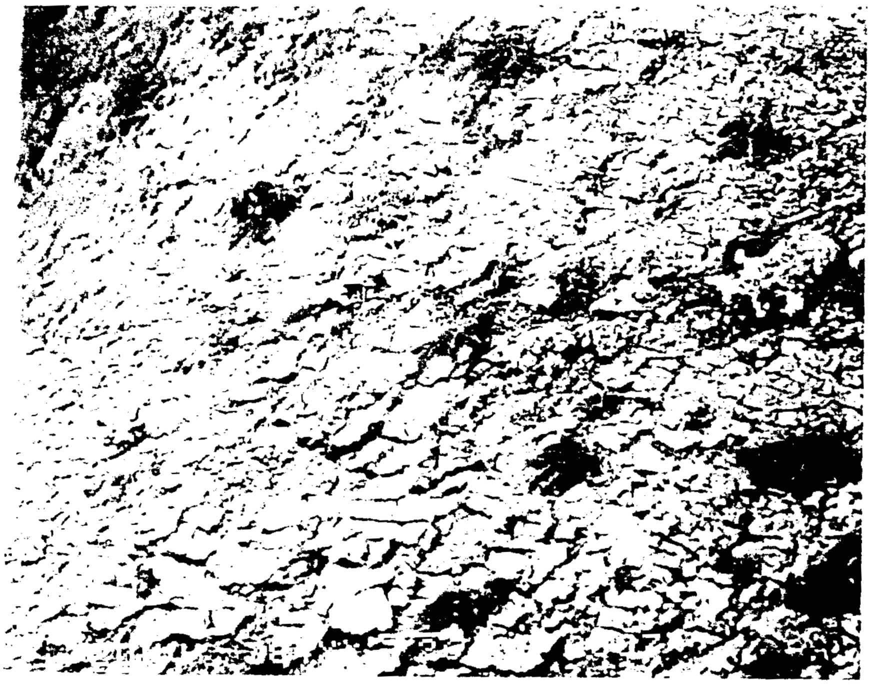


Figure 10. SEM back-scatter micrograph close-up of the residue streak. Note the residue is an irregularly deposited thin film. Mag: 346X

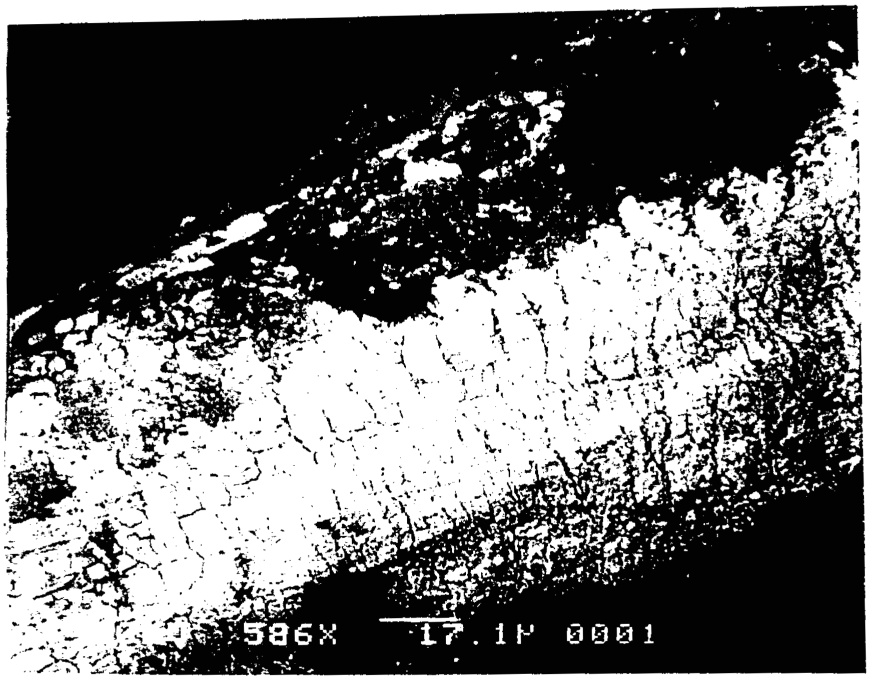


Figure 12. SEM micrograph of the tin coated copper wire in the crimp terminal. Note the cracked tin coating (lighter area) and the exposed copper which contained high levels of sulfur.
Mag: 586X

Analysis Of Trainer Aircraft Fuel Probes I

March 1990

PURPOSE

Determine the cause of the submitted fuel probe failures and if there is evidence of electrical arcing in the assembly.

BACKGROUND

Testing and analysis were conducted on two aircraft fuel probe sensors. The probes, serial numbers W-13 and N-230, were identified as field failures. A third sensor, serial number E0448, was a new unit used for comparison.

Field personnel reported the failure mode of the N-230 probe was an inaccurate fuel level readout. After removal from the aircraft, on-site visual inspection showed signs of an electrical short to the compensator housing with discoloration and possible arcing on the bottom of the compensator. W-13 was shipped with N230 and exhibited the same reported failure mode.

A new probe was ordered, serial number E0448, which arrived in a vacuum sealed package. This probe was used as a reference to assess the condition of the field failures.

The following information was obtained from the probes:

	Returned Unit 1	Returned Unit 2	New Unit
NSN:	6680-526-7186	Unmarked	6680-526-7186
MFR:	FG131B2	FG131B2	FG131B2
Series:	X4	1	4
Serial No.:	W-13	N-230	E0448

Nomenclature: Tank Unit, Fuel Quantity

It must be noted there are design differences between the W-13 and the N-230. The W-13 unit eliminated most of the wire in the active pattern of the inner electrode. Outer insulation was also present on the braided shield of the brown compensator lead wire which was not present on the N-230 probe. The unit E0448 was identical in design to W-13 unit.

Method Of Operation

The fuel probe determines the fuel quantity by measuring the capacitance between the outer and inner electrodes. Capacitance is a function of the dielectric constant which varies with the volume of fuel and air between the electrodes. The tubular inner electrode has two electrically isolated conductive patterns. The small pattern is used as a protective circuit and the large pattern is used to measure the capacitance of the mixture and is often referred to as the active pattern. The design of the probes is depicted in the exploded view of Figures 1, 2, and 3.

Analysis

The fuel probes received for analysis are pictured in Figure 4. The new probe, E0448, is pictured in Figure 5. A materials analysis of the parts is shown in Table 1.

W-13 Analysis

W-13 had small dents and deformations in the compensator plates. Upon disassembly, debris was found under the compensator support cap (Figure 6). Chemical analysis of the debris identified the conductive elements: aluminum, copper, silver, and iron. Blackened areas were present on exposed copper wire at the compensator solder and shielded wire joints (Figures 7 and 8). A blackened area under the compensator cap (Figure 9) was analyzed and found to be primarily carbon deposits. A melted area (Figure 10) on the nylon compensator represents an arc path to the inner electrode. The shielded brown compensator wire was also tarnished under its clear insulation (Figure 11). The outer electrode terminal was also tarnished. This tarnish was analyzed and found to be copper sulfide, CuS. Resistance measurements were made between the connector terminals and ground. Insulation resistance measured 0.5×10^{11} and 2.5×10^{12} ohms at 10 and 50 volts, respectively. These values are well within the limits of the new unit, E0448. Continuity tests revealed no anomalies.

N-230 Analysis

The N-230 probe was disassembled and revealed black residue throughout the unit. The inner electrode tube, compensator wiring support, the nylon supporting strip, two compensator electrodes, and the brown wire solder joint were covered with a thin coat of black residue (Figures 12, 13, 14, 15, and 16). The nylon compensator cap also had a small area that appeared to have been melted (Figure 17). Clearly this unit experienced a fire of some magnitude. Chemical analysis showed the black residue was carbon. The N-230 unit showed a 3.26k ohm low resistance path between the inner probe (terminal C) and ground (exterior case). An intermittent reading of 6.2k ohm was present when the internal wires were disturbed. Continuity checks were not run on the N-230 unit because of the damaged wiring. It appears the internal probe wires were damaged by a fire. Evidence of an electrical arc was evident on the nylon cap which would have provided the required energy needed to ignite residual fuel.

DISCUSSION

The W-13 probe was submitted to MLSA because of improper fuel level indications and a reported short. Subsequent testing of this unit showed no signs of an electrical short. The probe exhibited black residues on wiring that were identified as copper sulfide and black deposits on insulated surfaces that were primarily carbon. An arc track site was found on the nylon spacer separating the probe wiring. The black residue is due to a chemical degradation process between sulfur in the fuel and the silver plated copper wiring. An electrical arc between the probe wiring produced the arc track site on the nylon spacer. The probe most likely initially had a leakage current path in the internal wiring which caused inaccurate fuel readings. Subsequent electrical testing most likely produced an arc in the internal probe wiring which removed the leakage current path. An electrical arc, while in the fuel tank, would have caused considerably more damage.

N-230 was submitted with clear physical and electrical damage. An electrical short in the unit, when tested outside the aircraft, may have caused residual fuel in the probe to ignite. Submitted information describes a short occurring during the use of the bench top tester while off the aircraft. It must be noted, this tester can supply enough energy to ignite fuel. If any fuel remained in the probe after removal and was present during test, an ignition and flash could occur. This would create the carbon residue which was found in the probe. Indications of an arc path does exist in this unit but it is not clear when this path developed. It may have occurred on the aircraft or during testing.

Materials degradation of the fuel probes occurred due to normal aging and direct chemical reactions with the fuel. This deterioration can increase the potential for electrical shorts and arcing within the probe.

PREPARED BY:

GEORGE SLENSKI,
Team Lead
Materials Integrity Branch
Systems Support Division
Materials Directorate

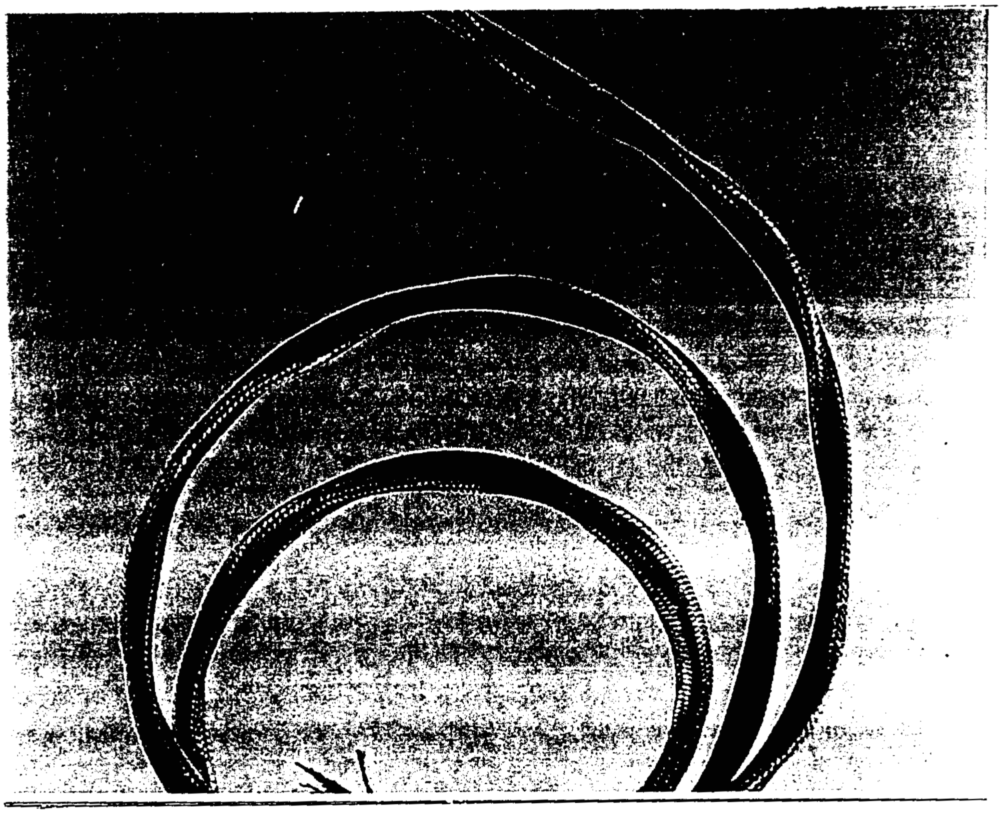


FIGURE 9. Fuel sensor cable blackening, K-329. Note that the black area corresponds to the shielded wiring only. Mag: 0.8X

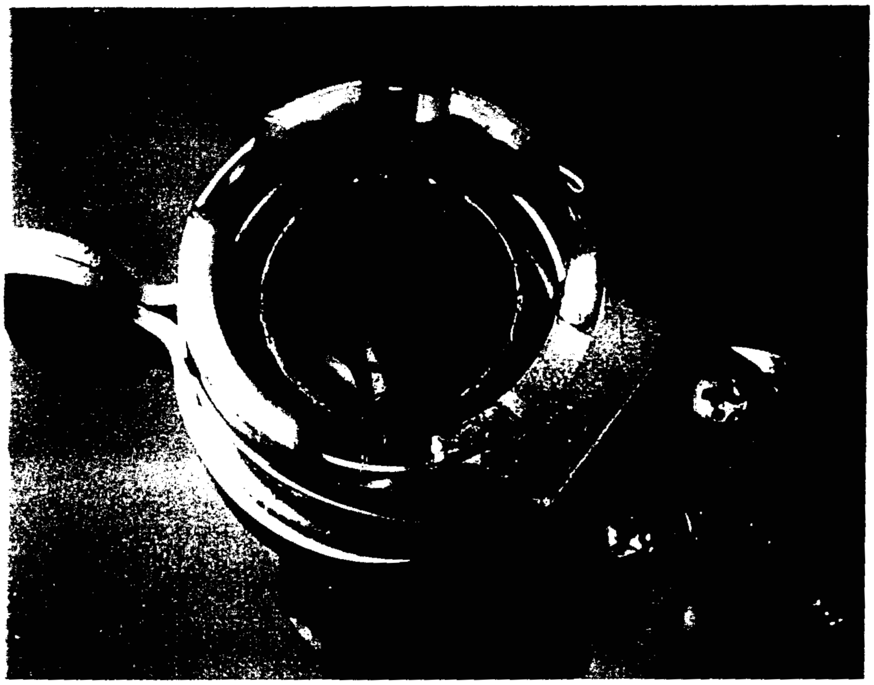


FIGURE 10. Fuel sensor top clamp exhibiting blackened area, L-78. Mag: 1.4X

Analysis Of Trainer Fuel Probes II

May 1992

PURPOSE

Identify submitted fuel probe failure mechanism.

FACTUAL DATA

Four fuel probe assemblies were submitted for analysis between January and March 1992. The probes were removed as defective units during maintenance on aircraft fuel quantity systems. MLSA was requested to identify the fuel probe failure mechanism. A previous MLSA evaluation report, WL/MLS 90-25, identified electrical arcing in a failed T-37 fuel probe. The parts received for analysis and their history are given below:

Probe Nr	Serial Nr	Date Code	Problem Reported
1	D-42	1966	"Shorted"
2	W-11	After 1973?	N/A
3	K-123	N/A	Failed Bench Test
4	C-53	1967	Low Capacitance

A representative probe is shown in Figure 1 and an illustration showing the various probe components and electrical wiring are given in Figure 2.

In the majority of cases, each probe exhibited black/gray residues on the outer compensator electrode (plate), nylon compensator support cap, and outer electrode (Figures 2, 3, 4, and 5).

Insulation resistance between the terminals of each probe were measured at 50 volts D.C. The results are given in Table 1. Probe number one exhibited a low resistance path of 15K between Terminal C (common lead) and the airframe attachment point (ground).

Probe capacitance was measured at 1KHz between two terminals and with the case and the third terminal connected to the test instrument guard. Results are given in Table 2. A new probe used in the previous analysis was used as a reference. All probes were slightly lower than the specification requirement between Terminals C and A. Probe number one exhibited a capacitance 23 percent higher than the specified value between terminals A and B. This unit was received partially disassembled and was reassembled for electrical testing.

Each probe was disassembled and examined for surface residues or other anomalies. All probes exhibited black/gray residues on internal component surfaces in similar locations. The residues appeared to follow a path from the inner compensator electrode wiring to the nylon compensator support cap and to the outer electrode (Figure 6). Residues typically formed near exposed wiring or terminals (Figures 7 and 8). The residue on the wiring inside the clear Teflon tubing is shown in Figure 9. The center compensator electrodes for each of the four probes are shown in Figure 10. Note the residues appear to have washed down the side of the compensator plate. Electrically probing residues on various surfaces with an ohmmeter gave readings between 1K and 100K, depending on probe distances and residue build-up.

Probe components exhibiting residues were analyzed using X-ray Fluorescence and a scanning electron microscope (SEM) with energy dispersive X-ray spectroscopy (EDXS). The Teflon tube protecting the inner and outer compensator plates (Figure 9) contained a residue (Figure 11). SEM examination and EDXS identified sulfur, silver, and copper (Figures 12 and 13). X-ray Fluorescence of the residue on the Teflon tube (Figure 9) identified the elements shown in Table 3. SEM examination and EDXS of the nylon support cap identified sulfur, silver, oxygen, and copper (Figures 14 and 15). The bottom active pattern inner electrode connection of probe number one was removed (Figure 16). A 20K resistance was measured between the green wire (terminal C) and rivets (ground) using an ohmmeter. This represents the low resistance path initially measured on probe number one. EDXS identified sulfur and copper in the residue area (Figure 17). Probe number two exhibited black/gray residues at the top inner electrode connection (Figure 18). Note that a coating is partially covering the connections. EDXS of the residue identified sulfur, silver, and copper. Residues were also noted on the inner electrode contact rivets (Figure 19) associated with the wires in Figure 14. The residues formed at cracks in the coating covering the connections. Probe number three exhibited a black residue streak associated with the top active inner electrode terminal (Figure 20). A summary of the elemental analysis results for various probe components and residues is given in Figure 21.

Electrical resistance of the residue streak noted on probe number three (Figure 20) was measured using a four-point probe method. A 1.0 mA current was injected between two probes separated 10mm apart in the residue. A 13.2 volt drop was measured giving a 13.2 K resistance. Small scintillating arcs were noted as the current was increased to 5mA. Several drops of JP-4 were placed on the residue, the current was reapplied and arcing without fuel ignition was noted. The heat generated by the current rapidly evaporated the fuel. Discolored areas in the residue film formed where arcing was noted. The residue measured open circuit (>20M) after a few seconds. The resistance of probe number one residue in Figure 16 was measured as 15.1K using the four-point probe method (0.87mA at 13.2V). The current was raised until arcing was noted at 7mA and maintained at 10mA. The resistance increased to 100K after injecting 10mA. The 10mA exceeded the current density of the residue and formed damage sites (Figure 22). The residues on the submitted probes did not exhibit the current induced damage sites noted in testing.

Tests were conducted in order to study electrical arcing in JP-4 fuel. Two silver plated copper wires were immersed in 10 ml of JP-4. The wires were connected to a 40 volt D.C. power supply and current limited to 400mA. Arcing was induced on the wires in and just above the fuel. The fuel was not ignited. However, a black residue was produced on the surface of the wires. Optical and SEM inspection revealed no damage to the wires. EDS identified carbon, copper, and silver. No sulfur was detected.

DISCUSSION

Only one of the four probes submitted (probe number one) was electrically failed. Failure was the result of a low resistance path (high leakage current) formed by a black residue between Terminal C and the case ground. All other probes exhibited a capacitance slightly below the T.O. specification value. This may be due to variations in the laboratory test setup and a factory built test fixture. High energy electrical arcing most likely did not cause the residues noted on the submitted probes. This type of arcing produces metal transfer, physical damage, and large amounts of carbon residue. Laboratory testing demonstrated the thin film residue is damaged under low current and voltage conditions (13V at 10mA). Small arcs were noted in the residue as the materials broke down under excessive current. The rupture sites noted were not found on the as received fuel probes. This indicates the residues were not subjected to high voltages or currents. It is possible the probe field tester used could supply enough power to cause arcing.

All probes exhibited conductive (1-100Ω) black\gray residues on the compensator electrodes, inner electrodes, and exposed terminations and wiring. The resistances of the residues were well below the 40 M required between the terminals and case ground. It is possible probe leakage currents produced by the residue paths are sufficient to cause variances in capacitance readings and system malfunctions. The residues act as a thin film resistor that will rupture and open if significant current is passed through the material.

Residue formation is most likely the result of a long-term degradation or corrosion process. Exposed silver plated copper wiring and other silver containing surfaces (electrodes) are apparently reacting with the sulfur in the fuel. This deterioration process is most likely time dependent and, as the probes age, more probe failures can be expected. Probe residues consisted of silver sulfide and copper sulfide. Analysis consistently detected silver, copper, and sulfur in residue areas and only sulfur outside the residues.

PREPARED BY:

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Materials Integrity Branch
Systems Support Division
Materials Directorate

Figure 11. Residues found inside the Teflon tubing (Figure 7) of probe number three. The residue appears to have deposited in layers. Mag: 10X

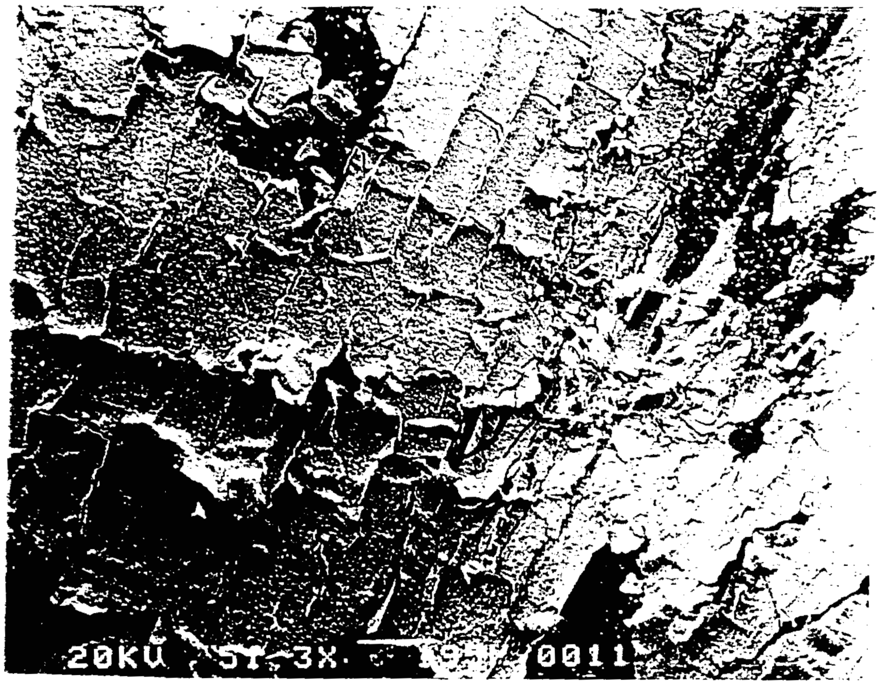


Figure 12. SEM micrograph of residue area in Figure 11. EDXS identified copper, silver, and sulfur. Mag: 51X

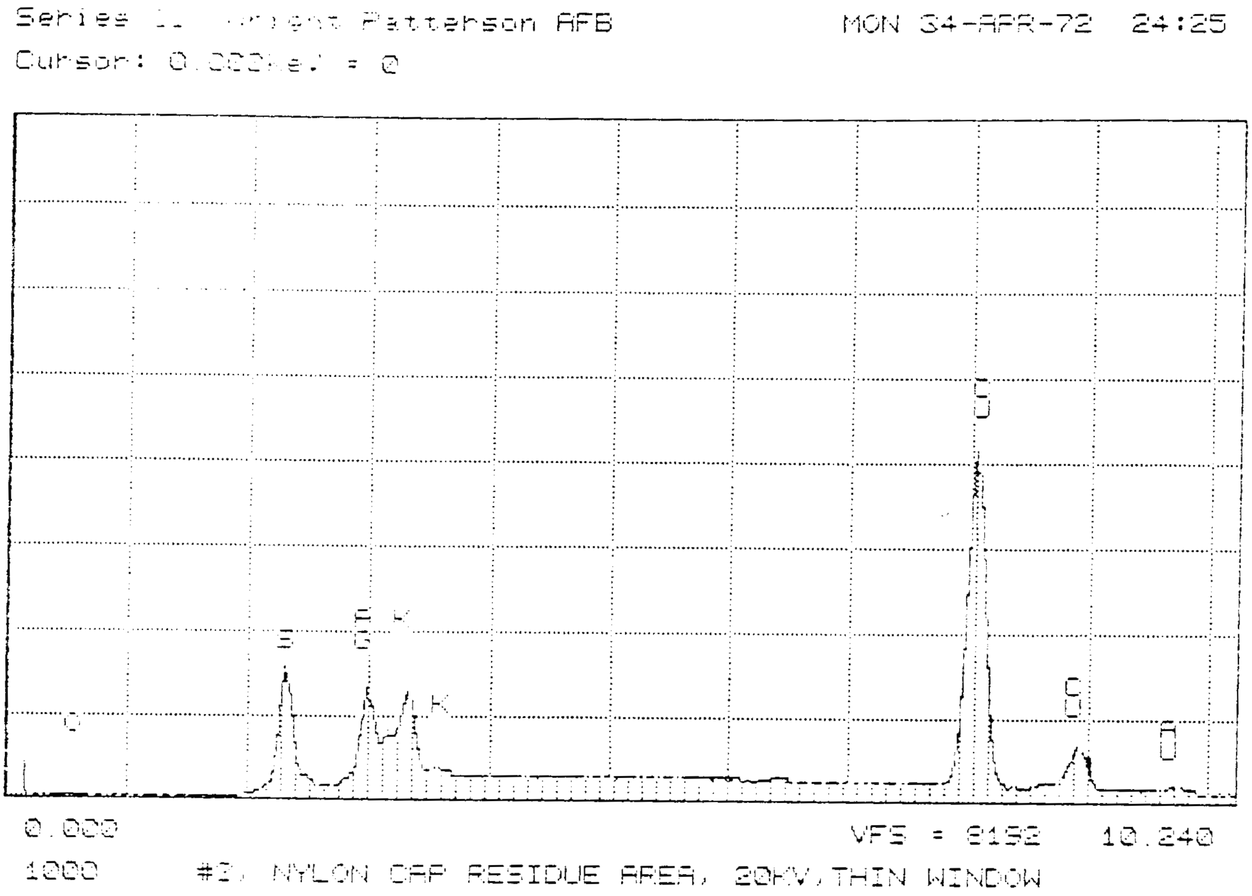
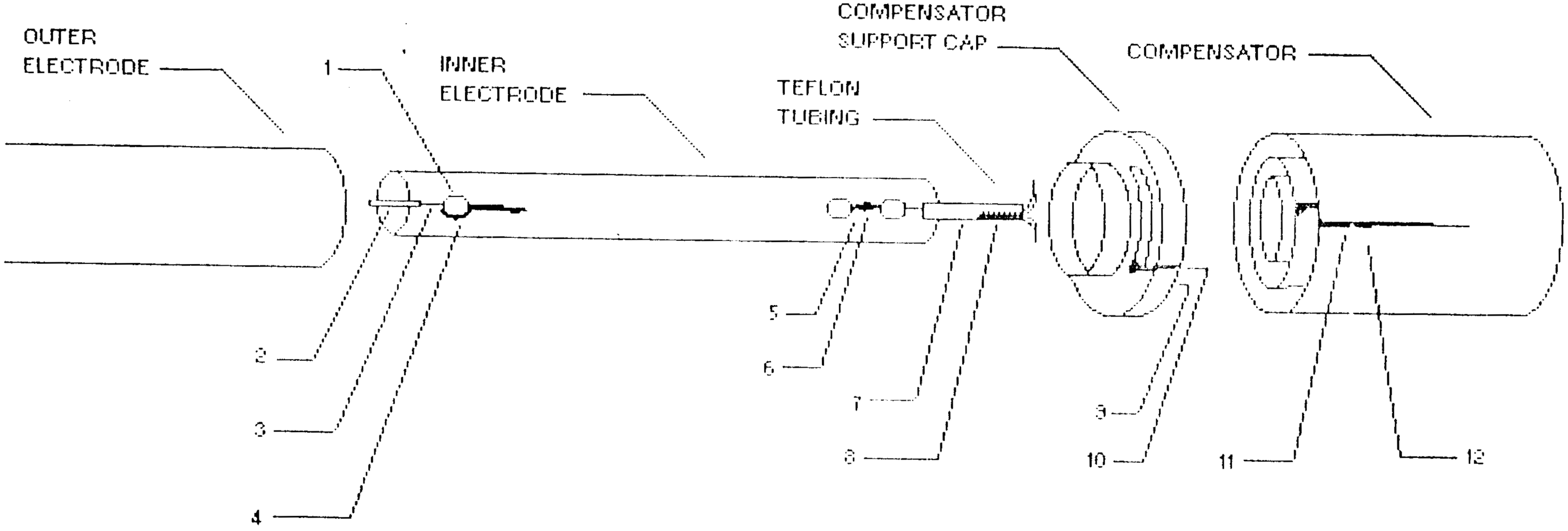


Figure 15. EDXS spectrum of residues on the nylon cap. Note presence of sulfur, silver, and copper. Areas outside of the residues did not contain these elements.



LEGEND

1 TERMINAL	= Sn Plated Cu	7. TEFLON TUBING	= F
2 WIRE INSULATION	= TEFLON	8 TEFLON TUBING CONTAMINANT	= S. Cu.
3 WIRE	= Ag Plated Cu	9. COMPENSATOR CAP CONTAMINANT	= Cu. S. Ag. K
4 INNER ELECTRODE CONTAMINANT	= S. Ag. Cu	10. COMPENSATOR CAP REFERENCE	= S. Na. K. Zn
5. INNER ELECTRODE REFERENCE	= S. C. Si. 0	11. COMPENSATOR CONTAMINANT	= S. Cu
6. INNER ELECTRODE CONTAMINANT	= S. Cu. Ag	12. COMPENSATOR REFERENCE	= Fe. Si

Figure 21. Summary of elemental analysis results for various probe components and residue locations.

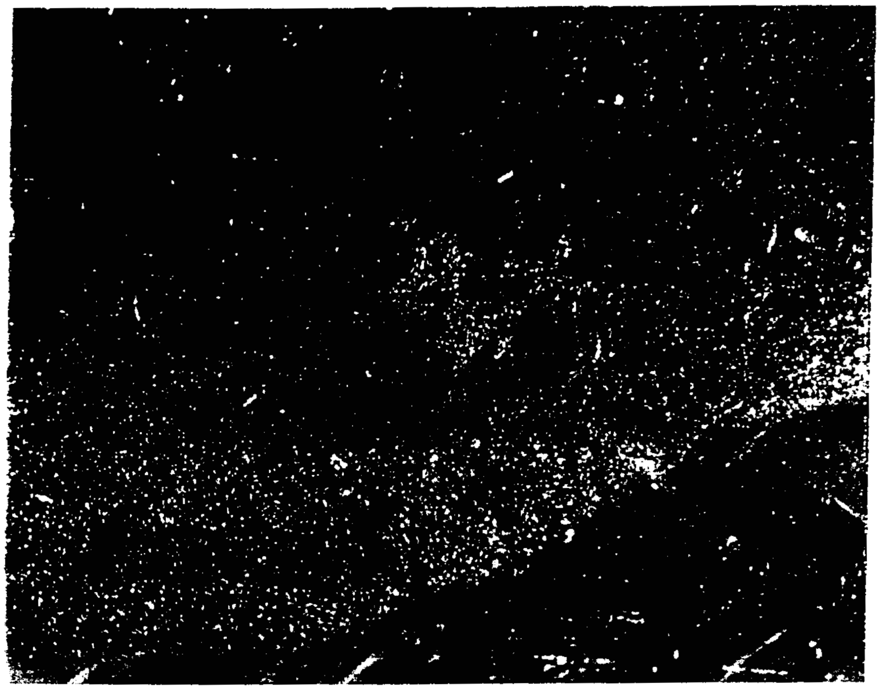
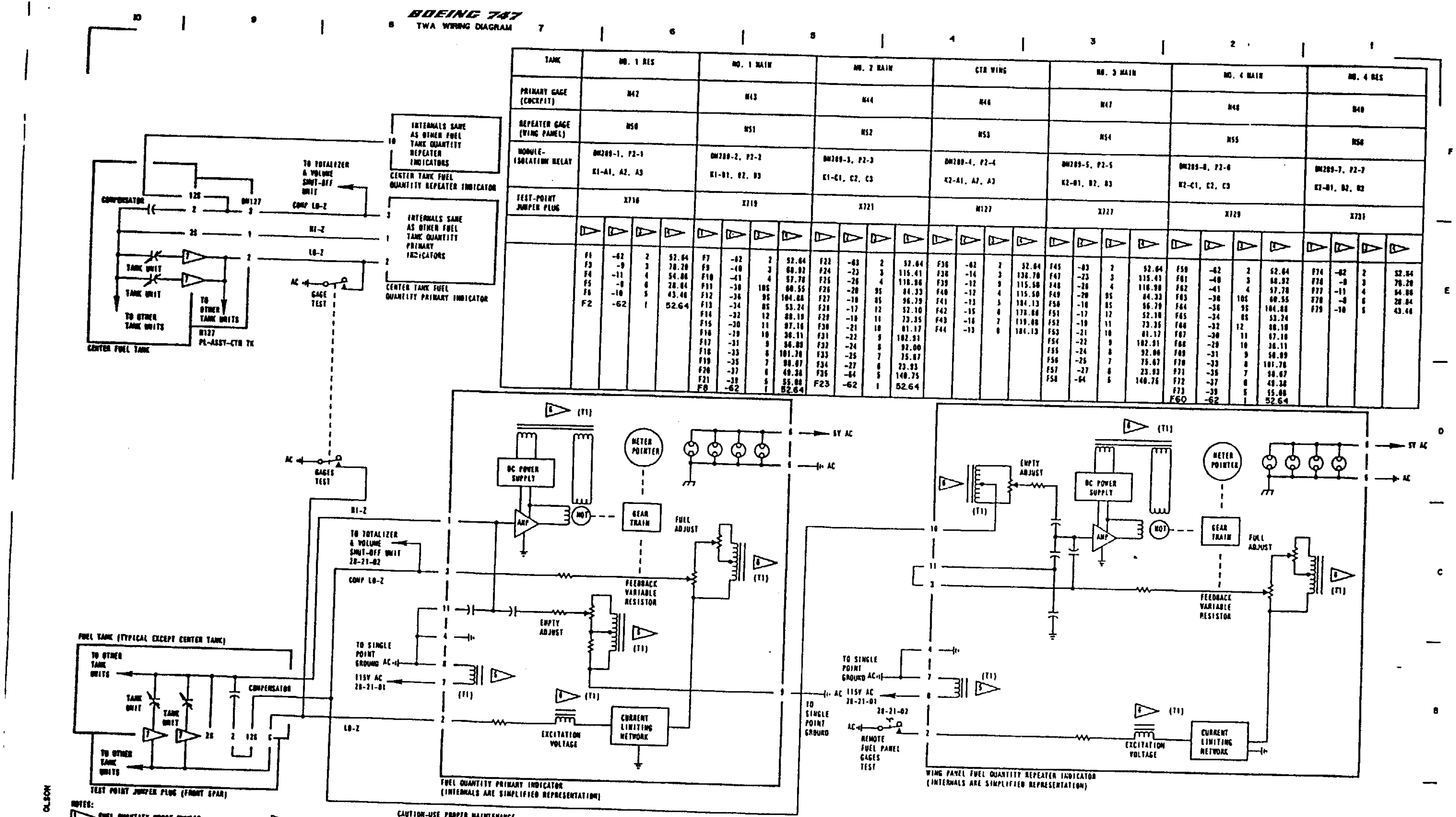


Figure 22. Rupture area in residue film after applying 10mA across material. This damage is typically seen when the current density of a film is exceeded.

SYSTEMS
FACTUAL
MM 28-41-02

BOEING 747
TWA WIRING DIAGRAM



TANK	NO. 1 RES				NO. 1 MAIN				NO. 2 MAIN				CTR WING				NO. 3 MAIN				NO. 4 MAIN				NO. 4 RES			
PRIMARY GAGE (COCKPIT)	M42				M43				M44				M46				M47				M48				M49			
REPEATER GAGE (WING PANEL)	M50				M51				M52				M53				M54				M55				M56			
MODULE-ISOLATION RELAY	DM289-1, P2-1 K1-A1, A2, A3				DM289-2, P2-2 K1-B1, B2, B3				DM289-3, P2-3 K1-C1, C2, C3				DM289-4, P2-4 K2-A1, A2, A3				DM289-5, P2-5 K2-B1, B2, B3				DM289-6, P2-6 K2-C1, C2, C3				DM289-7, P2-7 K2-D1, D2, D3			
TEST-POINT JUMPER PLUG	X716				X719				X721				M127				X727				X729				X731			
	▷1	▷2	▷3	▷4	▷1	▷2	▷3	▷4	▷1	▷2	▷3	▷4	▷1	▷2	▷3	▷4	▷1	▷2	▷3	▷4	▷1	▷2	▷3	▷4	▷1	▷2	▷3	▷4
	F1	-62	2	52.64	F7	-62	2	52.64	F22	-63	2	52.64	F36	-62	2	52.64	F45	-63	2	52.64	F59	-62	2	52.64	F74	-62	2	52.64
	F3	-9	3	70.20	F9	-40	3	60.92	F24	-23	3	115.41	F38	-14	3	136.70	F47	-23	3	115.41	F61	-40	3	60.92	F76	-8	3	70.20
	F4	-11	4	54.86	F10	-41	4	57.78	F25	-26	4	118.96	F39	-12	9	115.50	F48	-26	4	118.90	F62	-41	4	57.78	F77	-11	4	54.86
	F5	-8	6	28.04	F11	-38	10S	60.55	F26	-20	9S	84.33	F40	-12	4	115.50	F49	-20	9S	84.33	F63	-38	10S	60.55	F78	-8	6	28.04
	F6	-10	5	43.46	F12	-36	9S	104.88	F27	-18	8S	96.79	F41	-13	5	104.13	F50	-18	8S	96.79	F64	-36	9S	104.88	F79	-10	5	43.46
	F2	-62	1	52.64	F13	-34	8S	53.24	F28	-17	12	52.10	F42	-15	6	173.60	F51	-17	12	52.10	F65	-34	8S	53.24				
					F14	-32	12	88.19	F29	-19	11	73.35	F43	-16	7	119.08	F52	-19	11	73.35	F66	-32	12	88.19				
					F15	-30	11	87.16	F30	-21	10	81.17	F44	-13	8	104.13	F53	-21	10	81.17	F67	-30	11	87.10				
					F16	-29	10	30.11	F31	-22	9	102.91					F54	-22	9	102.91	F68	-29	10	30.11				
					F17	-31	9	56.09	F32	-24	8	92.00					F55	-24	8	92.00	F69	-31	9	50.09				
					F18	-33	8	101.78	F33	-25	7	75.87					F56	-25	7	75.87	F70	-33	8	101.78				
					F19	-35	7	98.67	F34	-27	6	23.93					F57	-27	6	23.93	F71	-35	7	98.67				
					F20	-37	6	40.38	F35	-64	5	140.75					F58	-64	5	140.75	F72	-37	6	40.38				
					F21	-39	5	55.08	F23	-62	1	52.64									F73	-39	5	55.08				
					F8	-62	1	52.64													F60	-62	1	52.64				

NOTES:

▷1 FUEL QUANTITY PROBE NUMBER
▷2 BOEING PROBE PART NO. 60B92010
▷3 JUMPER PLUG TEST PIN NO.
▷4 PROBE DRY CAPACITANCE (UUF)

▷5 TRANSFORMER PRIMARY
▷6 TRANSFORMER SECONDARY
▷7 SEE TABLE FOR PIN NO. ASSIGNMENTS FOR SPECIFIC TANK UNITS UNDER ▷

CAUTION-USE PROPER MAINTENANCE MANUAL PROCEDURES WHEN TESTING COMPONENTS WITHIN FUEL TANKS

RE DRAFTED BY: A. OLSON
CHECKED BY:
DRAWING NO: 6B74702
PAGE DATE: APR 1/91

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CHANGE:

28-41-02
PAGE 101

W.O.				FUEL QUANTITY SYSTEM SCHEMATIC
TWA	DWG NO. 1-84799	SH 1	CHG	EFFECTIVITY 104-80, 85-87, 89

RA104-RA110 RA164
RA83-RA85

000246

SYSTEMS
FACTUAL
28-41-02

6. ASSEMBLY. Paragraphs 6A to 6B(5).

A. General.

(1) Item numbers refer to the exploded view, figure 101.

(2) Refer to the wiring diagram, figure 501, for leadwire location. The diagram shows the FG6C1 Compensator, but applies to all models and series of the compensators.

B. Assemble Electrodes.

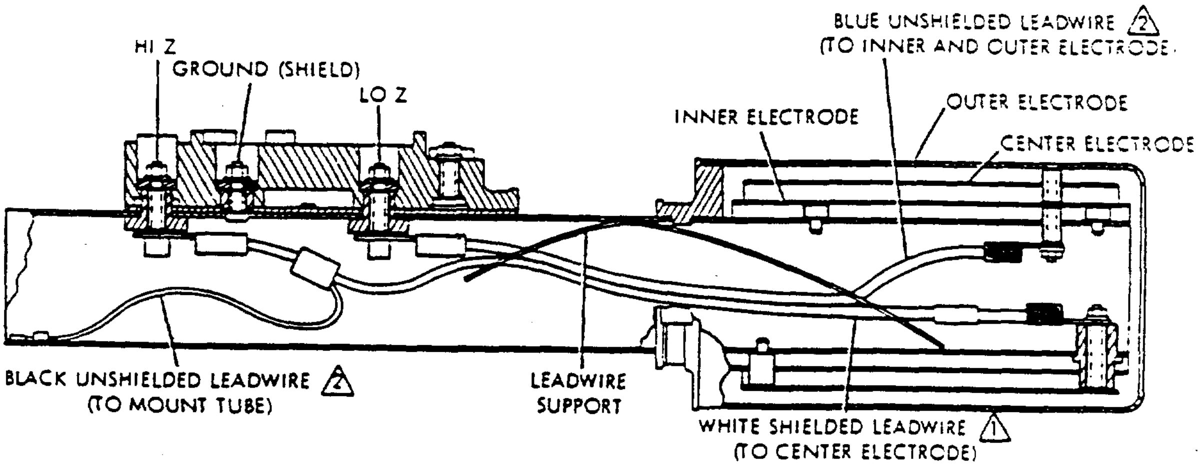
(1) Install items 23, 47 through 50, and 53 if they were removed during disassembly.

(2) Carefully feed leadwires through the holes of support (46) as it is placed into tube (55).

(3) Insert three spacers (43) and six spacers (45) into the holes provided for them in tube (55). Carefully slide the inner electrode (44) over spacers (45) until the slots are alined with spacers (43).

(4) Insert insulator (37) into the hole of tube (55) and aline with slot of inner electrode (44). Insert two spacers (43) into holes at the two remaining slots.

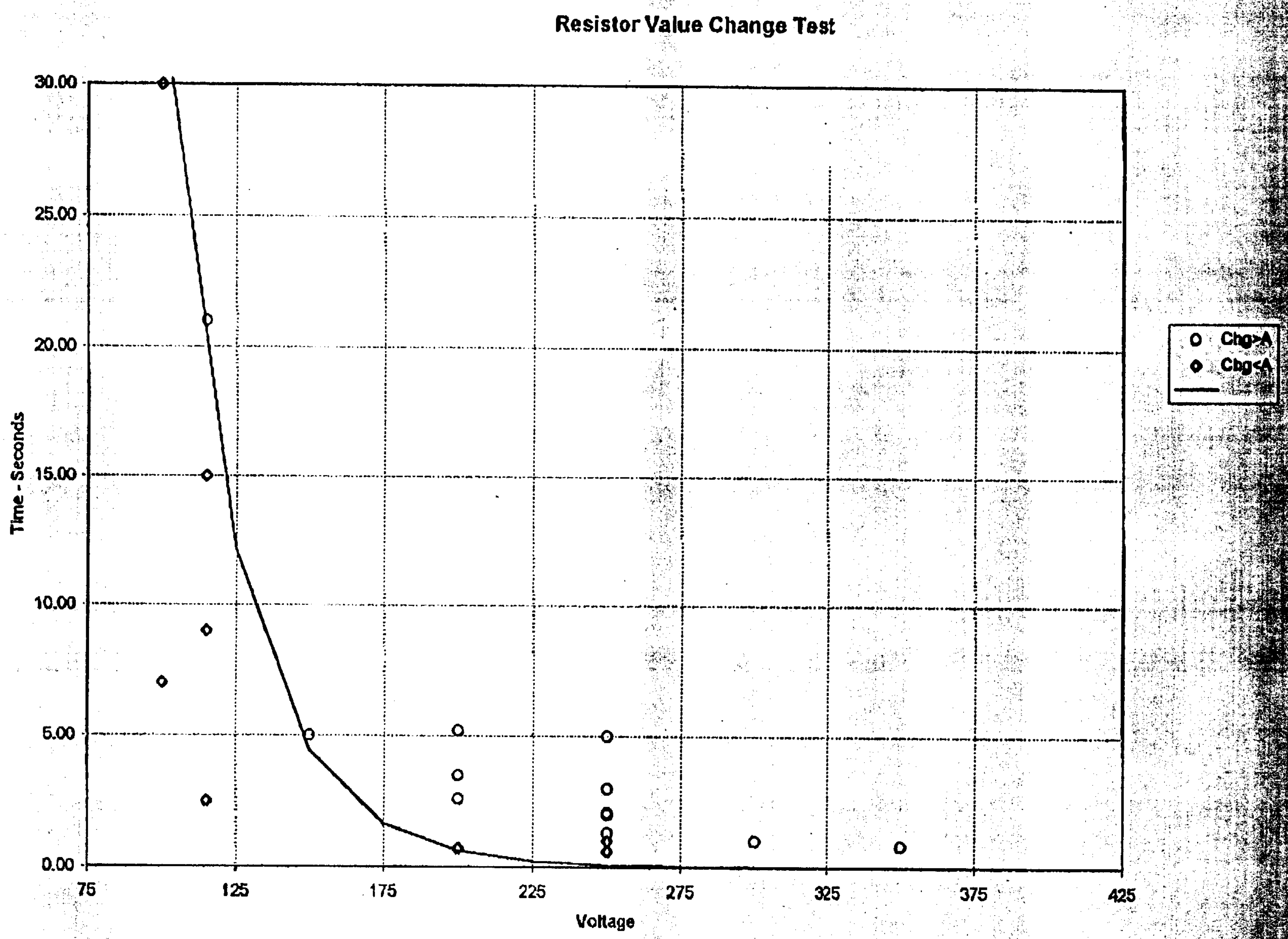
(5) Carefully slide the center electrode (35) over spacers (43). Aline the hole provided for screw (36) with insulator (37).



NOTES:

1. USE MIL-W-16878/5, NO. 22 AWG SHIELDED INSULATED LEADWIRE.
2. USE MIL-W-16878/5, NO. 22 AWG UNSHIELDED LEADWIRE.
3. FG6C1 CONFIGURATION SHOWN.

FG6C Fuel Quantity Compensator - Wiring Diagram
Figure 501



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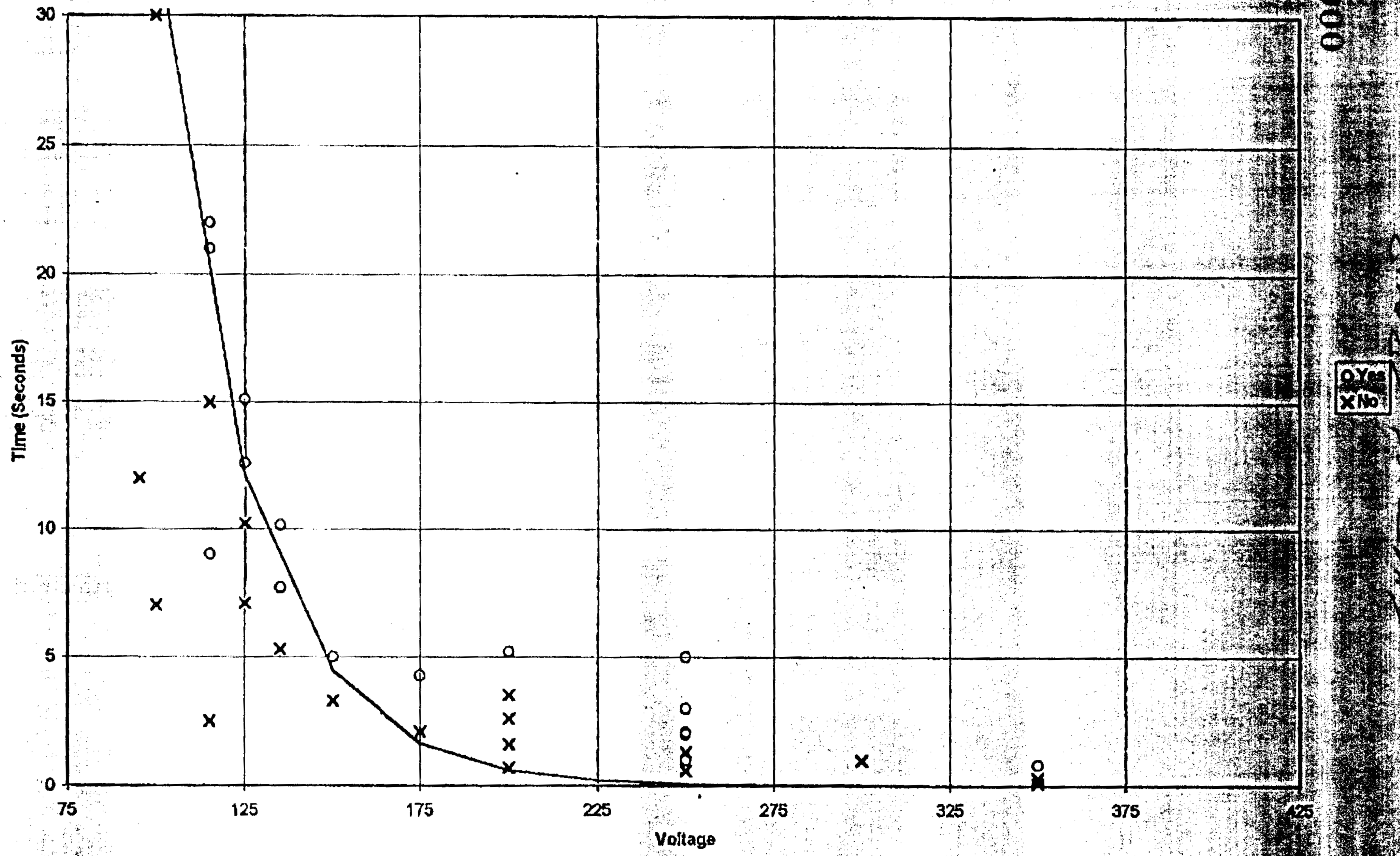
FUEL GAGE TEST RESULT
28-41-03

Resistor Discolorization Tests



SYSTEMS GROUP
FUEL GAGE TEST RESULT
28-41-03

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

BOEING

SYSTEM FACTUAL
28-41-09-INS

October 30, 1997
B-B600-16281-ASI

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

Subject: Center Wing Tank Probe Inspection/Rework

Reference: a) Telecon Boeing/NTSB on Oct 28, 1997
b) Telex M-7220-97-1725, dated Oct 27, 1997

Dear Mr. Swaim:

Here is a summary of the items noted during the reference a) telecon in regards to the upcoming Service Bulletin on Probe/Wiring inspections and items that the NTSB noted were important to include.

Summary of 747 Center Wing Tank Probe Inspection/Rework

Boeing is in the process of issuing a Service Bulletin pertaining to the Fuel Quantity Probes and wiring in the 747 Center Wing Tank. Damage to the CWT wiring has been observed which degrades the insulating capabilities of the wiring.

The Service Bulletin, discussed in the reference b) telex, will contain the following instructions:

A procedure to remove/replace/rework probes with Series 3 terminal blocks and wiring attached to those probes

- For R0001-R0058, R0501-R0506 recommend replacement of center tank wire harness. These airplanes have been identified as delivered with probes that had Series 3 terminal blocks.
- For all airplanes, if the fuel quantity probe has a Series 3 terminal block, replace probe with a probe that has a Series 4

SYSTEMS FACTUAL
ATA 28-41-09 IAS

terminal block <u>and</u> reterminate wires to affected probe or replace Center Tank FQIS Wire Harness

- Utilize maintenance manual and ATA 20 instructions for probe/wiring replacement/rework.

Inspection of probe terminal blocks for correct wire routing/wire damage:

- Inspect probe terminal block wiring to ensure conformance to drawing.
- If wiring has been misrouted, inspect for damage (abrasion against terminal block edges or terminal studs).
- Reterminate wiring to terminal block if wire is damaged.
- Reroute wiring to terminal block if not per drawing.
- Utilize maintenance manual and ATA 20 instructions for probe/wiring replacement/rework.

Includes a test procedure to perform an insulation resistance test of the Center Wing Tank wiring. This test can be performed without entering the tank:

- Conduct a low voltage insulation resistance test of the in-tank FQIS wiring utilizing approved explosion proof equipment.
- If this test fails, troubleshoot the failure per the approved MM procedures.

Estimated release date for this Service Bulletin is January 1998.

<u>NTSB Telecon Notes</u>

In a follow-on telecon with the NTSB, the following NTSB recommendations were noted and will be included in the Service Bulletin:

1) In regards to the retermination of the wire - a strong statement needs to be made in the SB that "<u>only</u> those repair procedures relating to the repair of ATA 28 in-tank FQIS wire may be utilized and that wire repair procedures for other wire in the airplane are <u>not</u> to be used." The NTSB wants both the positive statement on ATA 28 wire repair and the negative statement regarding other wire repair procedures. This is due to a repair that was found where tape was used to secure the shield on an FQIS in-tank wire bundle. The procedure used to repair this wire was not approved for use in fuel tanks.

SYSTEM FACTUAL
ATA 28 41-07 IAS

2) Include reporting requirements on the findings of the probe replacement and repair. The NTSB specifically requested that we try to get removed harnesses and probe wire terminations. They also requested that we add a request to report the results of the insulation resistance test - the pass/fail values and what was done to fix the airplane.

3) The NTSB also asked that we include data collection on any problems and rework required for Series 4 terminal block probes.

If you have any further questions, please do not hesitate to contact me at any time.

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

CC Mr. Al Dickinson, IIC

SYSTEMS PACKAGE
ATA 28-41-09

6B

CWT FQIS WIRES TIED IN WITH AIRCRAFT WIRING

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

SYSTEMS MANUALS
MA
28-41-09

October 14, 1997
B-B600-16270-ASI

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

BOEING

Subject: TWA 800 - Repair to Fuel Tank Probe Shield Pigtail

Dear Mr. Swaim:

The WPAFB lab found a questionable repair to a shield pigtail at a tank unit probe from TWA 800 tank 1 or 4. The solder had broken and the wire had been laid against the shield, wrapped with Teflon or Mylar tape, and tied with a string tie. As a result of this finding, you requested information regarding shield pigtail repairs.

1. Since the probe shields are daisy-chained, how much of the system would be ungrounded with an open at such a connection?

Response: The shield for the Hi-Z wire would be ungrounded from that point on.

2. What would be the gage's impedance to ground for each end of the broken connection?

Response: The gage impedance to ground would be unchanged. The gage is grounded near the indicator and is unaffected by a break in the shield pigtail. The only affect would be on the grounding of the Hi-Z shield (see question 1 above).

3. What standard (or other) repairs are known of that this could have been based?

Response: Boeing document D6-54446 "Chapter 20 Wiring Practices Manual" was reviewed and no procedures were found which would support the type of pigtail repair described above. This document contains Boeing recommended wiring practices and is provided to the airlines as part of the wire diagram manual.

SYSTEMS MANUAL
AMM 28-41-04

If you have any questions, please do not hesitate to contact me at any time.

Very truly yours,

John W. Purvis
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Fax (425) 237-8188

BOEING

SYSTEMS [illegible]
ATA 28-41-09

TRANS WORLD AIRLINES, INC.

UNITED STATES · EUROPE · MEXICO · MIDDLE EAST · CANADA · CARIBBEAN

TO: BOB SWAIM

FAX: 202-314-6349

DATE: 10/13/97

PAGES (INCLUDING COVER): 3

When asked if a repaired shield on probe fragment 31 was a standard repair, this was sent by TWA.
R. Swaim

MESSAGE:

ATTACHED ARE 2 PAGES FROM THE TWA ELECTRICAL & ELECTRONIC STANDARD PRACTICES MANUAL.

ALTHOUGH PARA 3. IS SHOWN FOR MAKING A SHIELDED WIRE SPLICE, THE PRINCIPLE OF USING AN UNINSULATED SPLICE CONNECTING TO THE SHIELD IS APPLICABLE TO ATTACHING A PIGTAIL LEAD TO A SHIELD AT A SHIELD TERMINATION.

PARA 3.I. INDICATES PROTECTION USING TEFLON TAPE AS A COVERING AND TYING THE TAPE ENDS.

FROM: K. S. CRAYCRAFT

FAX: 816-891-1999

PHONE: 816-891-4617

TRANS WORLD AIRLINES

SYSTEMS MANUAL
MM 28-41-09

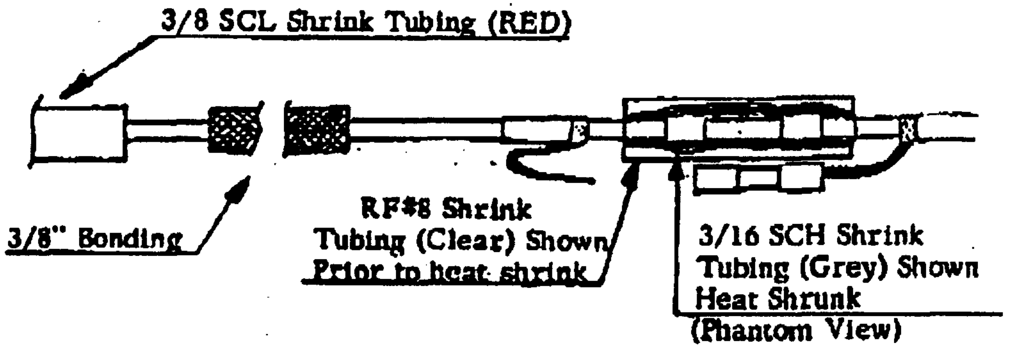
3. Installation - Single Conductor - Alternate Method No. 2

A. An alternate method of splicing single conductor, single braid shielded cables as shown in Figure 206.

B. Check that all items are in relative position shown on shielded lead and make splice connection of lead to aircraft harness shielded lead.

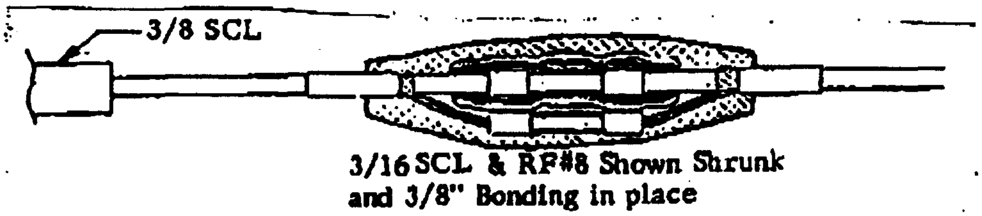
C. Position 3/16 SCL shrink tubing (grey) over joined splices and shrink with thermofit gun (apply 300 to 500 F. heat).

D. Position 1/4 RNF shrink tubing (white) over previously shrunk 3/16 SCL and shrink.



Conductor Spliced
Figure 206

E. Join shielded lead shields at splice and position 3/8" bonding over joined area. (See Figure 207.)

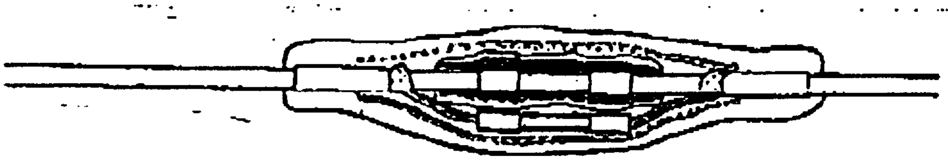


Shield Spliced
Figure 207

SYSTEMS MANUAL
ATA 28-41-09

F. Position 3/8 SCL shrink tubing (red) over 3/8" bonding and joined area and shrink to a form fit. (See Figure 208.)

NOTE: Tube shrinkage is not complete until material has pressed out of filled all voids and tubing ends close in firmly and completely around the conductor outer jacket for a moisture tight joint.



3/8 SCL Shown Shrunk over
3/8" Bonding and Joined Area.

Final Sealing of Splice
Figure 208

G. Join each of the applicable unshielded leads to corresponding aircraft harness lead and shrink the 1/4 RNF shrink tubing, (white), supplied, over the joined area.

H. Approved alternates for shielded lead knife splices.

(a) Uninsulated splices may be used in place of knife splices using the same insulation procedure outlined in Figure 206.

(b) Pre-insulated splices may be used in place of knife splices. When this type splice is used, only the 3/16 SCL thermofit is required over the splice. An un-insulated splice must be used for the shield. Ref. Figure 206 insulation procedure.

I. On the engines or other high temp areas use high temp splices. Insulate shielded lead splice with two layers of TFE #8 thermofit. The 3/8 SCL thermofit used over the bonding must be covered with Teflon Tape (TWA 41-2399). Tape must be tied at both ends.

J. On circuits which may have short sections unshielded due to location, an alternate method of splicing such as the following may be used.

(a) Splice wires and shielding with pre-insulated splices, stagger the splices. No bending or thermofit is required with this installation.

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

SYSTEMS FACTUAL
28-41-09

October 2, 1997
B-B600-16259-ASI

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

BOEING

Subject: FQIS Wire Shielding, TWA 747-100 Accident near Long Island, N.Y. 17 July 1996

Dear Mr. Swaim:

The following question was raised relative to shielding of FQIS wires:

Was there a shield over the Hi Z and Lo Z FQIS wiring added to the wiring inside the fuselage? Was it added to the left, Center and Right wing systems or just to one side. If so, what was the reason and the change authorization?

Following are our comments:

The 747 FQIS wiring inside the fuselage was revised to add an overall shield around the cable which contains the Hi Z and Lo Z wires from the Flight Engineers Panel to the center tank connector, and from the Flight Engineers Panel to the wing body disconnects for the right wing and left wing tanks. This change was authorized by PRR 75799 and was implemented from line position 244 and on. The reason was to improve the accuracy of the fuel quantity indication system.

Note: An apparent tabulation error occurred on our computerized wire data showing that TWA RA164 had this shielding on the right side only. That bundle dash number was created after the airplane had been delivered. The TWA Wiring Diagram Manual showing the delivery configuration for that airplane confirms that it did not have this shielding. There was no retrofit action for airplanes delivered prior to line position 244.

The 747 FQIS wiring within the Flight Engineer's Panel (P4) was revised to add a second shield over the Hi Z wires and a shield over the Lo Z wires. It also added a shield over the signal wire to the Total Fuel Indicator and the Aids Recorder. This change was authorized by PRR 79459 and was implemented from line position 428 and on. The reason was to eliminate erroneous fuel quantity gage readings caused by EMI from the 5 volt lighting dimming system. There was no retrofit action for airplanes delivered prior to line position 428.

We have no record of any in-service problems with the FQIS wire shielding. Copies of the front pages of PRR's 75799 and 79459 are enclosed for your information.

If you have any questions, please do not hesitate to contact me at any time.

Very truly yours,

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

cc: Mr. Al Dickinson, IIC

Encl: As noted 2 pages

SD/MW

SYSTEMS FACTUAL
28-41-09

PRODUCTION REVISION RECORD

PRR NO. 79459

MODEL: 747

APPLIES TO: RA001-RU999

ATA CHAPTER NO: 28

ISSUED 5-15-79

TITLE: SHIELDING - ADDITION - FUEL QUANTITY INDICATOR WIRING, P4 PANEL

REASON: TO ELIMINATE ERRONEOUS FUEL QUANTITY GAGE READINGS CAUSED BY E.M.I FROM 5 VOLT LIGHTING DIMMING SYSTEM.

GENERAL DESCRIPTION

ADD SHIELDING TO FUEL QUANTITY INDICATOR WIRING WITHIN THE ENGINEER'S PANEL (P4) INTEGRATION WIRE BUNDLE.

THIS CHANGE REQUIRES REVISION TO:

YES	NO	
☐	☒	OPERATIONS MANUAL
☐	☒	FLIGHT MANUAL
☐	☒	MAINTENANCE MANUAL
☒	☐	FLIGHT SIMULATOR
☐	☒	OVERHAUL MANUAL
☐	☒	STRUCTURAL REPAIR MANUAL
☐	☒	GROUND SUPPORT EQUIPMENT
☐	☒	FUNCTIONAL TEST REQUIREMENTS
☐	☒	RIGGING INSTRUCTIONS

YES	NO	
☐	☒	BUYER FURNISHED EQUIPMENT
☐	☒	SELLER FURNISHED EQUIPMENT

RETROFIT METHOD (CHECK APPLICABLE BLOCK)

☒ NONE

BOEING	SUPPLIER	
☐	☐	SERVICE BULLETIN ONLY
☐	☐	SERVICE BULLETIN & REWORK/PROD PARTS OR KITS
☐	☐	SERVICE BULLETIN & RECYCLE PROGRAM

COMMITMENT	APPROVED	DATE
PRODUCTION.		4-30-79
	[illegible]	5/10/79
	000261	
	Summers	5-15-9
	for LFS	

RETROFIT: SERVICE BULLETIN NO. ________ & DATE ________

FIRST PART/KIT AVAILABLE: ________

ENGINEERING CHANGE MEMO

PRR NO. 75799

MODEL: 747
APPLIES TO: RA 001 - RU999
ATA CHAPTER NO: 28

ISSUED 1-16-74
RECORD 3-7-74

TITLE: FUEL QUANTITY INDICATION WIRING — REVISION.

REASON: TO IMPROVE THE ACCURACY OF THE FUEL QUANTITY INDICATION SYSTEM

GENERAL DESCRIPTION:

REPLACE THE 10-60875-2 FUEL QUANTITY CABLES IN W332, W480 + W864 WITH A 10-60875-X CABLE. THE -X SHALL BE THE SAME AS THE -2 EXCEPT IT SHALL HAVE AN OVERALL SHIELD AROUND THE CABLE.

THIS CHANGE REQUIRES REVISION TO:

YES	NO	
☐	☒	OPERATIONS MANUAL
☐	☒	FAA MANUAL
☐	☒	MAINTENANCE MANUAL
☐	☒	FLIGHT SIMULATOR
☐	☒	OVERHAUL MANUAL
☐	☒	STRUCTURAL REPAIR MANUAL
☐	☒	GROUND SUPPORT EQUIPMENT
☐	☒	FUNCTIONAL TEST REQUIREMENTS
☐	☒	RIGGING INSTRUCTIONS

YES	NO	
☐	☒	BUYER FURNISHED EQUIPMENT
☐	☒	SELLER FURNISHED EQUIPMENT

RETROFIT METHOD (CHECK APPLICABLE BLOCK)

☒ NONE

BOEING	VENDOR	
☐	☐	SERVICE BULLETIN ONLY
☐	☐	SERVICE BULLETIN & REWORK/PROD PARTS OR KITS
☐	☐	SERVICE BULLETIN & RECYCLE PROGRAM

COMMITMENT	APPROVED	DATE
PRODUCTION: R0127 - R0299, R0306 - R0499, R0535 - R0999 R1060 - R1499, R1510 - R1899, R1904 - R3999 R4006 - R5994, R6004 - R9995 SEE PAGE 1.1	C V Larson	10-17-73
	R E Bird	10-30-73
	NEHER	11-1-73
	Ward	12/4/73
		1-16-74

000262

RETROFIT: SERVICE BULLETIN NO. ______ & DATE ______
FIRST PART / KIT AVAILABLE: ______

28-40-09

TWA 800
Description of Lighting Systems Wiring Adjacent to FQIS CWT Wiring

Reference attached drawings pages 2 through 6.

Page 2: (A) Lighting transformer T110 supplies power to window lights in the STA 950 area.

Page3: The power line from transformer T110 (B1) is spliced to the wire bundle W1300 at (B2). The specific wire that is adjacent to FQIS wiring is indicated at (C). Ballast module M930 at STA 950L is a dual lamp arrangement as shown at (D).

Page 4: The center wing tank FQIS wire harness "W480" is shown at (E). This bundle is a continuous run bundle from P4 panel (flight engineers station) to the CWT rear spar where it is connected to the intank system at connector DM127.

Page 5: In this section of the airplane, the FQIS bundle "W480" runs down the sidewall at (H) ref. sta 920. At point (G), the lighting wire (W1300-L2282 page 3 (C)) is tapped off the main bundle running horizontally and is routed with the other bundles running vertically down the side wall. At point (F) the wire is taken back out of the vertical run and is routed over to the lighting module connected to D229P.

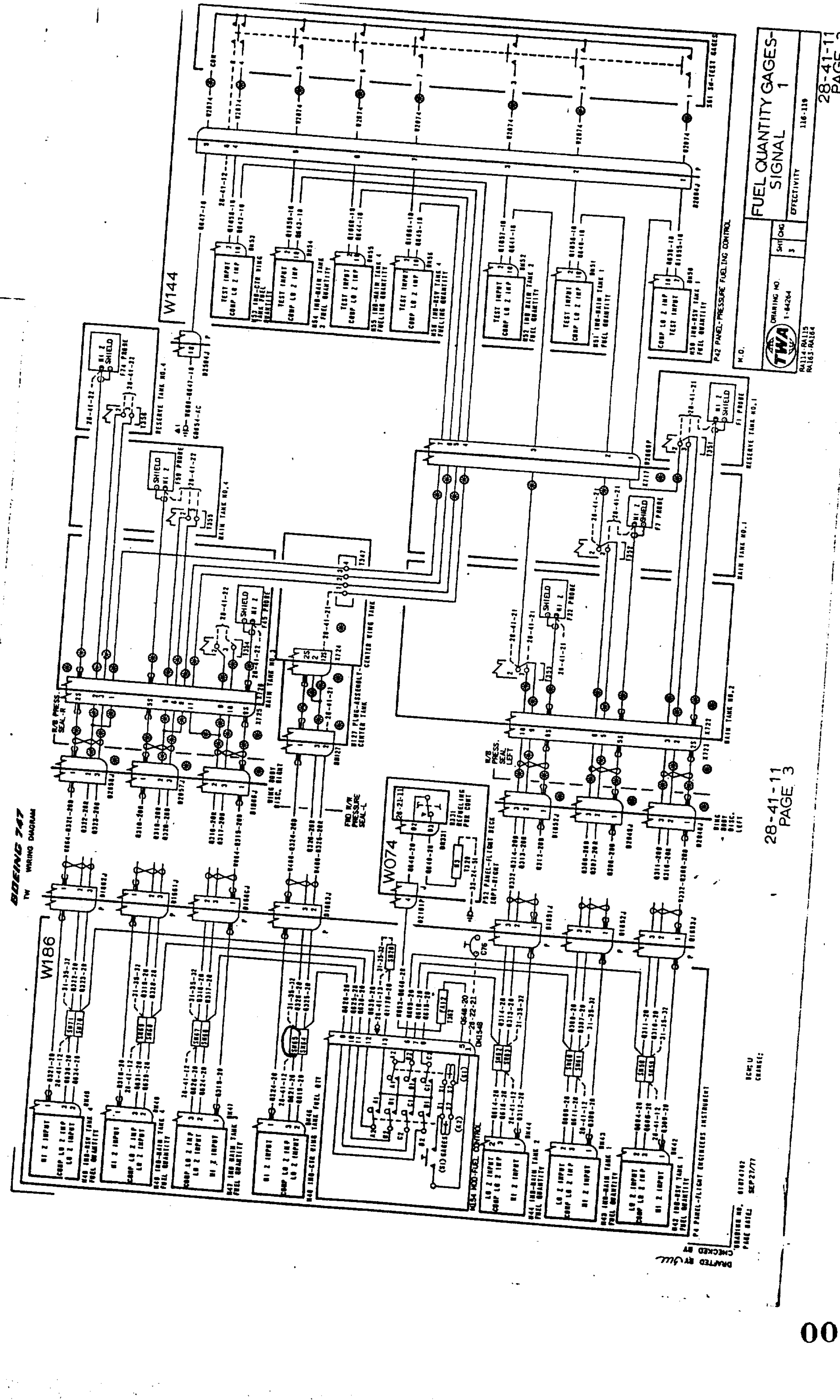
The entire run of the FQIS bundle has been examined from the P4 (flight engineers station to the CWT rear spar to determine if any lighting wires are adjacent. This is the only case found were they do.

Page 6: The installation of a dual lamp setup for window lights is shown at (J). (K1) indicates the shipside connector, in this analysis case D229P. The module is located at (K2) with the wiring connecting to the second lamp shown at (K3). Note that the connection for the second lamp is routed directly to it from the adjacent window where the module is mounted. The wiring from the ballast to the lamps is not routed with the FQIS bundle.

R.B. Parks ← Boeing Engineer.
Electrical Systems
342-6276

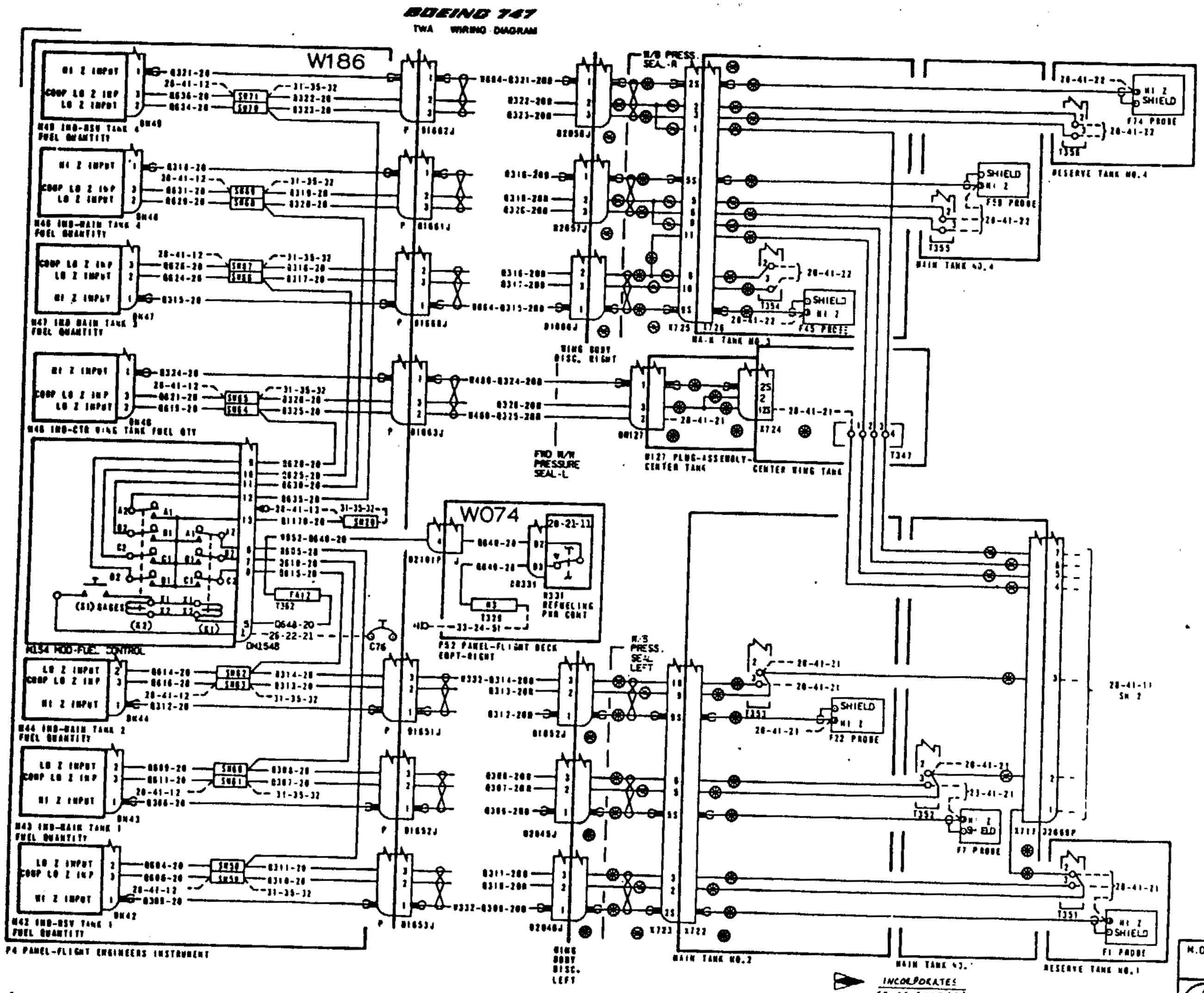
R. Swain

SYSTEMS
FACTUAL
ATTACHMENT



000264

BOEING 747
TWA WIRING DIAGRAM



DRAFTED BY *Anne Je.*
CHECKED BY *R*

DRAWING NO. 61874703
PAGE DATE: OCT 1/80

DCN: V
CHANGE: 50

28-41-11
SH1 PAGE 6

INCORPORATES
SB 28-2069 (K1) FOR 116-117, 119 (RA1.4-RA10, RA164)

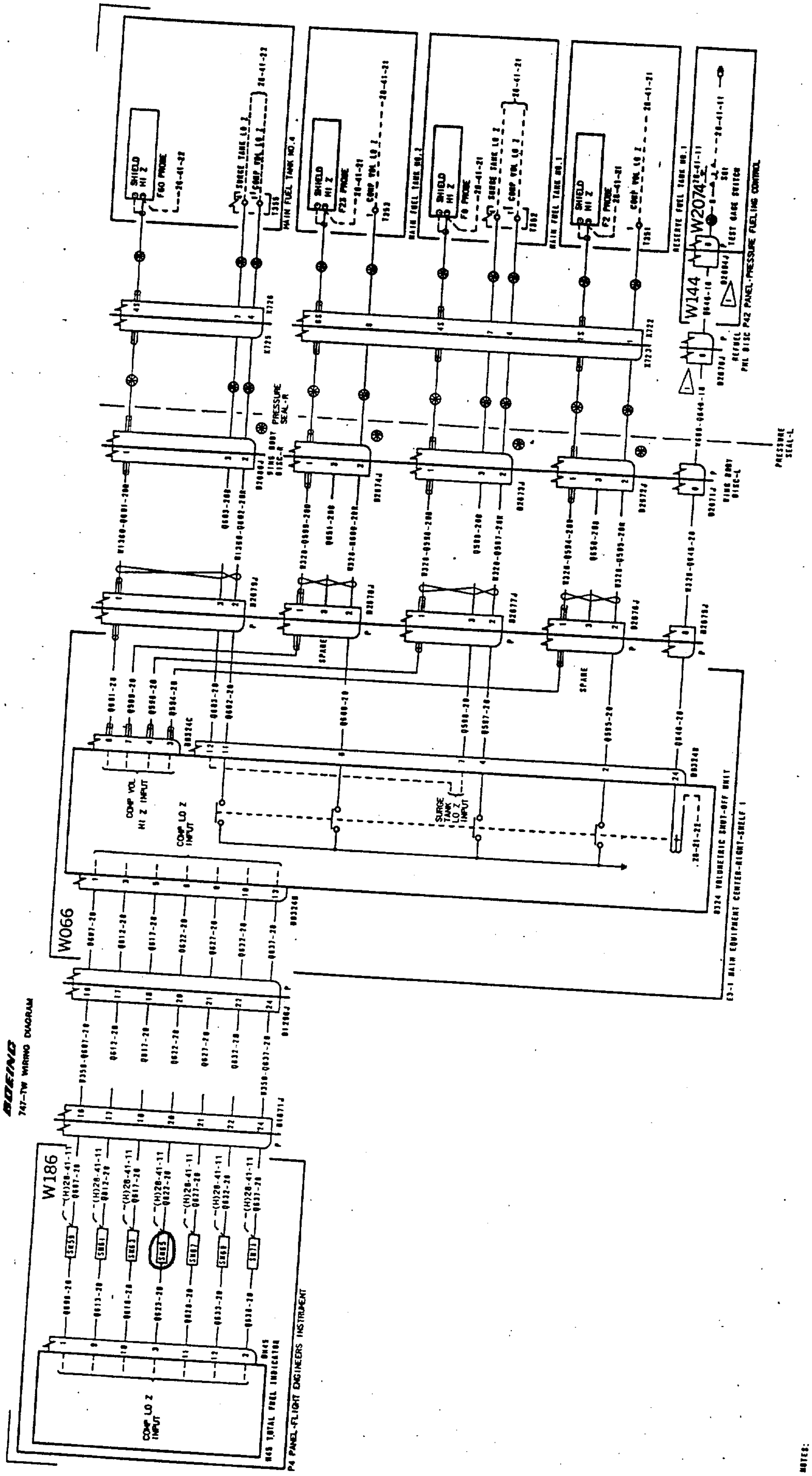
M.O.			FUEL QUANTITY GAGES-SIGNAL 1
TWA DRAWING NO. 1-84264	SHT 3	CHG	EFFECTIVITY 116-117, 119

RA114-RA115
RA164

28-41-11
SH1 PAGE 6

SYS ENG
FACTUAL
ATA 28-41-11

SYSTEMS
FACTUAL
NA 28-41-12



28-41-12
PAGE 2

NOTES:
△1 20 GAGE ACCEPTABLE FOR 107-108(RA107-RA108)

DCN: G
CHANGE:

DRAWING NO.: D1074702
PAGE DATE: MAR 26/71

DRAFTED BY
CHECKED BY

W.O.

TWA

RA107-RA108

DWG NO. 1-04265

SHT	CHG
2	

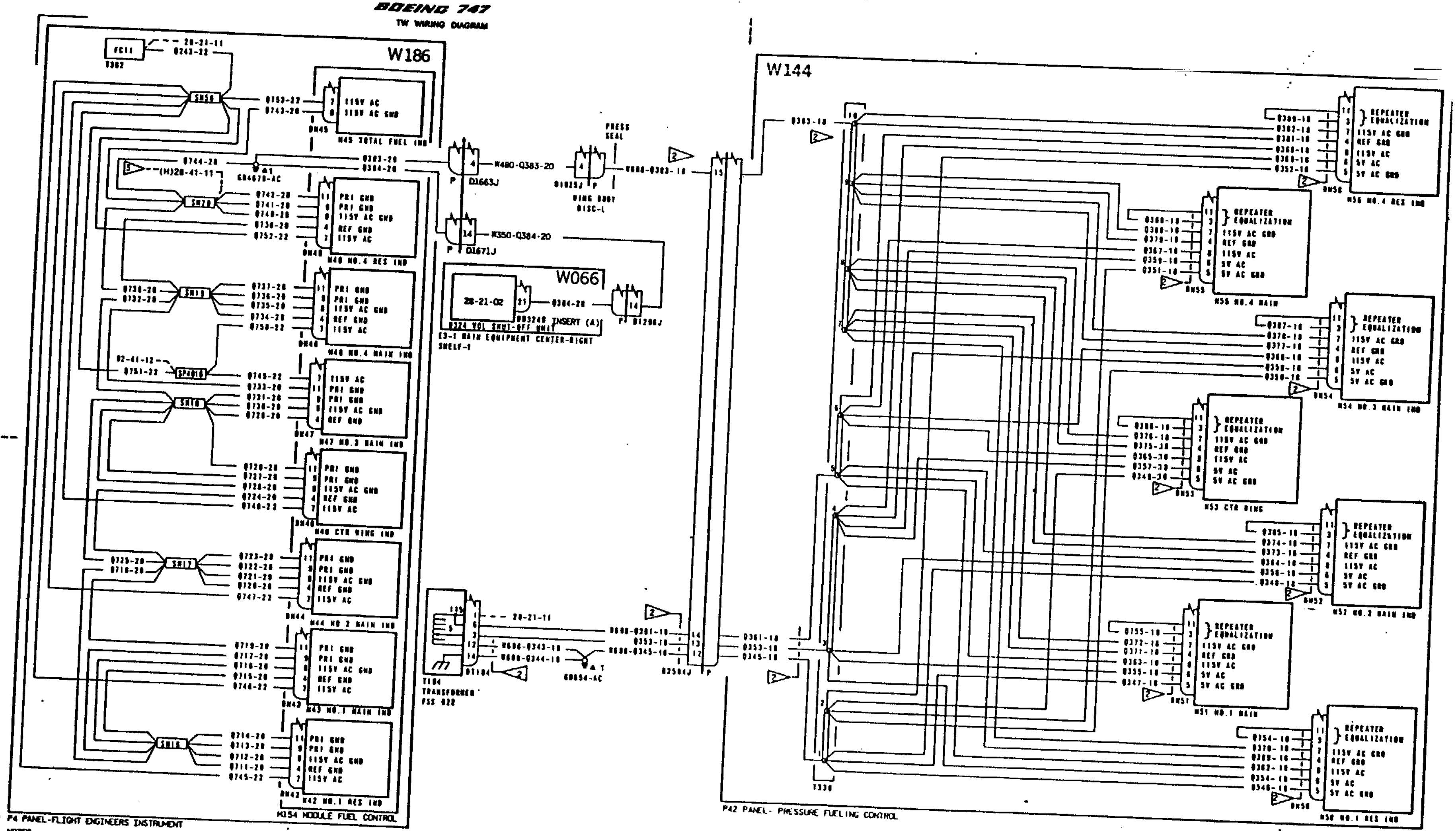
FUEL QUANTITY GAGES-SIGNAL 2

EFFECTIVITY 107-999

28-41-12
PAGE 2

BOEING 747

TW WIRING DIAGRAM



NOTES:

2 20 GAGE WIRE ACCEPTABLE FOR 102-109 (RA102-RA109)

3 EFF FOR 116-999 (RA114-RA159,RA163-RA199)

DRAFTED BY SHC
CHECKED BY

DRAWING NO. 61874702
PAGE DATE: MAR 29/74

ECN: S
CHANGE:

28-41-13
PAGE 1

W.O.

TWA

DWG NO. 1-64266

SHT 1

CHG

FUEL QUANITITY GAGES-POWER

EFFECTIVITY ALL

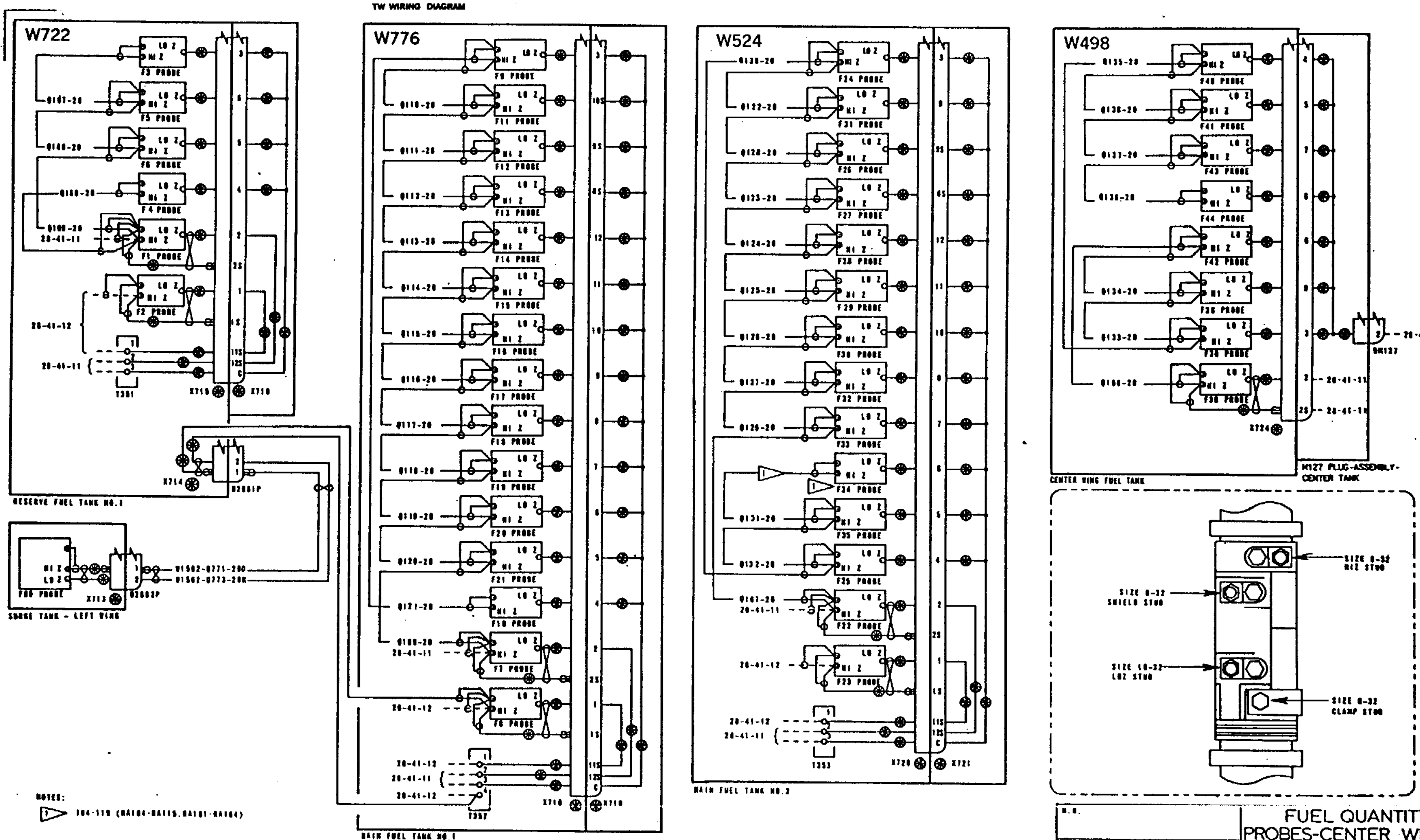
RA101-RA199

28-41-13
PAGE 1

SYS ... FACTUAL
ATM 28-41-B

000267

BOEING 747
TW WIRING DIAGRAM



NOTES:
1 104-119 (RA104-RA115, RA101-RA104)

DRAFTED BY
CHECKED BY

DRAWING NO.81074707
PAGE DATE: SEP 3/74

BCK'T
CHANGE:

W.O.

TWA
DWG NO. 1-84267
SHT 2
CHG

FUEL QUANTITY PROBES-CENTER WING AND LEFT WING

EFFECTIVITY
104-999

RA104-RA189

FACTUAL
28-41-21

Boeing Commercial Airplane Group
P.O. Box 3707
Seattle, WA 98124-2207

SYSTEMS FACTUAL
ATA 73-30-00

April 4, 1997
B-B600-16087-ASI

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

BOEING

Subject: Wire Routing, TWA 747-100 N93119 Accident off Long Island, N.Y. 17 July 1996

Dear Mr. Swaim:

In response to your request for information regarding wire routing for the No. 4 engine fuel flow wiring and fluorescent light wiring, we offer the following:

The wire supplying 350 volts AC power to the ceiling fluorescent lights in Zone A and B routes in close proximity to the No. 4 engine fuel flow wiring for a short distance in the right hand sidewall at approximately station 360. The fuel flow wiring is the wiring between the fuel flow indicator and the fuel flow signal conditioning module. Refer to the enclosed drawing pages 2 through 6.

Page 2: (A) Lighting transformer T63 supplies power to ceiling lights in the STA 360 area.

Page 3: The power line from transformer T63 is fed through a series of wire bundles to the area of entry door 1 where it connects to bundle W1306. The specific wire, (W1306-L1892-22), that is adjacent to No. 4 engine fuel flow wiring is shown at (B). Ballast module M345 at STA 370R is a dual lamp arrangement as shown at (C).

Page 4: The No. 4 engine fuel flow wire harness W1360 is shown at (D). This bundle runs from the P4 panel (Flight Engineers Station) where the fuel flow indicator is located, to the E3-1 (Main Equipment Center-Right Shelf 1) where the fuel flow module, M836 is located.

Page 5: In this section Rt Raceway "J" of the airplane, the No. 4 fuel flow bundle W1360 runs down the sidewall at (E) ref. STA 360. At point (F), the lighting wire [W1360-L1892 page 3 (C)] is tapped off the main bundle running horizontally and is routed with the other bundles running vertically up the sidewall. At point (G) the wire is taken back out of the vertical run and is routed over to the lighting module M345.

Page 6: The dual lamp setup of the ceiling light fluorescent fixture with the ballast located between the two lamps is shown in figure B. Wire W1360-L1892-22 supplies power to terminal A2 on the ballast. The wires from the ballast to the lamps are routed locally within the fixture.

If you have any questions, please do not hesitate to contact me at any time.

Very truly yours,

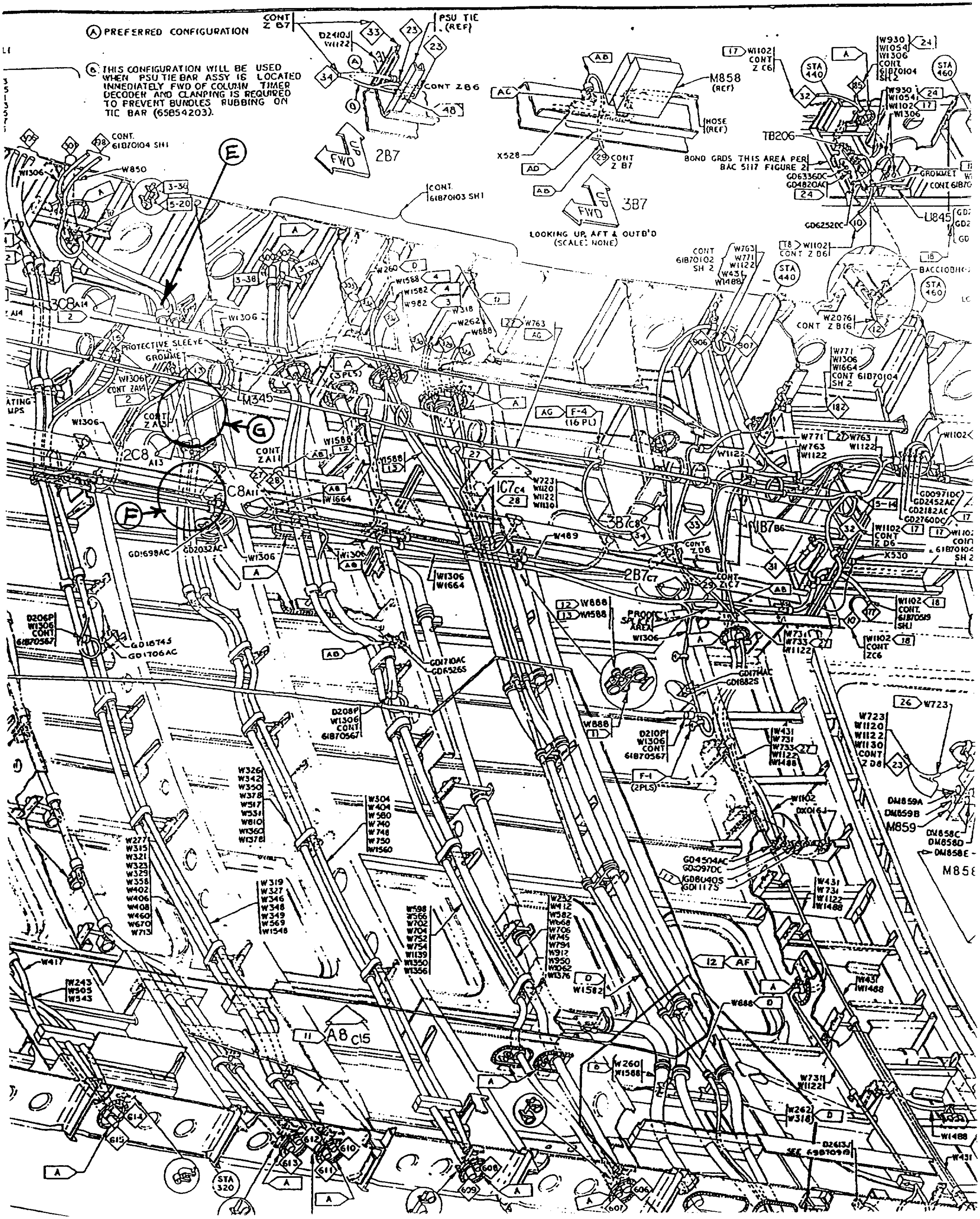
BOEING

for

John W. Purvis
Director, Air Safety Investigation
Org. B-B600, M/S 67-PR
Telex 32-9430, STA DIR PURVIS
Phone (206) 237-8525
Fax (206) 237-8188

Enclosure: As noted, 5 pages

cc: Al Dickinson, IIC



Ⓐ PREFERRED CONFIGURATION

Ⓑ THIS CONFIGURATION WILL BE USED WHEN PSU TIE BAR ASSY IS LOCATED IMMEDIATELY FWD OF COLUMN TIMER DECODER AND CLAMPING IS REQUIRED TO PREVENT BUNDLES RUBBING ON TIE BAR (65B54203).

LOOKING UP, AFT & OUTB'D (SCALE: NONE)

BOND GRDS THIS AREA PER BAC 5117 FIGURE 2