FUSELAGE

9/28
"STR1"
"My Documents"

Red Zone Fuselage Pieces: Fracture Directions / Deformations

Longitudinal fractures through rivet lines were examined for evidence of "net area tension" (direct circumferential tension, crack initiation equally from both sides of the rivet holes). The area with the most predominant features of net area tension was on the right side of the fuselage, between pieces RF95 (green zone) and LF6A (red zone), along stringer S40R, and at the aft end of the forward cargo bay (forward of FS 1000 to about FS 940). This area is indicated by the solid red line in the accompanying drawing. A second area with possible net area tension was found on the left side of the fuselage, at the lower end of piece LF5, along stringer S34L and between FS 820 and 900. It was noted that the skin in this area was separated along the lower rivet line of the lap joint, through the underlying skin piece, and that the lower end of the upper skin piece was deformed outward over much of this area. This area is indicated by a dashed red line in the accompanying drawing.

DRAWINGS 1, 2

Crack directions in the skin were determined where ever possible, based on the rivet-to-rivet fracture pattern, separations in the shear ties, etc. The directions of skin cracking, where determined, are indicated by the red arrows in the accompanying drawing. (DRAWING 1, 2)

Several pieces of belly skin (LF24A and LF24B) from the left side of the fuselage were totally separated from the frame shear ties and stringers.

Many of the red zone pieces exhibited peeling deformation to the skin, The direction of peeling was determined to be as if the pieces were moving away from the fuselage, with the final point of separation being the end of the curl in the peeled area. This point generally had the greatest amount of deformation. The points at the ends of peels are indicated by red dots in the accompanying drawing. The extent of the peel area is indicated by the grouping of red lines associated with the red dots. On pieces where the peeling extended to an edge instead of a point, multiple red dots were used. Only two pieces (RF1 and LF5) that were located below the window belt level contained peels. These pieces were nearly symmetric in appearance and were peeled up and aft into the window belt.

(DRAWING 1, 2)

Both window belts and skin above the belts contained compression buckling deformation from compression loads in the longitudinal direction. In the skin above the belts, the compression damage was generally more severe adjacent to the belts and extended upward almost to the top of the fuselage. On the right side, the compression in the window belt extended from the aft side of the R2 passenger door (FS860) to FS960. The skin compression damage on the right side extended upward from this portion of the window belt approximately to the top of piece RF35 (stringer S6R). On the left side, the compression damage in the window belt extended from the aft side of door L2.

Both window belts and skin above the belts contained compression buckling deformation from compression loads in the longitudinal direction. In the skin above the belts, the compression damage was generally more severe adjacent to the belts and extended upward almost to the top of the fuselage. On the right side, the compression in the window belt extended from the aft side of the R2 passenger door (FS860) to FS960. The skin compression damage on the right side extended upward from this portion of the window belt approximately to the top of piece RF35 (stringer S6R). On the left side, the compression damage in the window belt extended from the aft side of door L2.

Many of the red zone pieces above the window belts contained peeling deformation on one corner or edge of the piece. The major exception was piece RF35, which had a large amount of compression damage. The peeling damage appeared to be sequential from the top and aft sides of piece RF 35 (peeling in pieces RF21, RF20, RF19, and RF46) across the top of the airplane and down the left side (peeling in pieces LF74 and then LF12A) to the left window belt piece (LF12B).

Because of the complex fracture pattern on the red zone pieces on the lower right side of the fuselage, the fracture locations in this area were plotted on a slightly larger scale (see attached drawing). (DRAWING 3)

Major longitudinal fractures in the green zone pieces (aft of the red zone pieces) were also examined for evidence of net area tension, and no such areas were found. All examined fractures that progressed along rivet lines were running fractures, mostly in the aft direction. (DRAWING 4 and 5)

J F Wildey II
NTSB

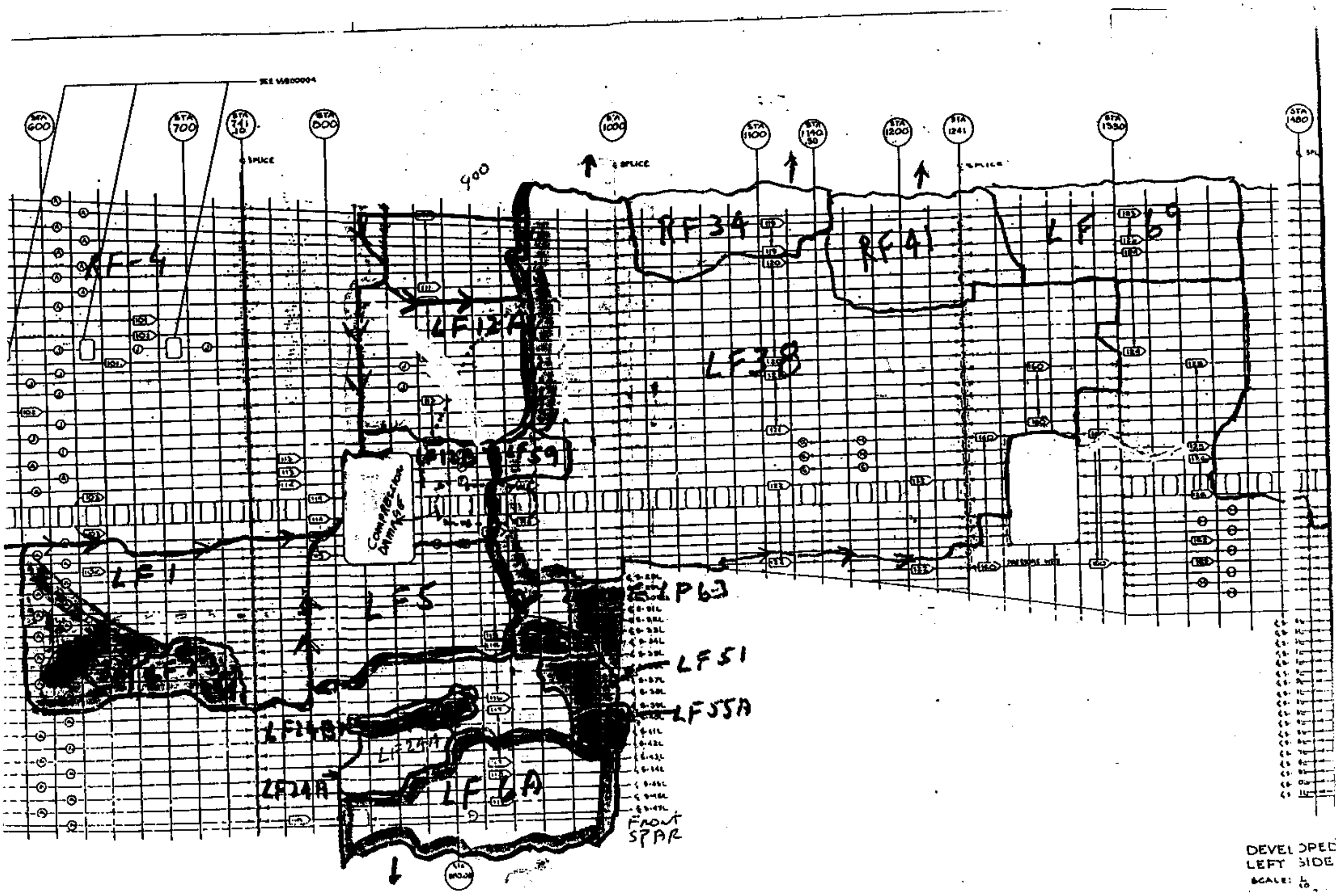
[signature]
GEORGE FLEIS
BOEING

oct '96

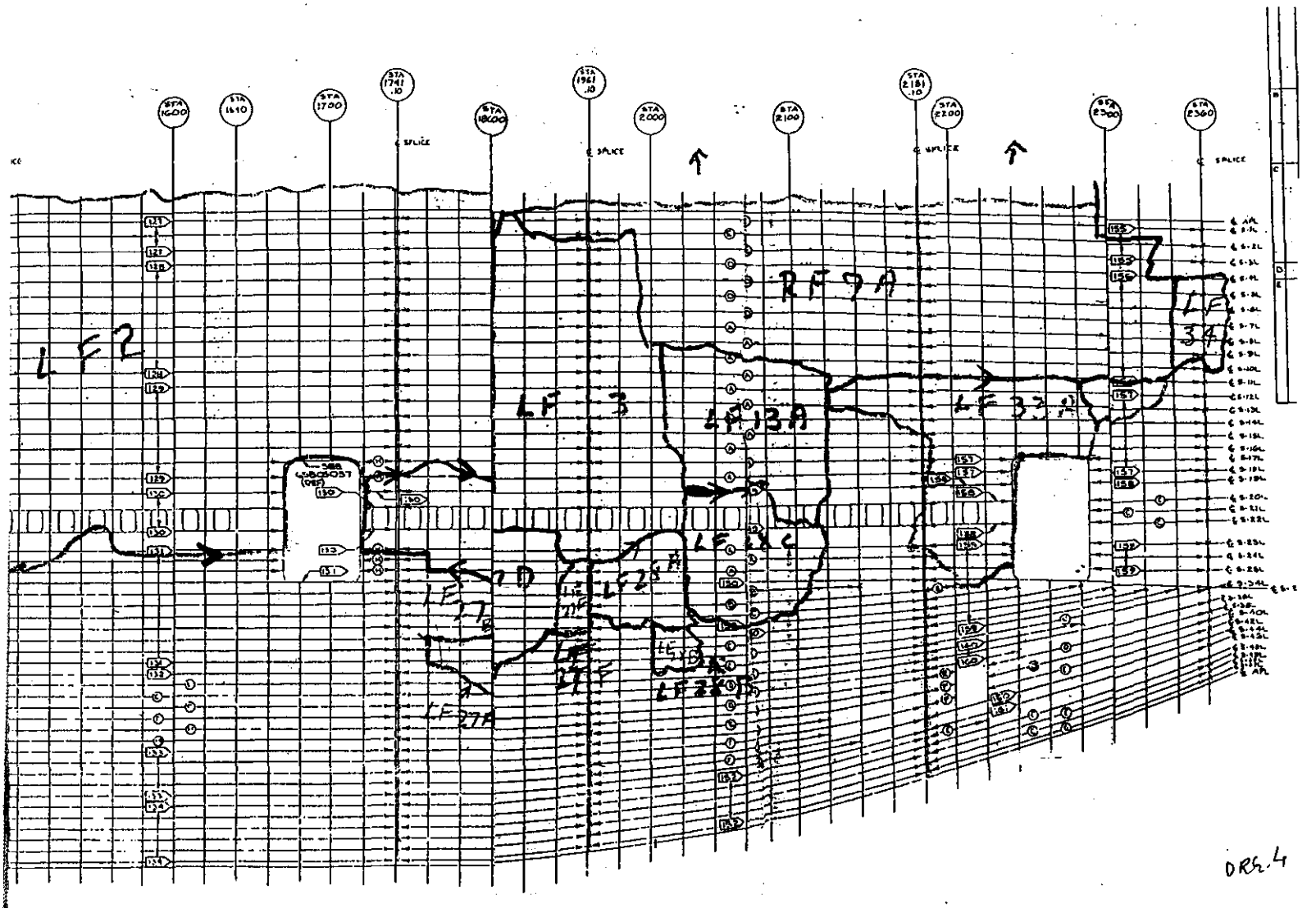
[signature]
ALPA Pgs 1-2
Drwgs 1-5

Ronald Brackett
I.A.M.

Stephen F. Klapacll Sr.
FAA 10-29-96



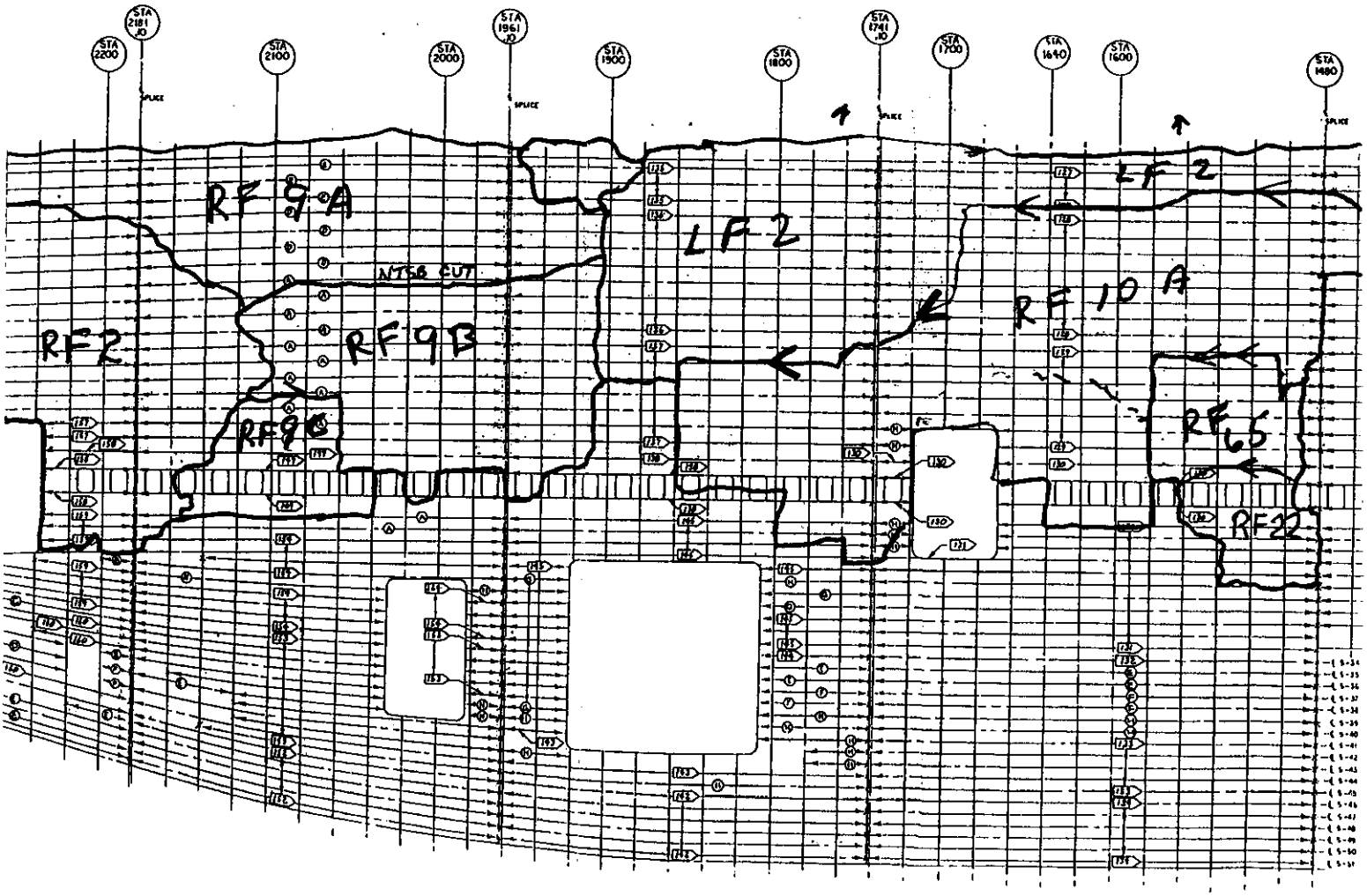
DEVELOPED
LEFT SIDE
SCALE: 1/10

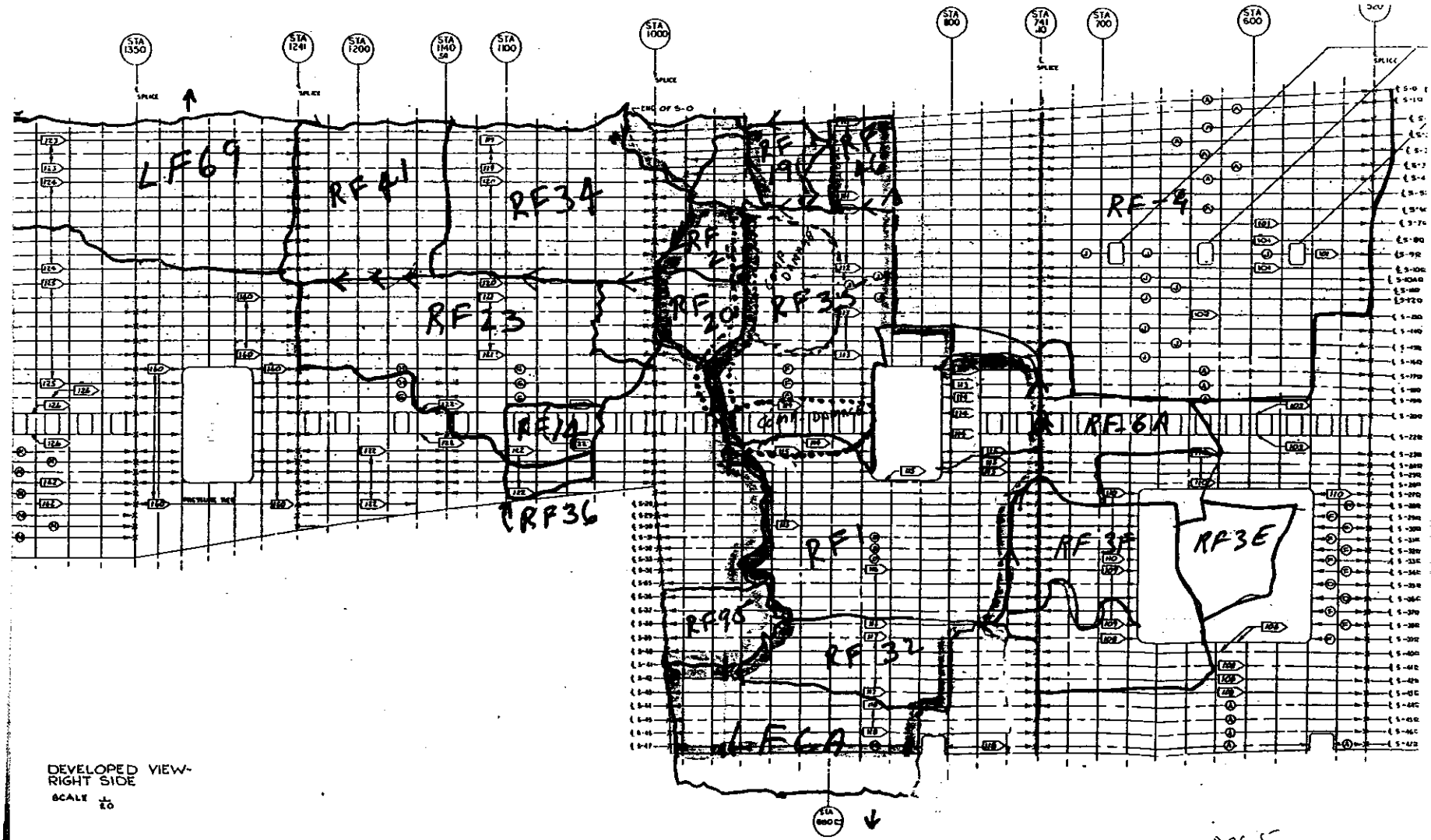


DRG. 4

VIEW-

747

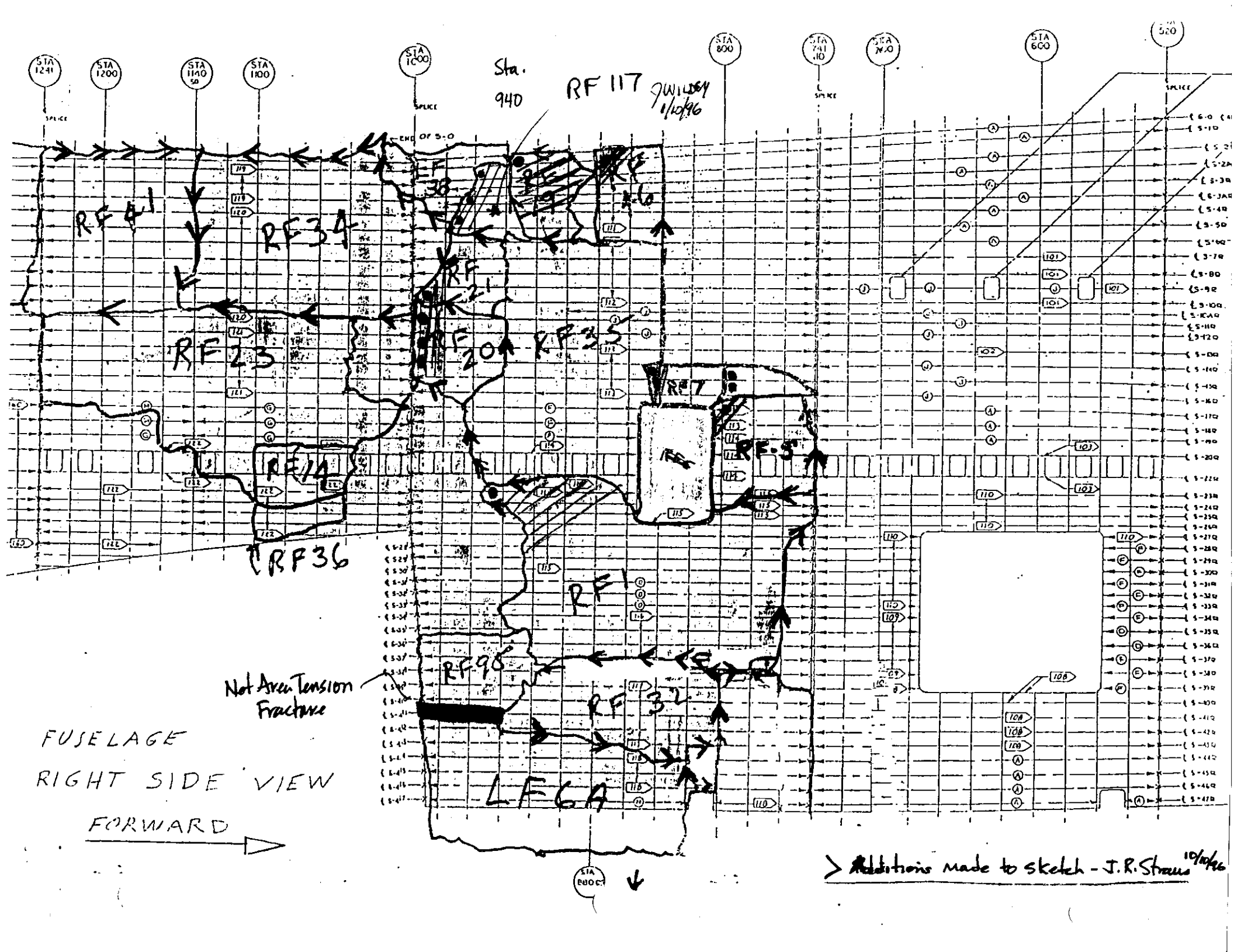

STA 2200
STA 2181.10
STA 2100
STA 2000
STA 1961.10
STA 1900
STA 1800
STA 1741.10
STA 1700
STA 1640
STA 1600
STA 1480
SPLICE
RF 9A
RF2
NTSB CUT
RF9B
RF9C
LF2
RF10A
RF6
RF22

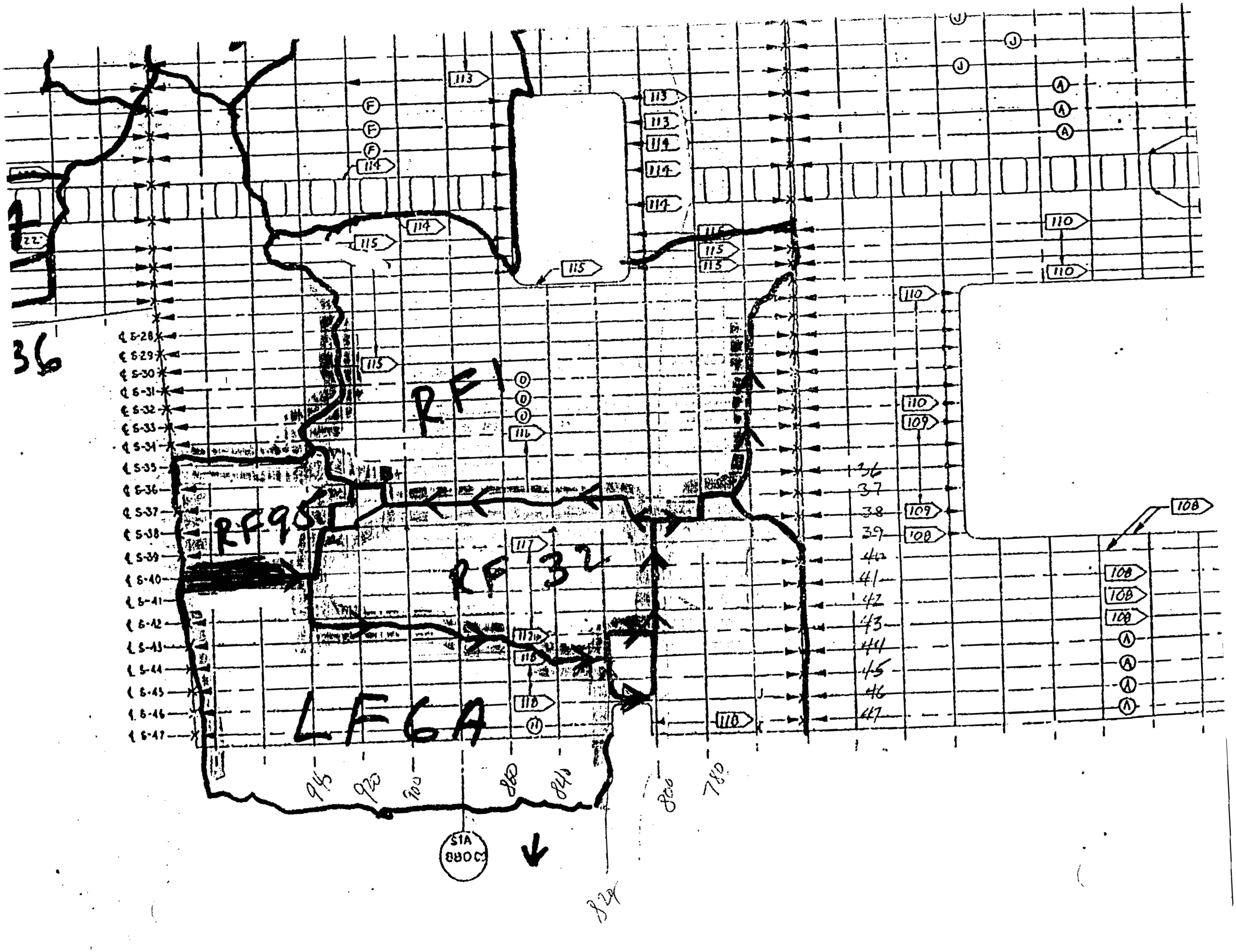


DEVELOPED VIEW-
RIGHT SIDE

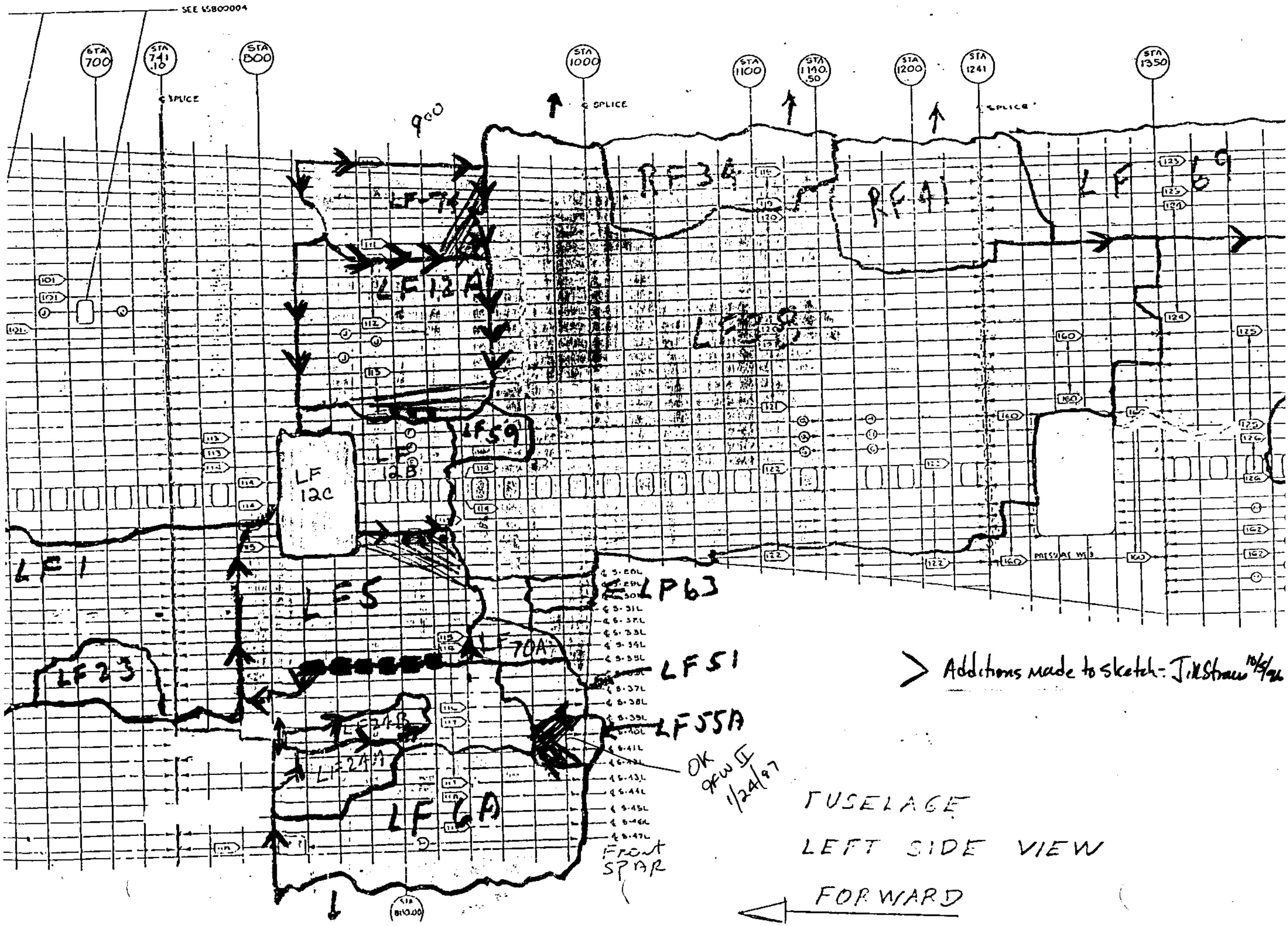
SCALE 1/2

DRG. 5


STA 1241
STA 1200
STA 1140 50
STA 1100
STA 1000
STA 800
STA 741 .10
STA 700
STA 600
STA 520
SPLICE
END OF S-0
Sta. 940
RF 117
J WILSON 11/10/96
RF 41
RF 34
RF 23
RF 14
RF 36
RF 21
RF 20
RF 35
RF 7
RF 5
RF 1
RF 96
RF 32
LFC6A
Not Area Tension Fracture
FUSELAGE
RIGHT SIDE VIEW
FORWARD
STA 880 C
> Additions made to sketch - J.R. Straus 10/10/96



RF1
RF32
RF98
LFGA
36
STA 880C
℄ S-28
℄ S-29
℄ S-30
℄ S-31
℄ S-32
℄ S-33
℄ S-34
℄ S-35
℄ S-36
℄ S-37
℄ S-38
℄ S-39
℄ S-40
℄ S-41
℄ S-42
℄ S-43
℄ S-44
℄ S-45
℄ S-46
℄ S-47
36
37
38
39
40
41
42
43
44
45
46
47
945
920
900
880
840
800
780
824
108
109
110
113
114
115
116
117
118



> Additions made to sketch - Jill Strauss 10/5/96

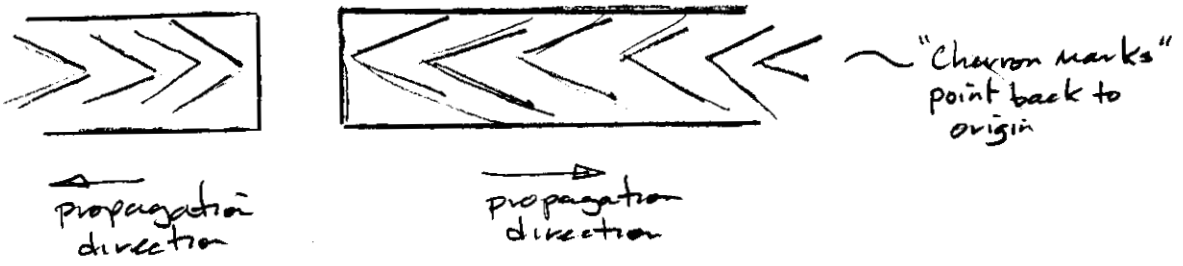
FUSELAGE

LEFT SIDE VIEW

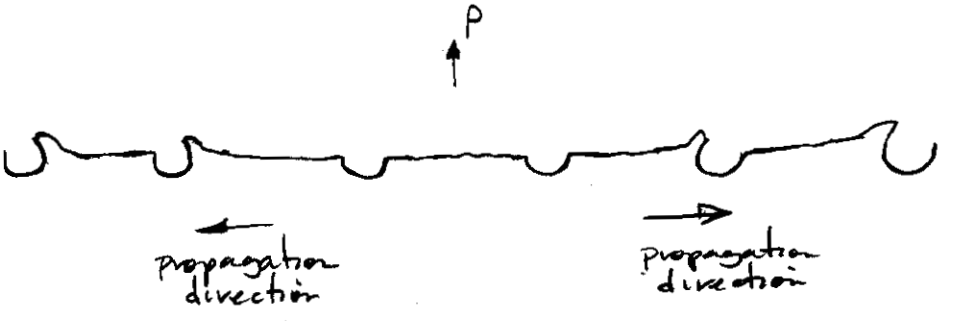
FORWARD

Determining Fracture Directions

- Fracture direction can be determined using the following methods
  - Thick Structure - evidence of chevron marks indicating direction



  - Thin Structure - hole to hole fracture profile. Viewing the fracture profile of a cracking running through a series of fastener holes.



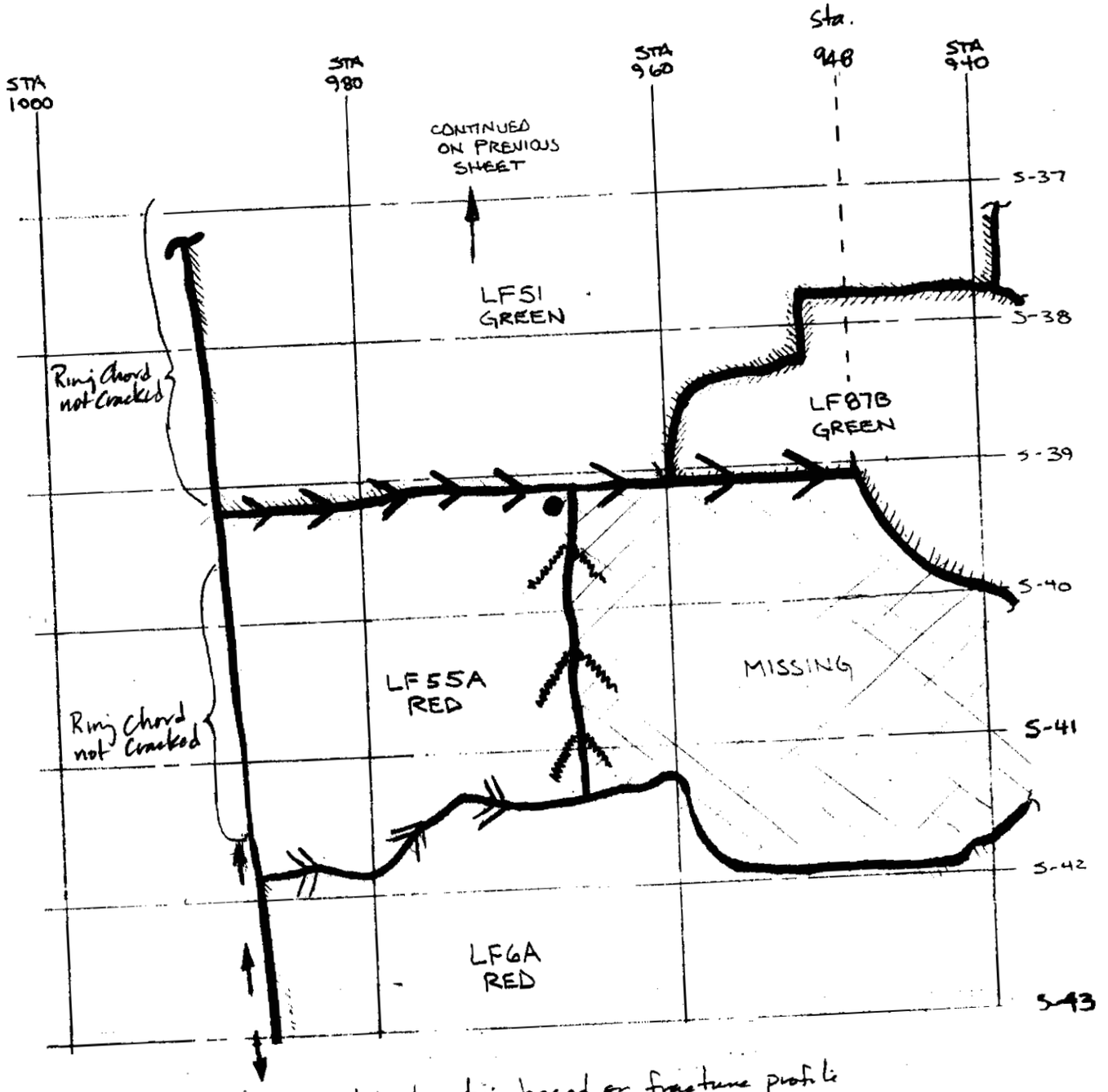
  - Peeling deformation - final separation point being the end of the curl in the peeled area. (Most common in thin structure).

The left side fuselage pieces forward of the underwing bulkhead (AKA Smiley face bulkhead) from S-26L to S-43L were examined to determine the fracture propagation direction. The three previously decribed methods of determining fracture direction were employed. The thickness of the skins was such that Chevron marks were not readily apparent; however, the thicker ring/chord did reveal some chevrons aiding in the determination of crack propagation directions in the circumferential direction (these are noted in the attached sketches by ⟶). Most fuselage pieces in this area did not fracture along a row of fasteners and were severely distorted* resulting in no possible method of determining fracture propagation direction. Fuselage pieces LF55A, LF51, LF87B LF89, and LF24B all contained a recognizable fracture path along a row of fasteners. The fracture propagation directions for these pieces is shown in the attached sketches. Examination of LF55A, LF51 and LF87B revealed that the ductile fracture grew down the underwing bulkhead at LBL 66.65 through the ring/chord and forward along the S-39L rivet line to station 948. At this point the fracture no longer followed the S-39L fastener row, thus providing no concrete evidence of continued forward propagation. AFT propagating fractures were observed in the following locations: at S-40L from Station 800-816, at S-39L from Station 820-880, at S-38L from Sta. 886-935, at S-37L from Sta. 840-860, at S-36L from Sta. 886-900, and at S-35L from Sta. 902-920.

JCWH 1/24/97

J.R. Strauss 11/15/96

* No consistent peeling deformation was present in these small pieces.



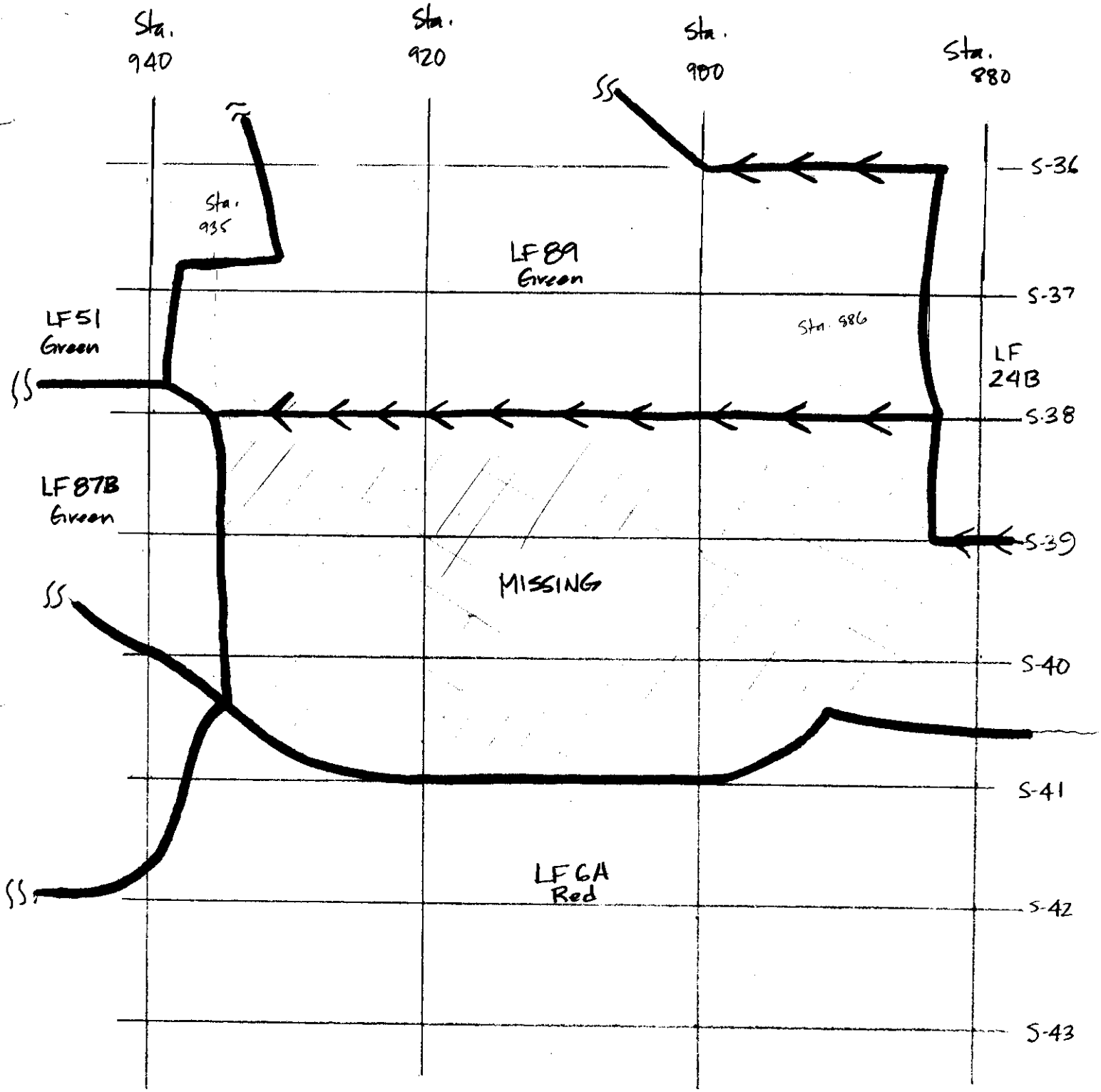
› Fracture propagation direction based on fracture profile through a number of fastener holes.

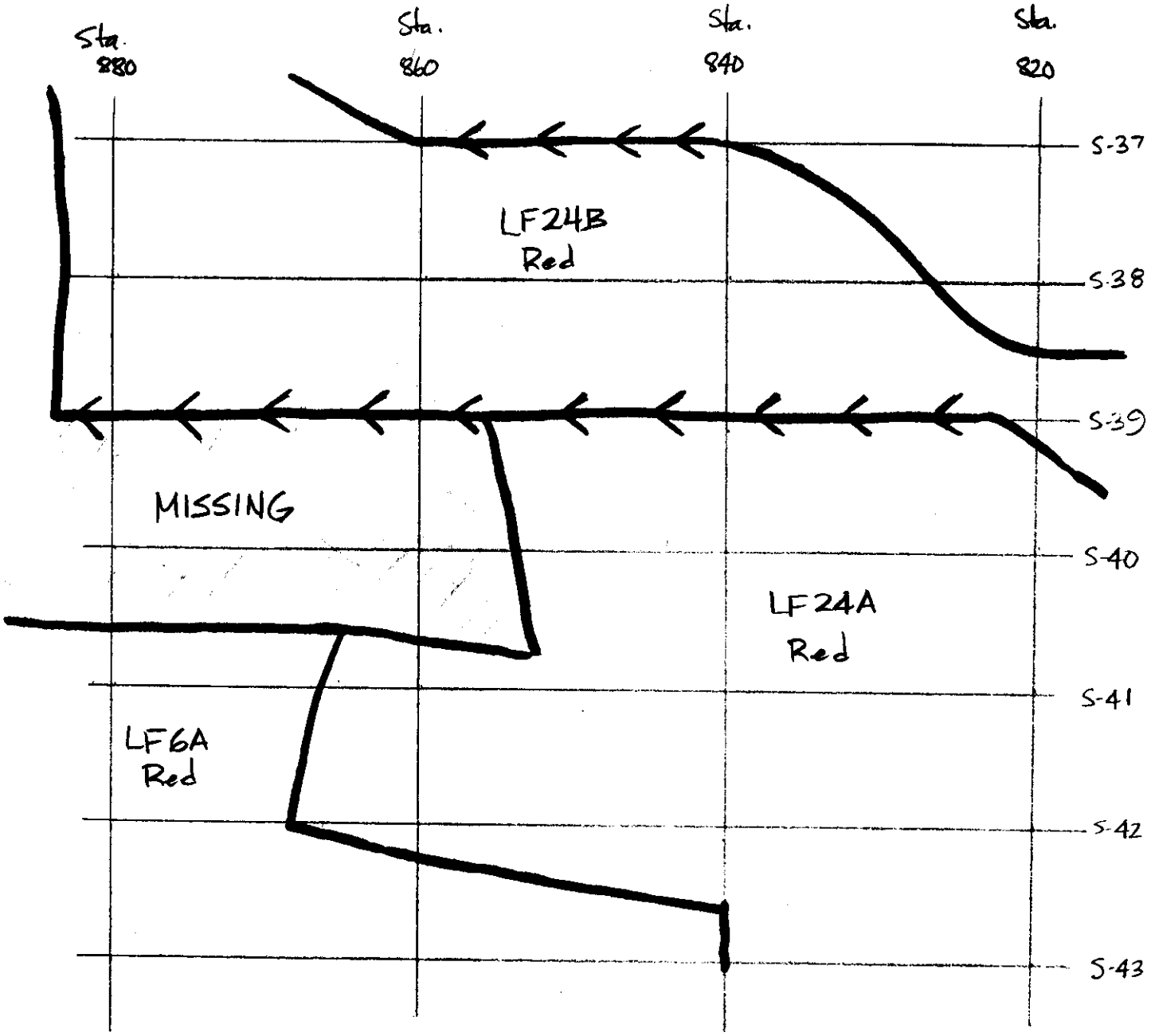
» Fracture direction documented by J. Widely & G. Fleis.

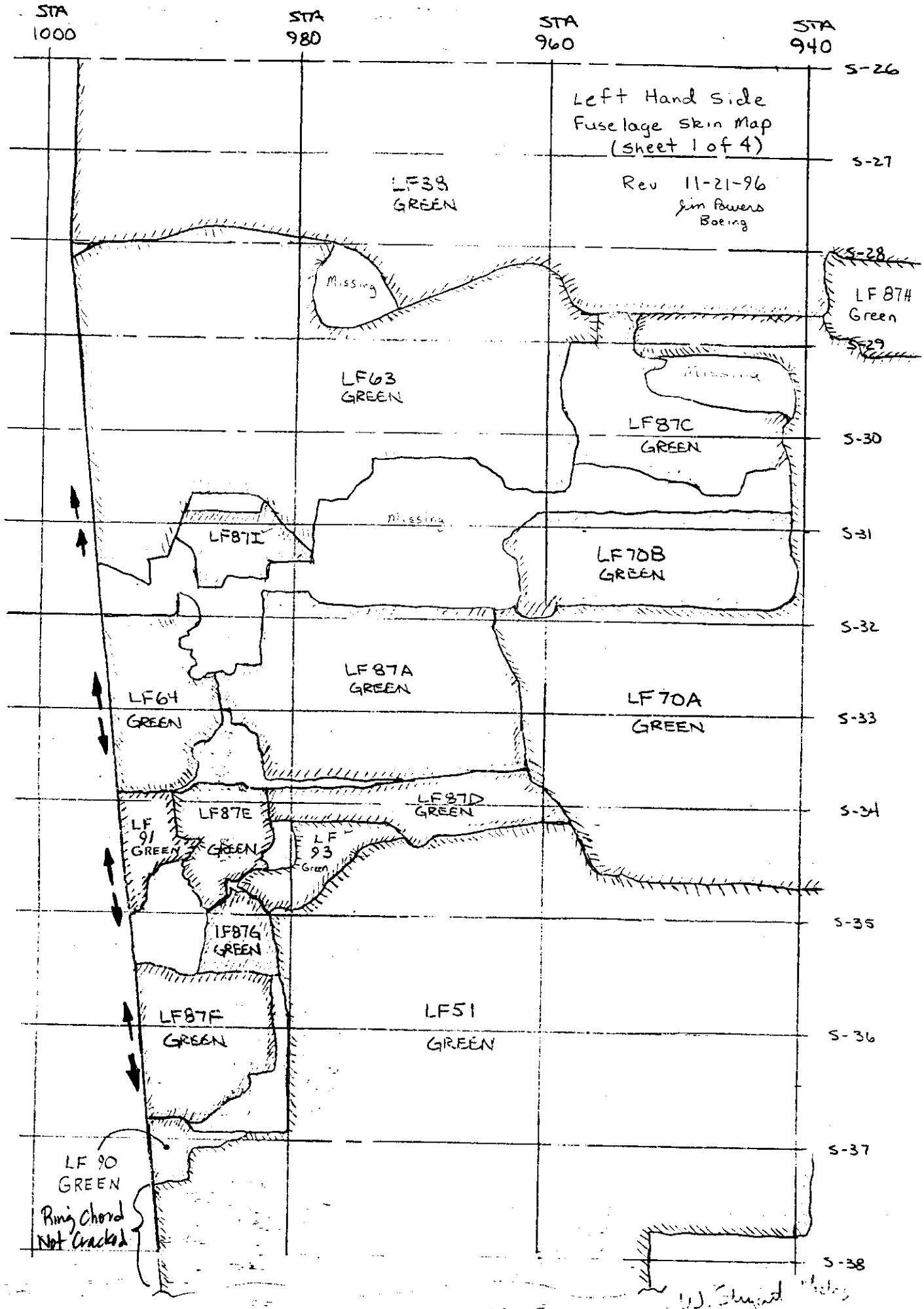
⟩ Fracture direction based on extension of fracture path confirmed as above and peeling deformation observed. Final separation point being the end of the curl in the peeled area.

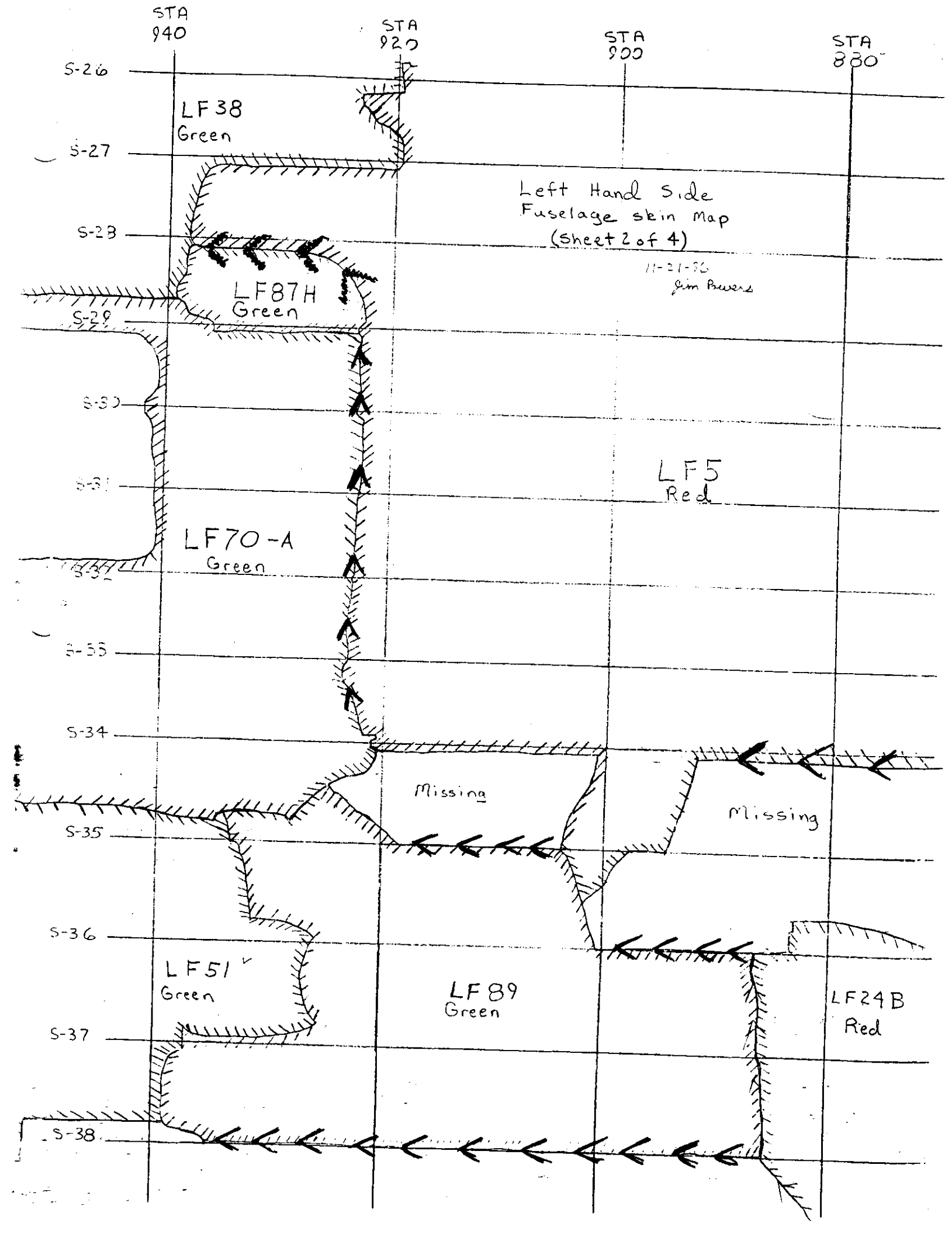
● End of curl in a peeled area

→ Fracture direction in ring chord based on macroscopic fracture features ("chevrons").


Sta. 940
Sta. 920
Sta. 900
Sta. 880
Sta. 935
Sta. 886
S-36
S-37
S-38
S-39
S-40
S-41
S-42
S-43
LF 89 Green
LF 51 Green
LF 24B
LF 87B Green
MISSING
LF 6A Red


Sta. 880
Sta. 860
Sta. 840
Sta. 820
S-37
S-38
S-39
S-40
S-41
S-42
S-43
LF24B Red
MISSING
LF24A Red
LF6A Red


STA 1000
STA 980
STA 960
STA 940
S-26
S-27
S-28
S-29
S-30
S-31
S-32
S-33
S-34
S-35
S-36
S-37
S-38
Left Hand Side
Fuselage Skin Map
(sheet 1 of 4)
Rev 11-21-96
Jim Bowers
Boeing
LF38
GREEN
Missing
LF 87H
Green
LF63
GREEN
LF87C
GREEN
LF87I
LF70B
GREEN
LF87A
GREEN
LF64
GREEN
LF70A
GREEN
LF87D
GREEN
LF87E
LF
91
GREEN
GREEN
LF
93
Green
LF87G
GREEN
LF87F
GREEN
LF51
GREEN
LF 90
GREEN
Ring Chord
Not Cracked
W.J. Stuart
Rev 11-

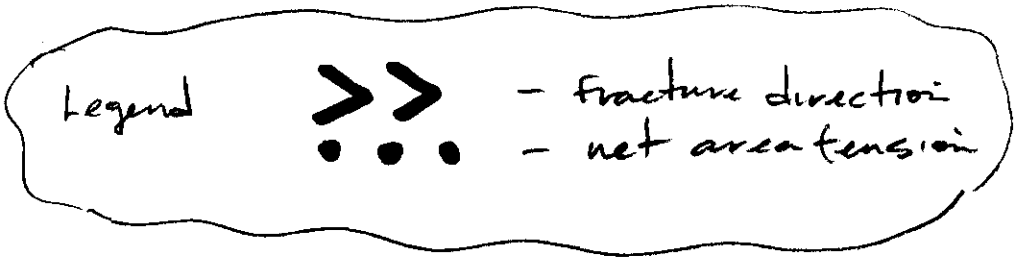

STA 940
STA 920
STA 900
STA 880
S-26
S-27
S-28
S-29
S-30
S-31
S-32
S-33
S-34
S-35
S-36
S-37
S-38
LF38
Green
LF87H
Green
LF70-A
Green
LF5
Red
LF51
Green
LF89
Green
LF24B
Red
Missing
Missing
Left Hand Side
Fuselage skin Map
(Sheet 2 of 4)
11-21-86
Jim Powers

Fracture Direction Documentation - Red Zone (Supplement)

The following sketches are intended to supplement the original fracture direction maps generated by Jim Wildey and George Fleis on 9/28/96. The maps contain fuselage pieces recovered since the original documentation as well as a more accurate description of their size and location. Many of the directions were previously documented but are included because they were re-confirmed.

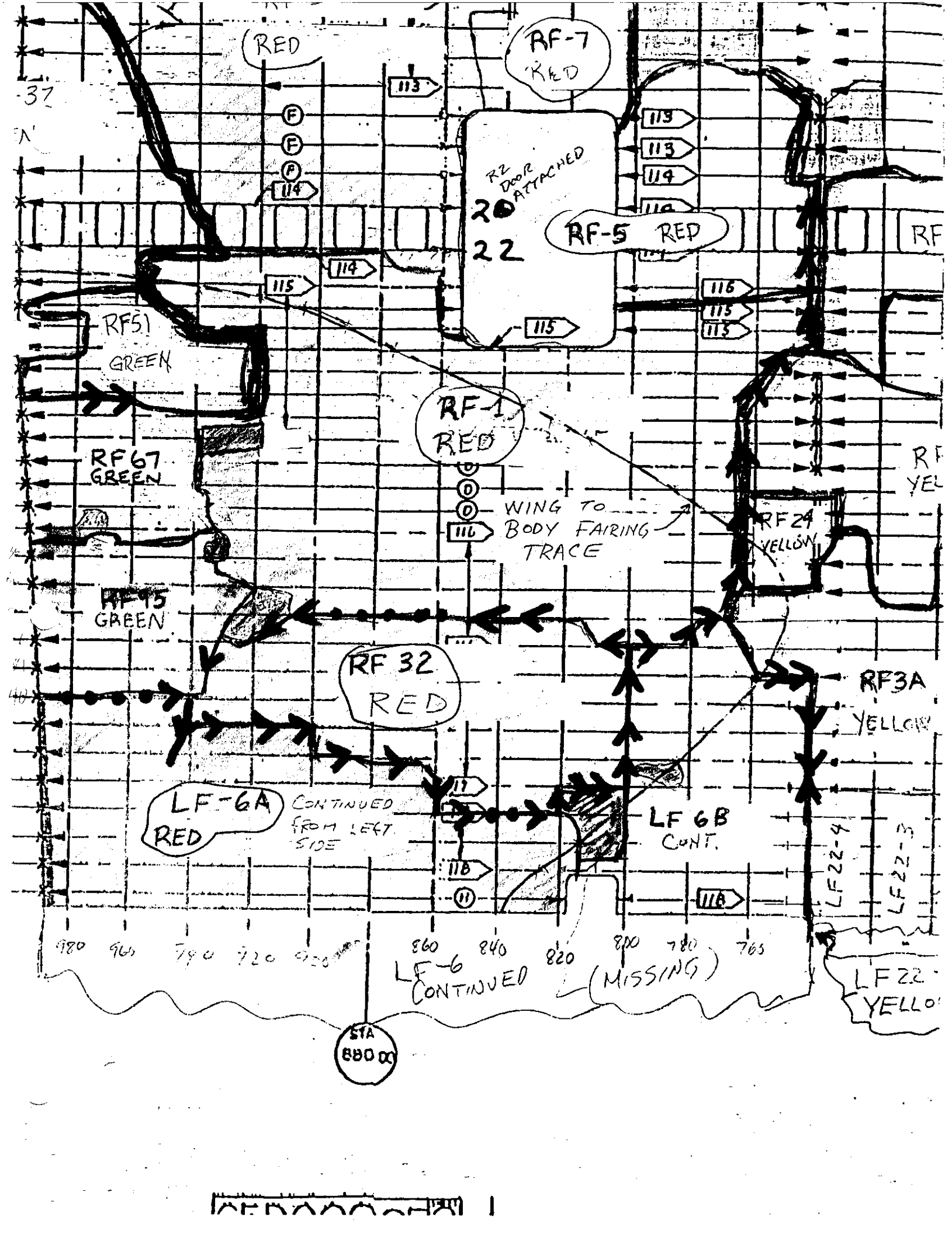
Two additional areas of net area tension through the longitudinal fastener line were observed along S-37R from Station 850-900 and along S-44R from Station 830-840. Unlike the previously documented areas containing net area tension, the fracture directions leading to and departing from these newly identified areas of net area tension were the same.

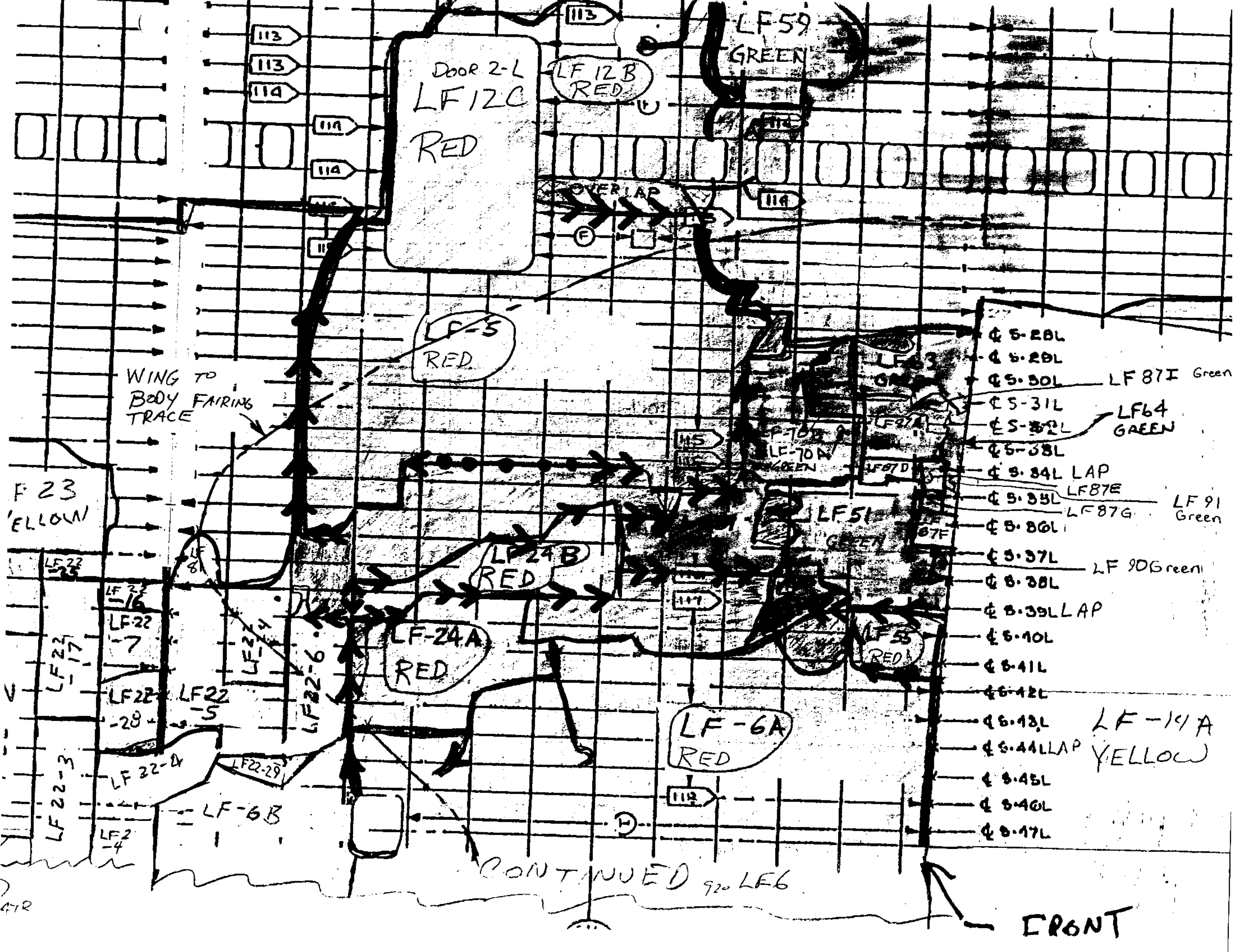
J.R. Straus 11/19/96

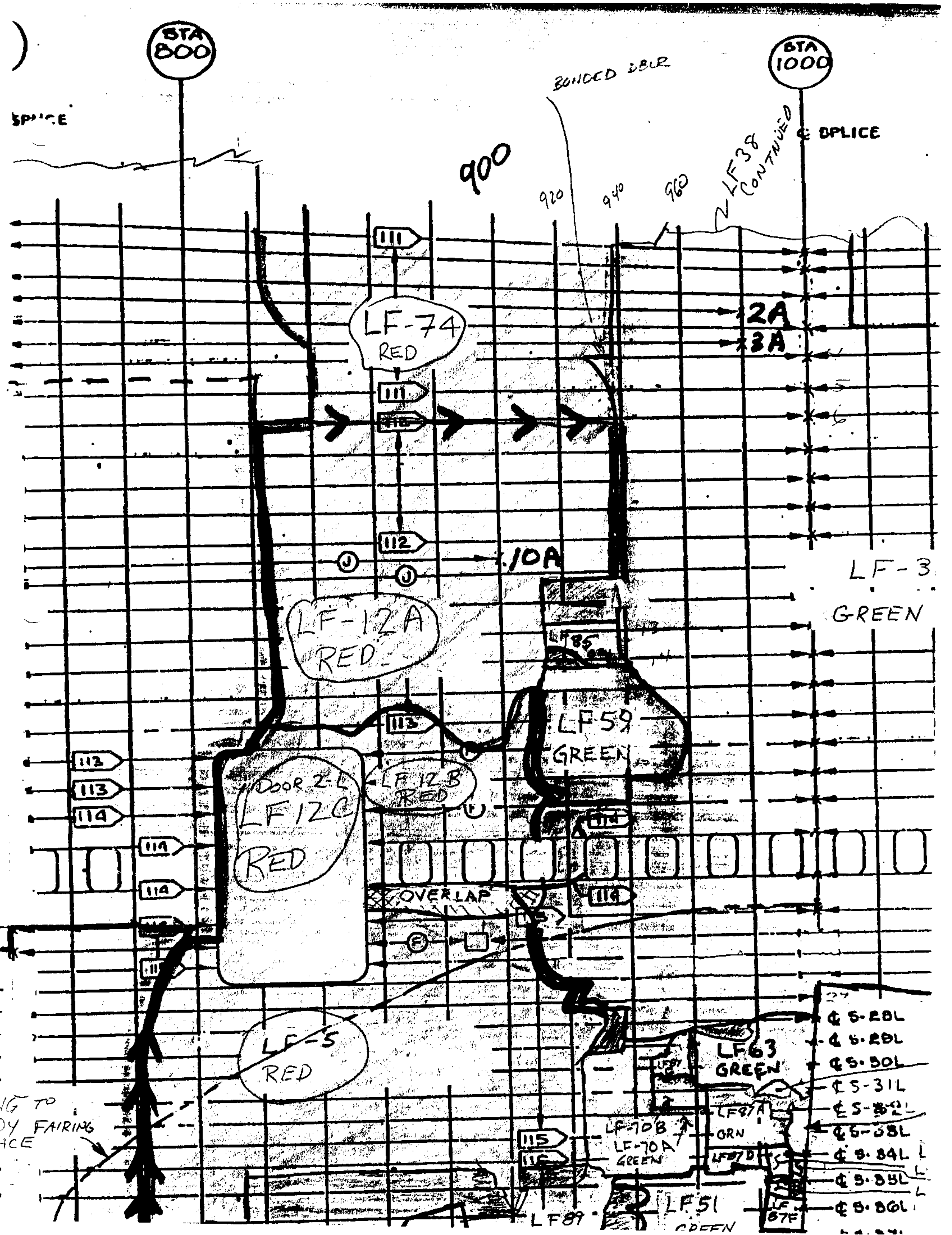


OK: But see Sequencing Group Report For Final Definition Of NetArea Tension And Fracture Directions In Red Area Pieces

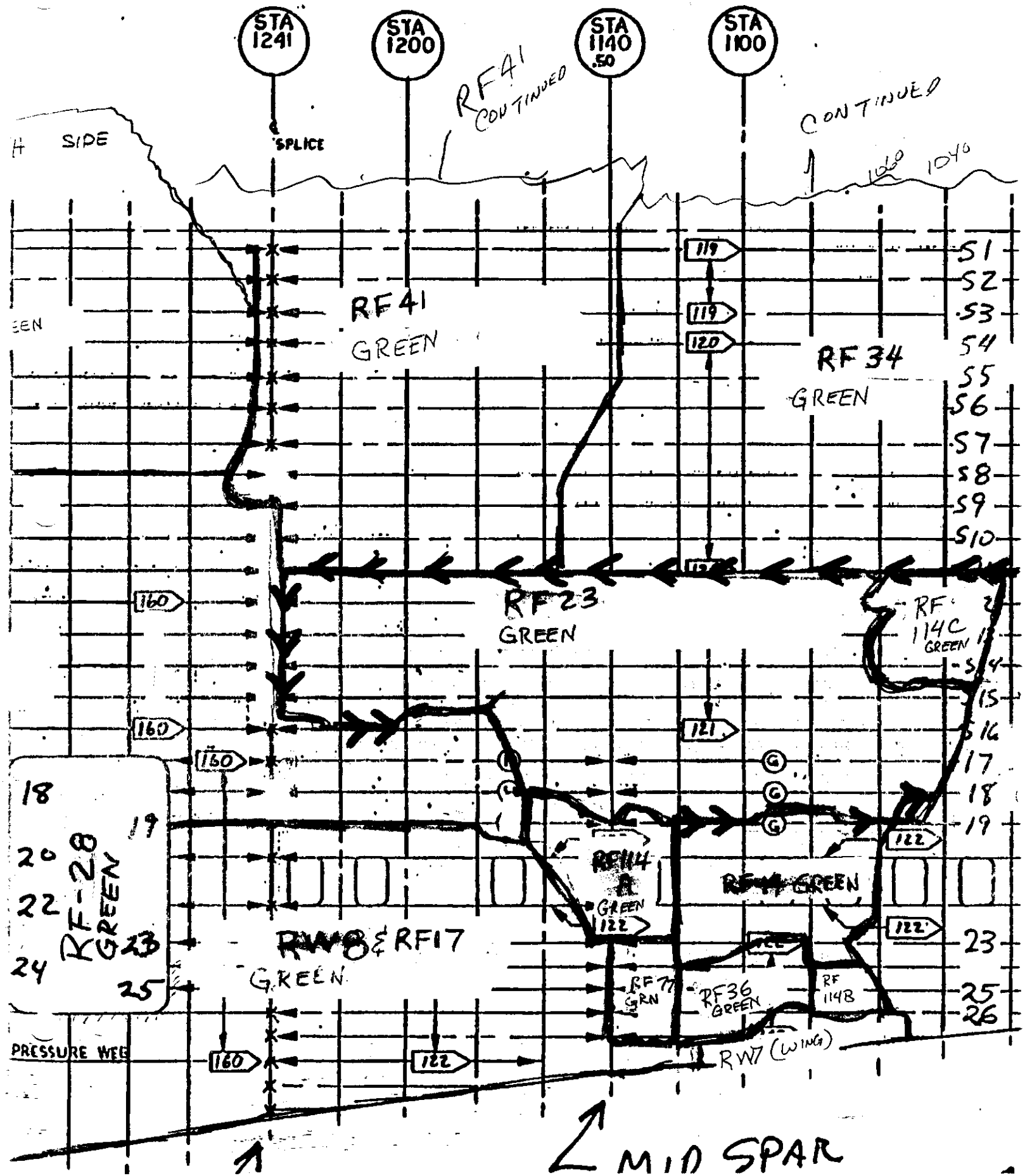
Jim Wildey 1/24/97

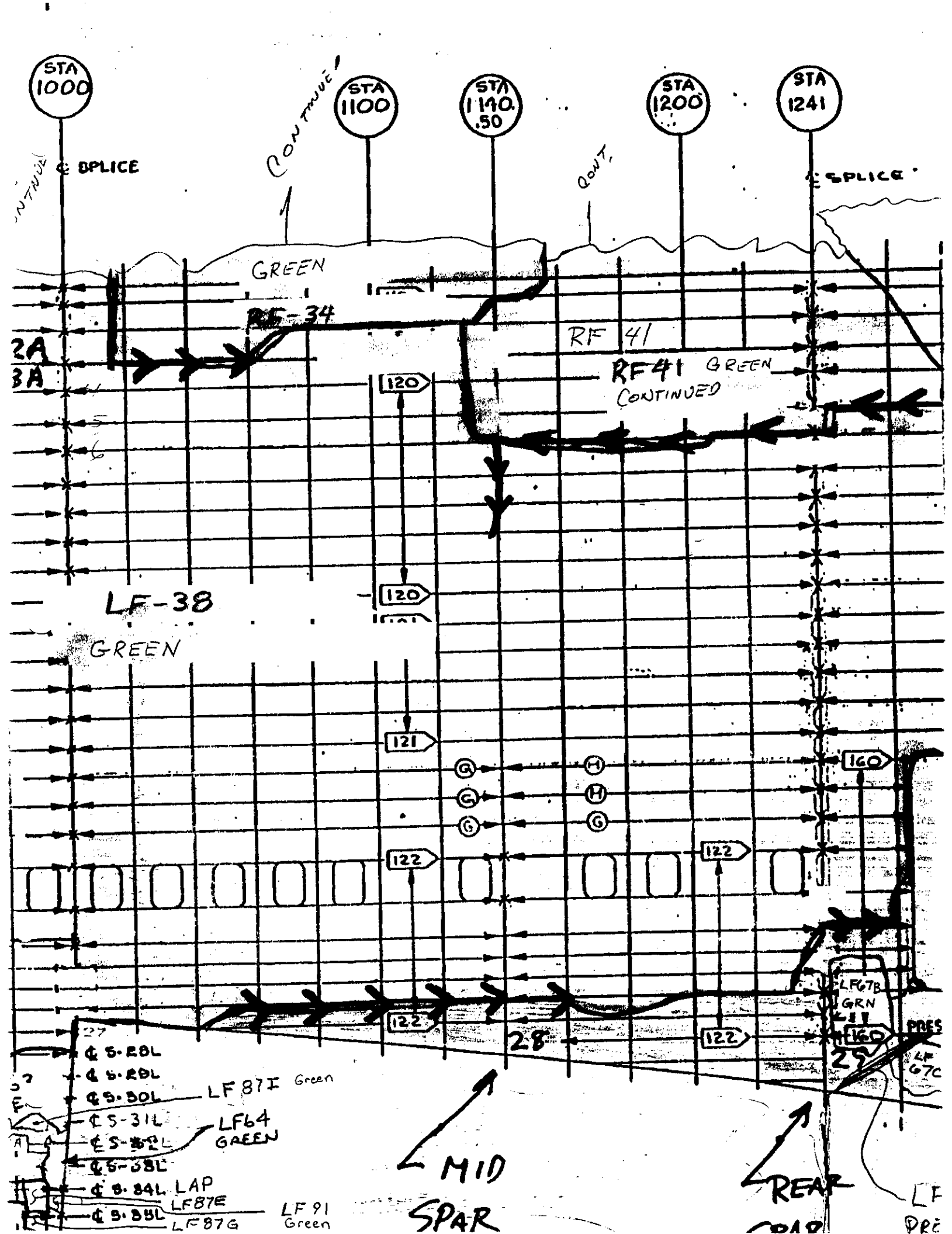

RED
RF-7
RED
113
F
F
F
114
R2 DOOR ATTACHED
20
22
RF-5 RED
113
113
114
115
114
115
116
115
115
RF51
GREEN
RF-1
RED
RF67
GREEN
D
D
116
WING TO BODY FAIRING TRACE
RF 24
YELLOW
RF95
GREEN
RF 32
RED
RF3A
YELLOW
11
LF-6A
RED
CONTINUED FROM LEFT SIDE
LF 6B
CONT.
116
11
118
LF22-4
LF22-3
980
960
940
920
860
840
820
800
780
760
LF-6
CONTINUED
(MISSING)
LF22
YELLO
STA
880 00

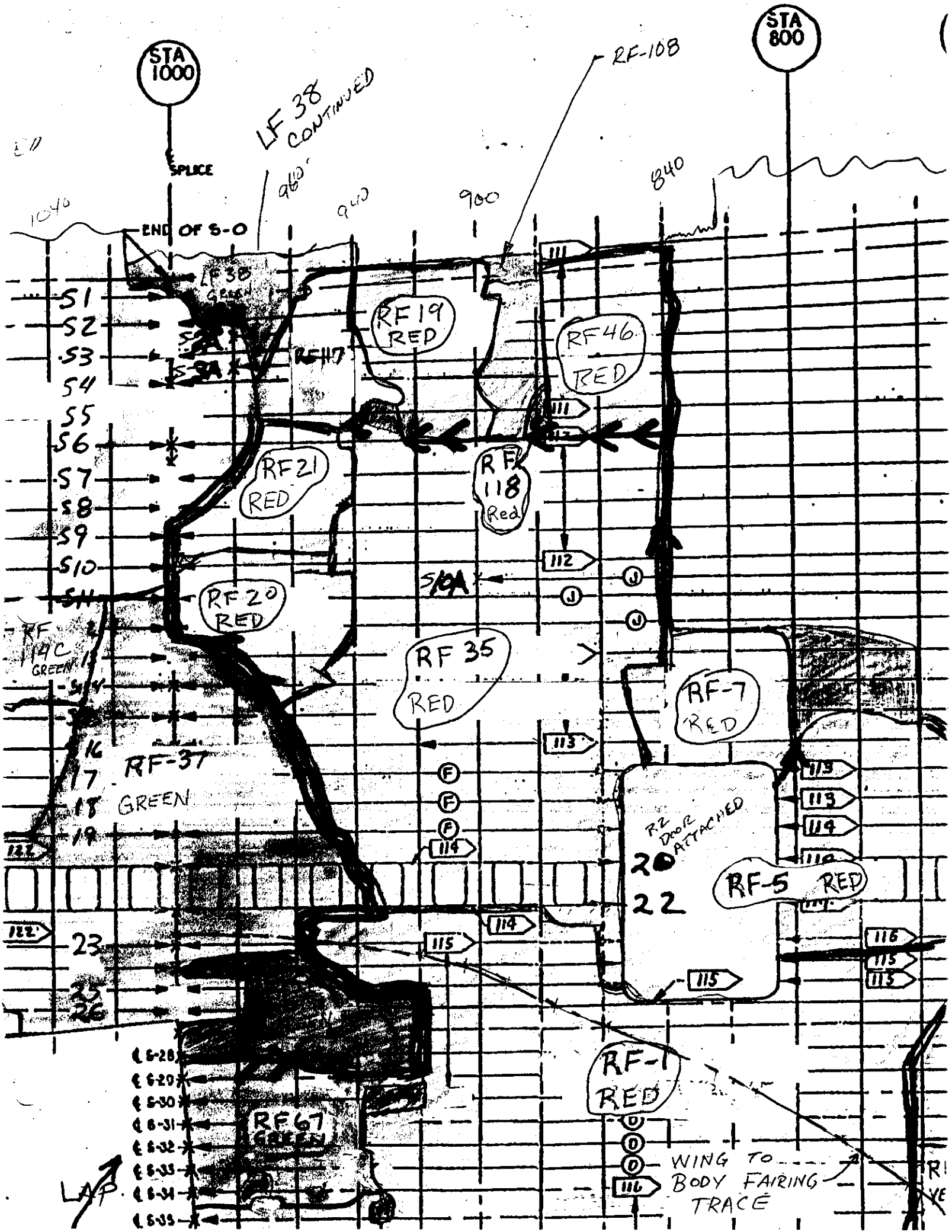

Door 2-L
LF12C
RED
LF 12B
RED
LF59
GREEN
OVERLAP
LF-5
RED
WING TO
BODY FAIRING
TRACE
LF 23
YELLOW
LF 81
LF24B
RED
LF-24A
RED
LF51
GREEN
LF55
RED
LF-6A
RED
LF-6B
LF 22-25
LF 22-16
LF22-7
LF22-17
LF22-28
LF22-5
LF22-6
LF22-4
LF 22-3
LF 22-29
LF2-4
LF-70A
GREEN
LF87D
LF87A
87F
¢ S-28L
¢ S-29L
¢ S-30L
¢ S-31L
¢ S-32L
¢ S-33L
¢ S-34L LAP
¢ S-35L
¢ S-36L
¢ S-37L
¢ S-38L
¢ S-39L LAP
¢ S-40L
¢ S-41L
¢ S-42L
¢ S-43L
¢ S-44L LAP
¢ S-45L
¢ S-46L
¢ S-47L
LF 87I Green
LF64
GREEN
LF87E
LF87G
LF 91
Green
LF 90Green
LF-14A
YELLOW
CONTINUED 920 LF6
FRONT
113
113
113
114
114
114
115
115
117
112


STA 800
STA 1000
SPLICE
BONDED DBLR
900
920
940
960
LF38 CONTINUED
℄ SPLICE
111
LF-74
RED
2A
3A
5
6
111
112
10A
LF-3
GREEN
LF-12A
RED
LF85
LF59
GREEN
113
113
113
114
DOOR 2-L
LF12C
RED
LF 12B
RED
114
114
114
OVERLAP
114
LF-5
RED
FAIRING
℄ S-28L
℄ S-29L
℄ S-30L
℄ S-31L
℄ S-32L
℄ S-33L
℄ S-34L
℄ S-35L
℄ S-36L
LF63
GREEN
LF87A
ORN
LF87D
LF-70B
LF-70A
GREEN
115
116
LF89
LF51
LF 87F

SIDE


STA 1241
STA 1200
STA 1140 .50
STA 1100
RF41 CONTINUED
CONTINUED
SPLICE
RF41 GREEN
RF34 GREEN
RF23 GREEN
RF 114C GREEN
RF-28 GREEN
RW8 & RF17 GREEN
RF114 A GREEN
RF 114 GREEN
RF77 GRN
RF36 GREEN
RF 114B
RW7 (WING)
PRESSURE WEB
MID SPAR
119
120
121
122
160


STA 1000
STA 1100
STA 1140.50
STA 1200
STA 1241
℄ SPLICE
CONTINUE
CONT.
℄ SPLICE
GREEN
RF-34
RF 41
RF41 GREEN CONTINUED
2A
3A
120
120
LF-38
GREEN
121
122
122
122
122
160
160
LF67B GRN
PRES
LF 67C
27
28
29
℄ 5.28L
℄ 5.28L
℄ 5.30L
LF 87I Green
℄ 5-31L
LF64 GREEN
℄ 5-38L
℄ 5.84L LAP
LF87E
℄ 5.85L
LF87G
LF 91 Green
MID SPAR
REAR SPAR
LF
PRE


STA 1000
STA 800
LF 38 CONTINUED
SPLICE
END OF S-0
1040
980
940
900
840
RF-108
LF 38 GREEN
RF 19 RED
RF 46 RED
RF 21 RED
RF 118 Red
RF 20 RED
RF 14C GREEN
RF 35 RED
RF-7 RED
RF-37 GREEN
RZ DOOR ATTACHED
RF-5 RED
RF-1 RED
RF 67 GREEN
WING TO BODY FAIRING TRACE
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
16
17
18
19
20
22
23
25
26
111
112
113
114
115
116
119
S-28
S-29
S-30
S-31
S-32
S-33
S-34
S-35

Internal Overpressure Indication and Fracture Direction Survey

Objective: Survey all recovered fuselage structure noting on skin panel diagram areas which show indications of damage due to internal overpressurization.

> **Note: The following indications may not result solely from overpressure**

Indications of Internal Overpressure Damage

1) Outward uniform pillowing of skin in a frame/stringer bounded bay (Should be judged on the basis of more than one adjacent bay). Pillowing may not be obvious or even detectable in areas of thicker skin gage.

2) Generally symmetric skin dimpling at countersunk fasteners (partially or fully pulled through).

3) Stringers and/or frames pulled generally straight away from skin (as opposed to being twisted off laterally). There should be no obvious indications of stringer or frame crushing. Indications may include shear ties fractured in a tension clip mode.

4) Skin (typically minus substructure) fairly uniformly "rolled" or "curled" outward along some distance of the edge.

5) Net tension failure of the skin at horizontal fastener lines. [It's important to distinguish between in-plane overload (caused by internal overpressure) and out-of-plane overload (more typically due to break-up). In-plane overload will result in very uniform appearance of fastener holes and adjacent material from one side to the next in the direction of the fastener row. Out-of-plane overload (a tearing action) will cause out-of-plane deformations at the fastener holes and adjacent material along the fastener line. Note: net tension failures will normally only be in a hoop loading direction (i.e., along stringer fastener line)].

6) Stringers generally bent outward in a zone.

LENISE HIGHTOWER - TWA 12/12/96 (7 PAGES ATTACHED)

GEORGE FLEIS, BOEING

J. WILDEY II NTSB

NTSB.

FAA

OVERPRESSURE INDICATIONS

SEGMENT	APPROX. FUSELAGE STATION	INDICATIONS				
		Outward Pillowing	Symmetric Dimpling	Stringers or Frames Pulled Away	Skin Minus Substructure Curled Along Some Distance	Net Area Tension Failure
LF-1	680	X		X		
LF-2 (LH)	1680			X		
LF-2 (RH)	1680		X	X		
LF-3	1920	X	X	X		
LF-4	680					
LF-5	860			X	X	X
LF-6A	900			X		X
LF-7A	410					
LF-7B	480					
LF-7C	310					
LF-7D	240					

("X" denotes observation of indication)

OVERPRESSURE INDICATIONS

SEGMENT	APPROX. FUSELAGE STATION	INDICATIONS: Outward Pillowing	Symmetric Dimpling	Stringers or Frames Pulled Away	Skin Minus Substructure Curled Along Some Distance	Net Area Tension Failure
LF-12A	900			X (2)	X (1)	
LF-12B	880					
LF-12C	820					
LF-13A	2180		X	X		
LF-19A	460					
LF-19B	460					
LF-21	520					
LF-23	700	X	X	X		
LF-24A	820			X		
LF-24B	860			X		
LF-25	360		X	X		

("X" denotes observation of indication)

JRStraus 11/20/96

JCWH 11/23/97

(1) Skin curled outward from S-13L down.

(2) Frames are missing below S-12L, Stringers below 13L are missing from this panel but are contained on LF12B

JRStraus 11/20/96

OVERPRESSURE INDICATIONS

SEGMENT	APPROX. FUSELAGE STATION	INDICATIONS				
		Outward Pillowing	Symmetric Dimpling	Stringers or Frames Pulled Away	Skin Minus Substructure Curled Along Some Distance	Net Area Tension Failure
LF-26	2320					
LF-27A	1780		X	X		
LF-27B	1780	X	X	X		
LF-27C	1830	X	X	X		
LF-27D	1890	X	X	X		
LF-27E	1830	X	X	X		
LF-27F	1950	X	X	X		
LF-28A	1980	X	X	X		
LF-28C	2060	X	X	X		
LF-33A	2200		X	X		
LF-33B	2300			X		

("X" denotes observation of indication)

OVERPRESSURE INDICATIONS

SEGMENT	APPROX. FUSELAGE STATION	INDICATIONS: Outward Pillowing	Symmetric Dimpling	Stringers or Frames Pulled Away	Skin Minus Substructure Curled Along Some Distance	Net Area Tension Failure
LF-34	2400			X		
LF-38	1100			X		
LF-39A	1400					
LF-51	970		X	X		
LF-55A	1000		X	X	X	
LF-59	930		X	X		
LF-63	980	X		X		
LF-69	1350			X		
RF-1	860	X	X	X	X	X [2]
RF-2	2200			X		
RF-4	700					
LF-74	840-940		X (3)	X	X	
LF-89	890-940			X		

("X" denotes observation of indication)

(2) bottom edge

(3) Forward end (Sta. 840-820)

J.R. Straus 10/7/96
[signature]
JRStraus 11/17/96

OVERPRESSURE INDICATIONS

SEGMENT	APPROX. FUSELAGE STATION	INDICATIONS				
		Outward Pillowing	Symmetric Dimpling	Stringers or Frames Pulled Away	Skin Minus Substructure Curled Along Some Distance	Net Area Tension Failure
RF-5	770			X		
RF-7	820					
RF-8A & B	300	X	X	X	X	
RF-9A (LH)	2100		X	X		
RF-9A (RH)	2100		X	X		
RF-9B	2000			X		
RF-9C	2100		X	X		
RF-10A	1660		X	X		
RF-14	1080			X		
RF-15	2320		X	X		
RF-19A	920		X	X	X	

("X" denotes observation of indication)

OVERPRESSURE INDICATIONS

SEGMENT	APPROX. FUSELAGE STATION	INDICATIONS				
		Outward Pillowing	Symmetric Dimpling	Stringers or Frames Pulled Away	Skin Minus Substructure Curled Along Some Distance	Net Area Tension Failure
RF-19B	890		X	X	X	
RF-20	960		X	X		
RF-21	960		X	X		
RF-23	1120		X	X		
RF-27	2350		X	X		
RF-32	870			X	X (1)	X
RF-34	1050			X		
RF-35	900			X		
RF-36	1100			X	X	
RF-37	1000					
RF-38	1420					

J.R. Strauss 10/7/96

("X" denotes observation of indication)

(1) Top / FWD end Sta. 840 FWD

J.R. Strauss 10/7/96

OVERPRESSURE INDICATIONS

SEGMENT	APPROX. FUSELAGE STATION	INDICATIONS: Outward Pillowing	Symmetric Dimpling	Stringers or Frames Pulled Away	Skin Minus Substructure Curled Along Some Distance	Net Area Tension Failure
RF-41 (RH)	1200		X	X		
RF-41 (LH)	1200		X	X		
RF-42	1350				X[5]	
RF-46	860		X	X		
RF-51	960					
RF-65	1550	X	X	X		
RF-95	860			X(6)		X

("X" denotes observation of indication)

(5) corner only

RF 118	880			X		
RF 108	880			X	X	
RF 117	940-960		X	X	X	

JRStraus 11/17/96

J.R.Straus 10/7/96

JRStraus 11/17/96

(6) Stringer crushing damage is evident at S-37R, 36R, 35R from Sta. 960 FWD

1/24/97

Metallurgy Field Notes - Fuselage

The notes and shaded diagram of the skin of the airplane on the following pages reflect fractographic examination performed until the beginning of October 1996, and does not indicate all of the pieces that were examined at a later date. All of the fuselage skin and adjoining structure examined contained features characteristic of overstress separations except as noted in the fatigue section of this notebook.

5/30/97

Michael Marx, Supervisor Metallurgist

Metallurgy Group Notes - Fuselage

The purpose of this survey was to supplement the Structures notes by making detailed observations about the skin panel segments recovered in the red zone along with the yellow and green zone parts immediately forward and aft of the red zone. In addition, detailed observations were made about the Sta. 140 and Sta. 2360 bulkheads. When possible, modes of fracture (tension, compression, torsion, bending) as well as deformation directions and patterns were documented in each of the examined panels. Some fracture surfaces were also examined to determine if there was any evidence of pre-existing slow growth cracks (i.e. fatigue or stress corrosion) in these areas. This detailed data exists is the Structures Fuselage books as well.

The attached airplane fuselage maps give a running log of the pieces analyzed and to what extent. A high lighted line around the perimeter of the piece means the fracture surfaces have been examined with no evidence of any pre-existing slow growth cracks found. A completely high lighted orange section means that both general observations and all fracture surfaces were examined. A orange high lighted box around the ID implies that general observations were only made.

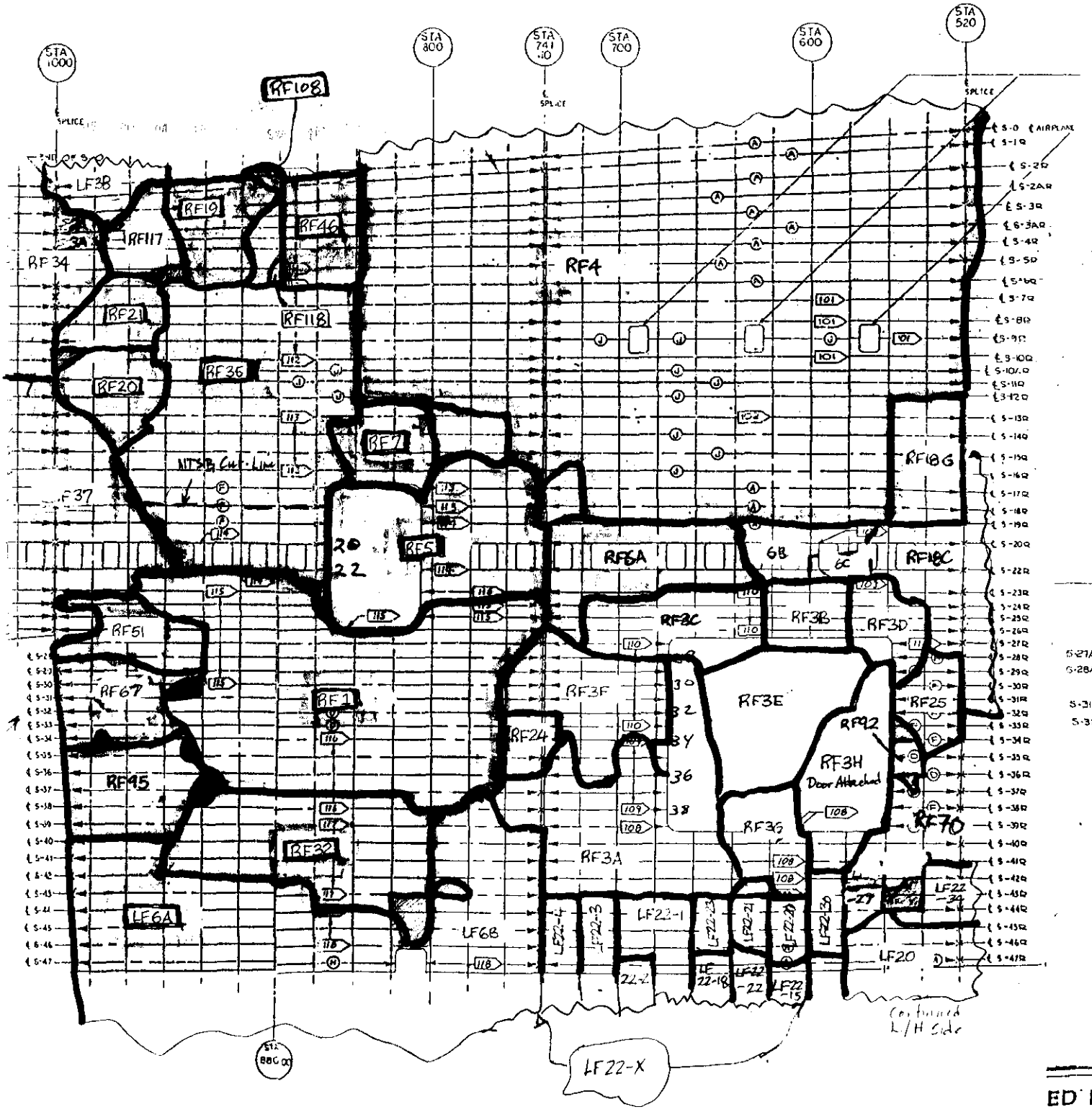
In the back of this section are the notes specific to the Keel Beam Study as well. Again this data exists in the Structures Fuselage book as well.

J. R. Straus, Boeing

Frank Zakar

F. Zakar, NTSB

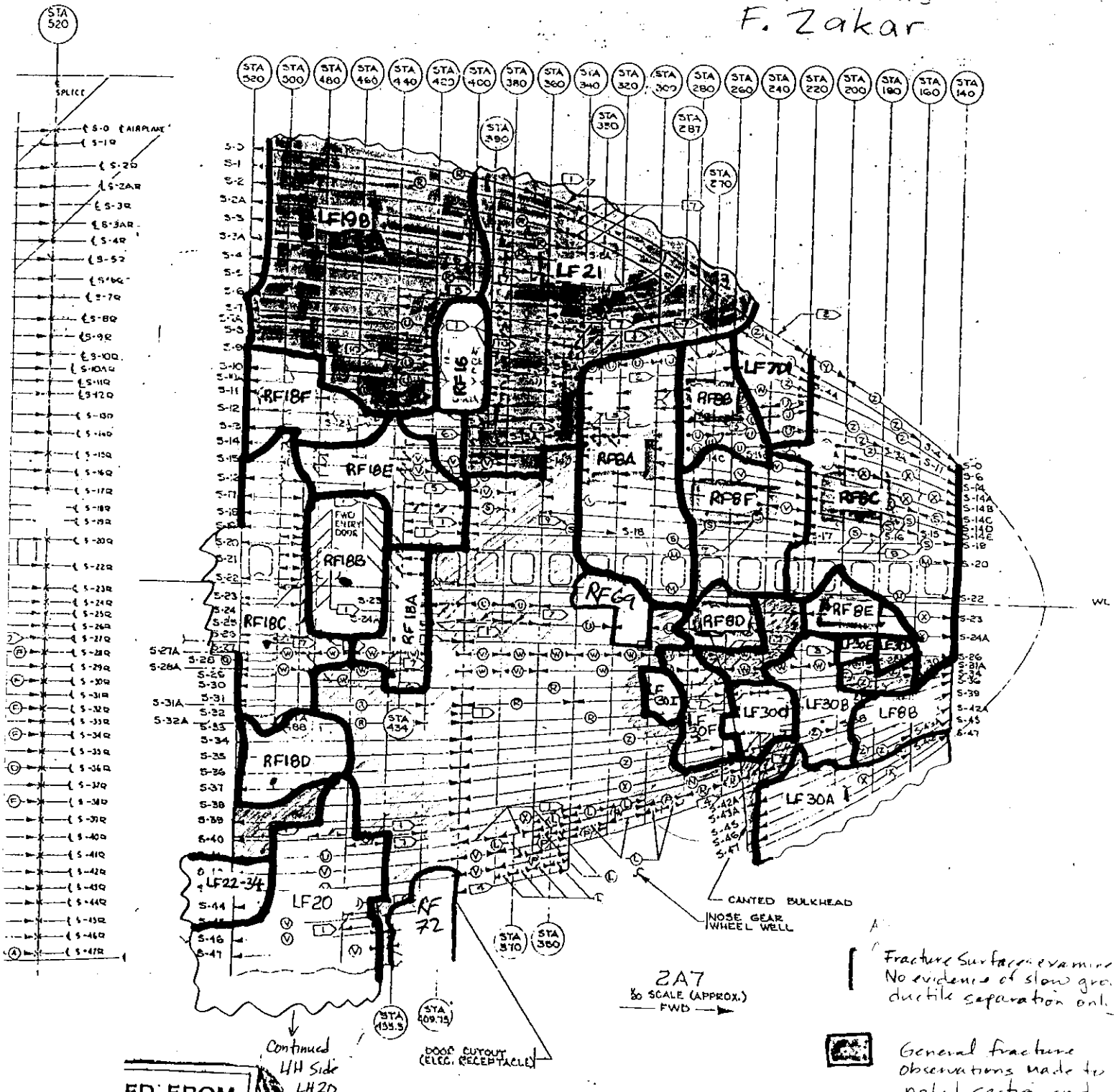
SECTION 42 – STA. 520-1000 (R/H Side)



Metallurgical / Fracture Observations Log

SECTION 41 - STA. 140-520 (R/H Side)

J. R. Straus
F. Zakar

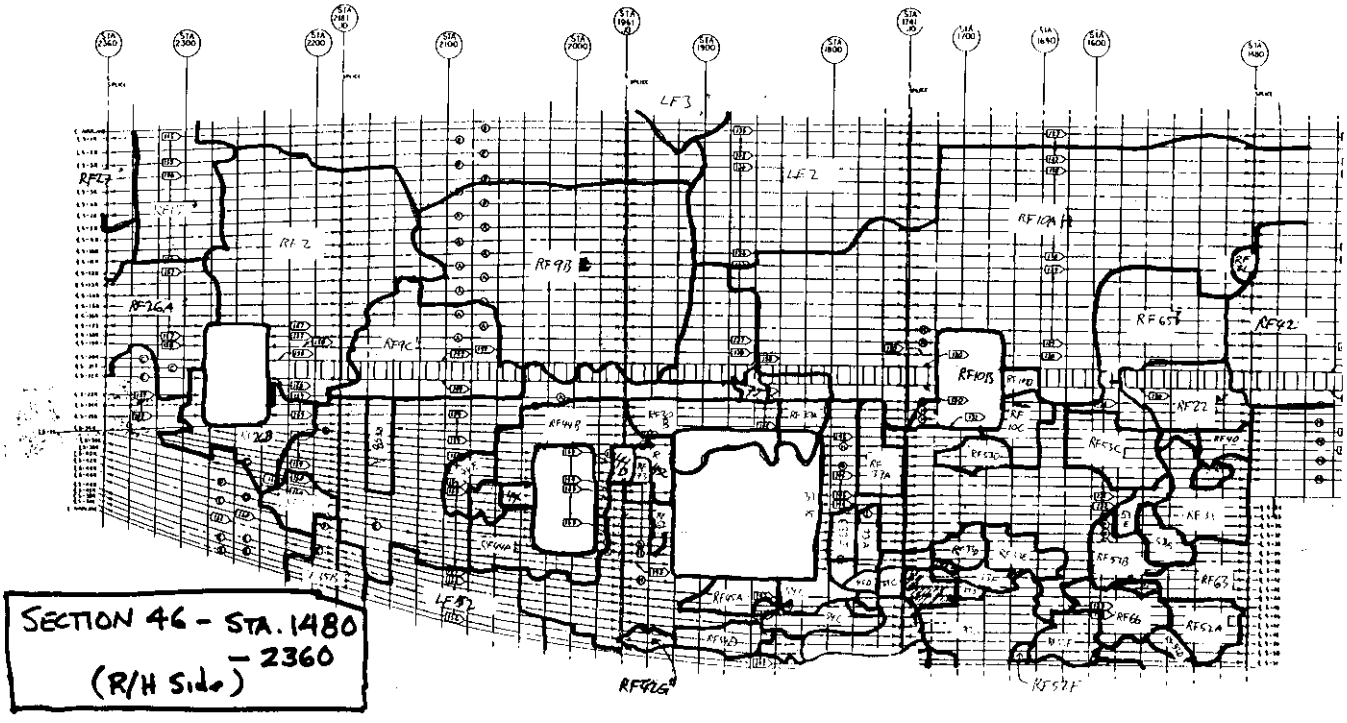


Continued LH Side LH20

Fracture Surfaces examined No evidence of slow growth ductile separation only

General fracture observations made to noted section and documented in ring binder

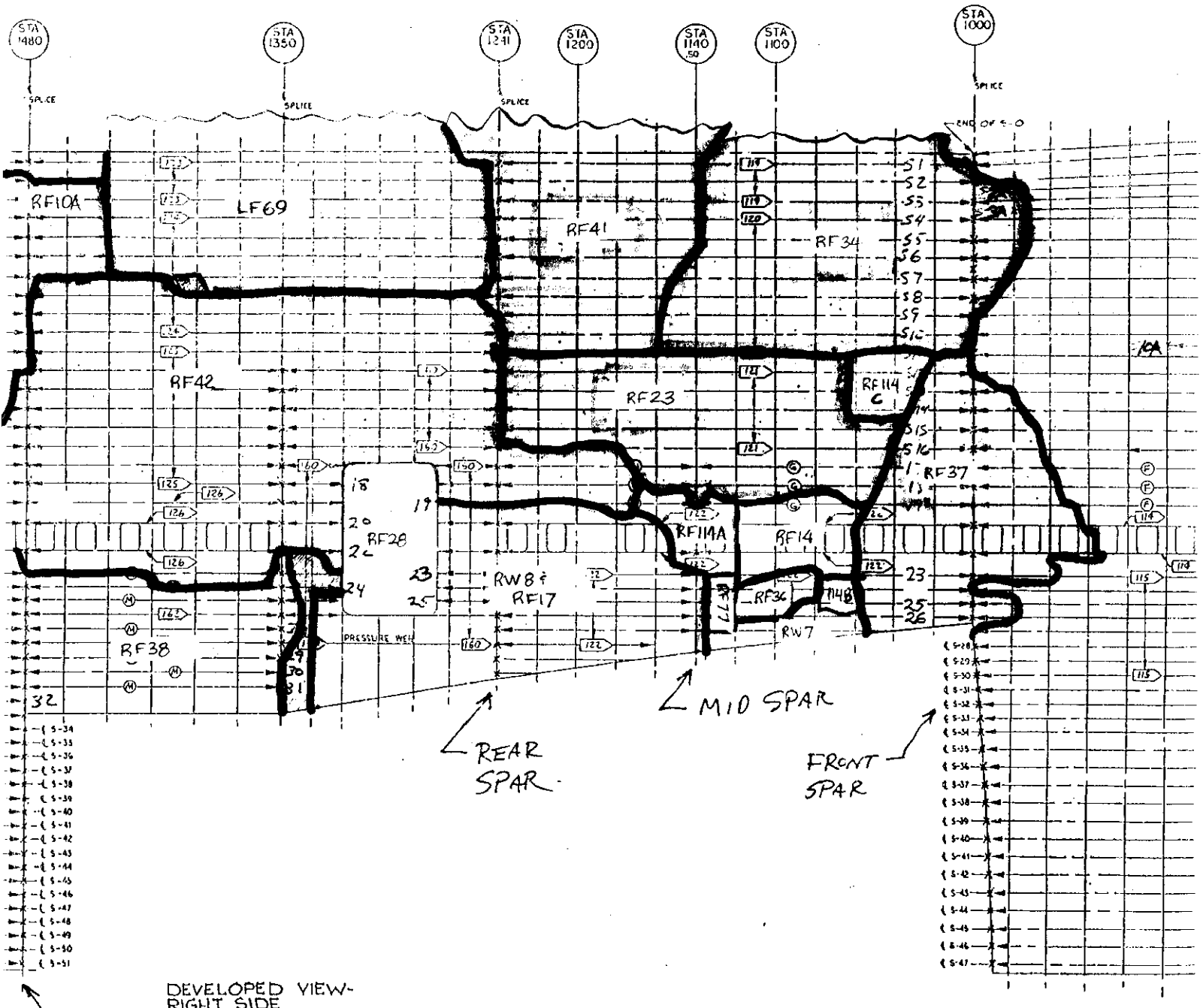
[redacted] F R 2



SECTION 46 - STA. 1480 - 2360
(R/H Side)

SECTION 44 - STA. 1000-1480 (R/H Side)

RIGHT HAND SIDE



DEVELOPED VIEW-
RIGHT SIDE
SCALE 1/20

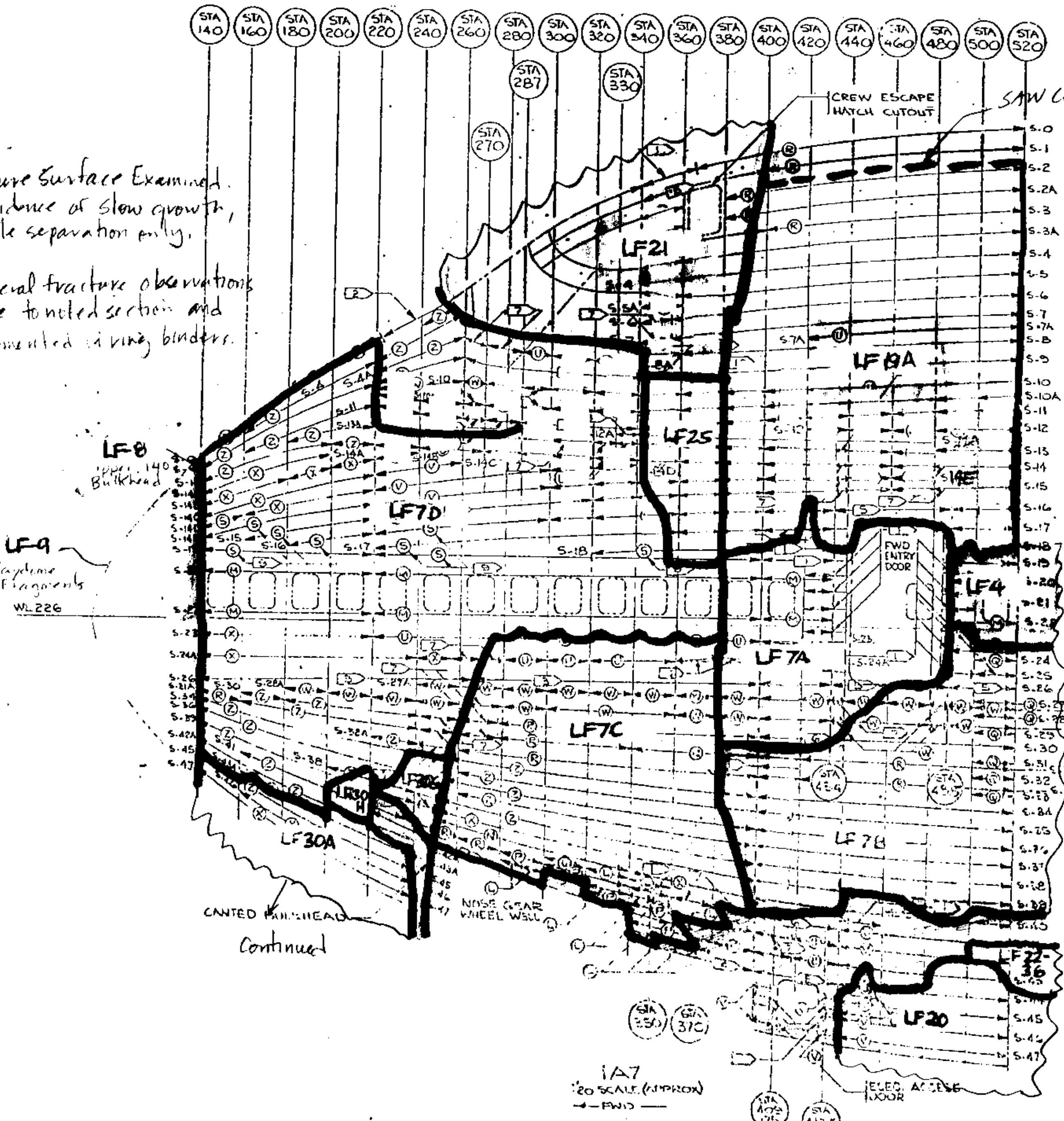
MAIN GEAR
W/WELL BLKHD

SECTION 41 - STA. 140 - 520 (L/H Side)

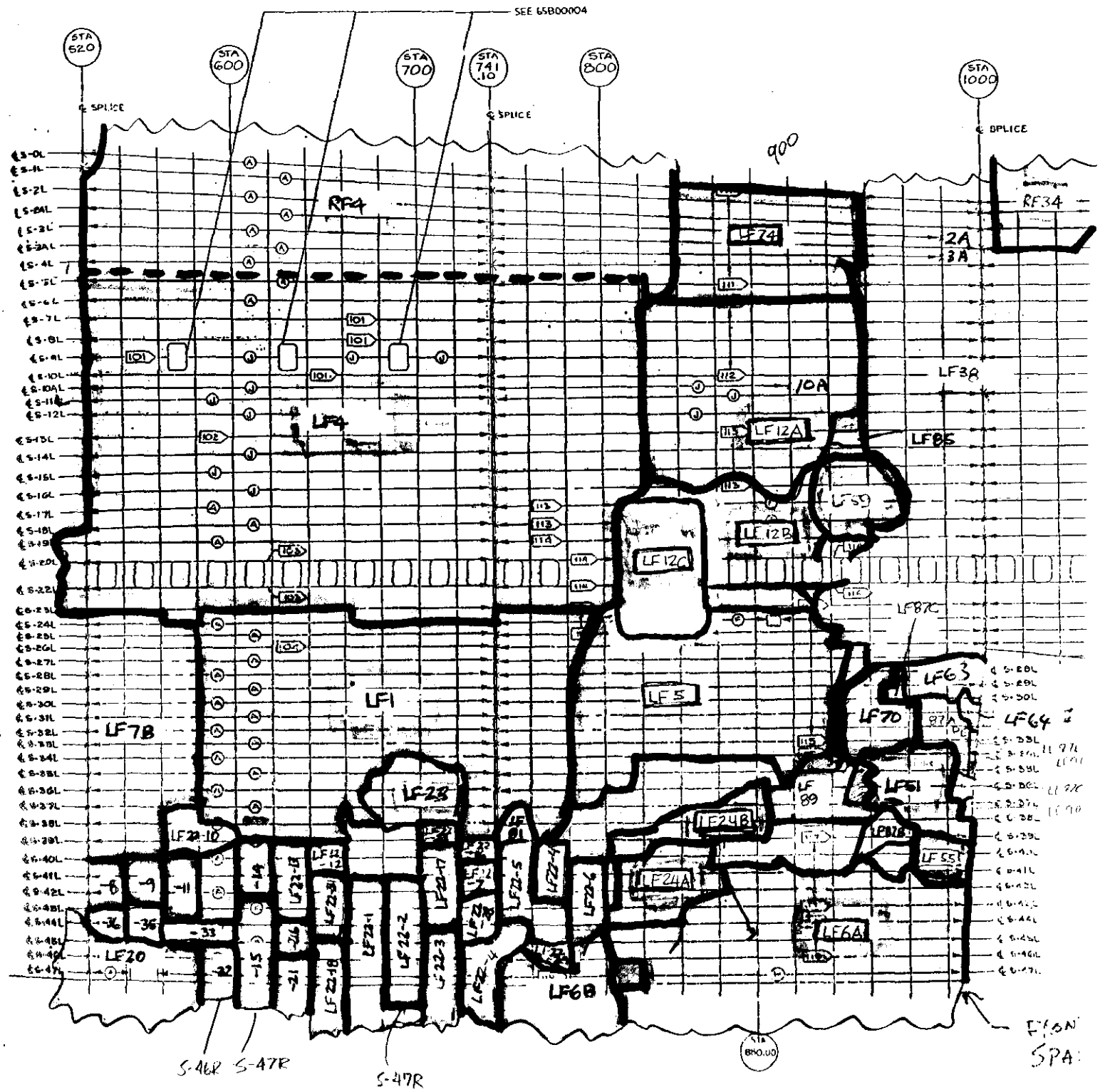
J. R. Shaw
F. Zurn

Fracture Surface Examined. No evidence of slow growth, ductile separation only.

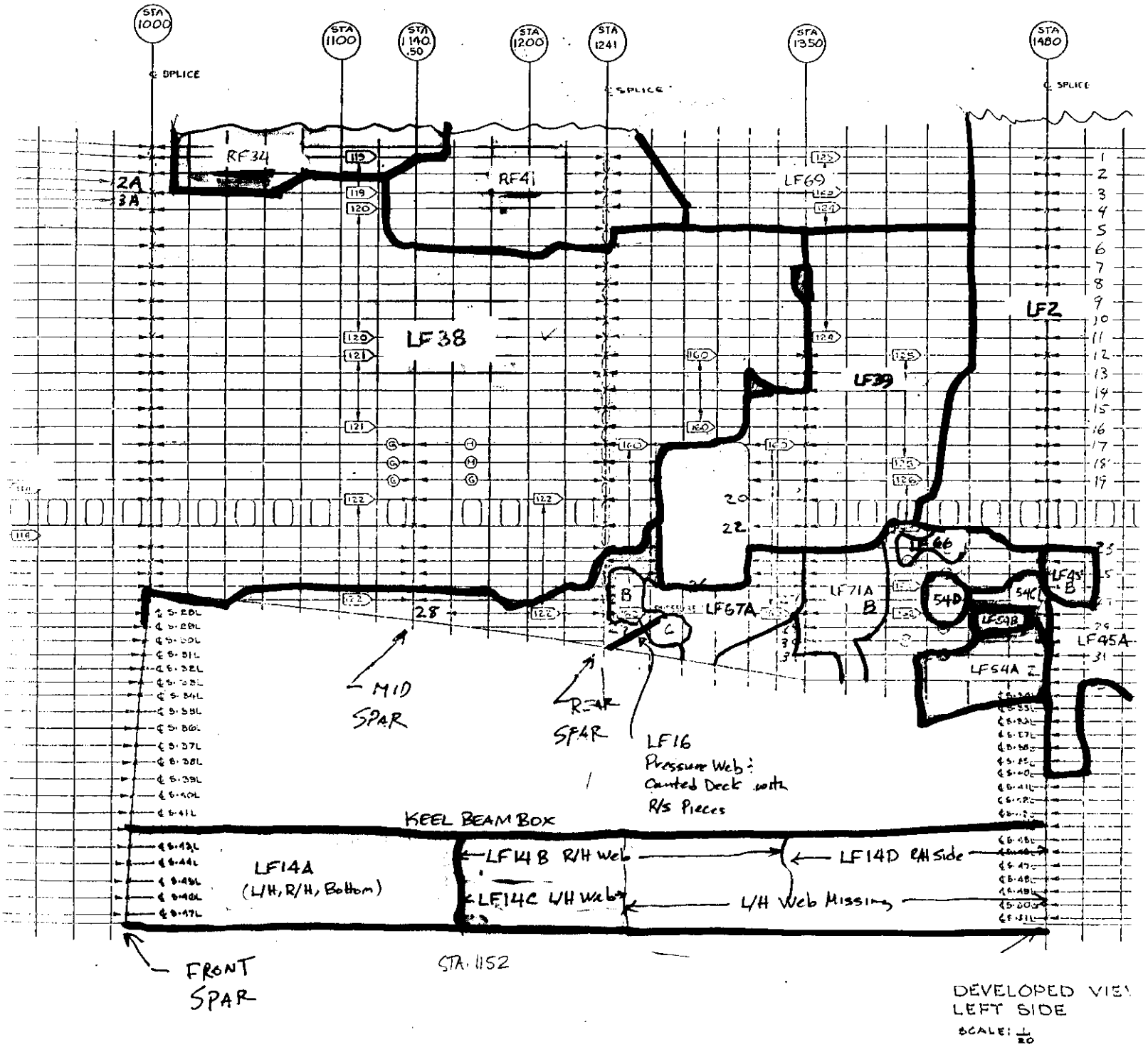
General fracture observations made to noted section and documented in ring binders.



SECTION 42 - STA. 520 - 1000 (L/H Side)



SECTION 44 - STA. 1000 - 1480 (L/H Side)



Error

An error occurred while processing this page. See the system log for more details.

Ground Rules: (Criteria)

To say a stringer has fractured by pure tension look for the following characteristics:

1). No evidence of the frames having been pulled away from stringers or fractured shear ties (i.e. intact frames)

2). No evidence of bending in the stringer adjacent to the fracture

3). Fairly straight transverse fractures

4). Fastener hole elongation in the ^ direction (primarily in the thin FWD/AFT Member)

To say a part exhibits water impact damage look for the following characteristics:

1). Flattened Stringers, frames, or shear ties

2). Inward distorted skin

3). Heavy twisting in the skin panel

4) Exterior paint badly damaged from skin yielding and impact.

METALLURGICAL NOTES

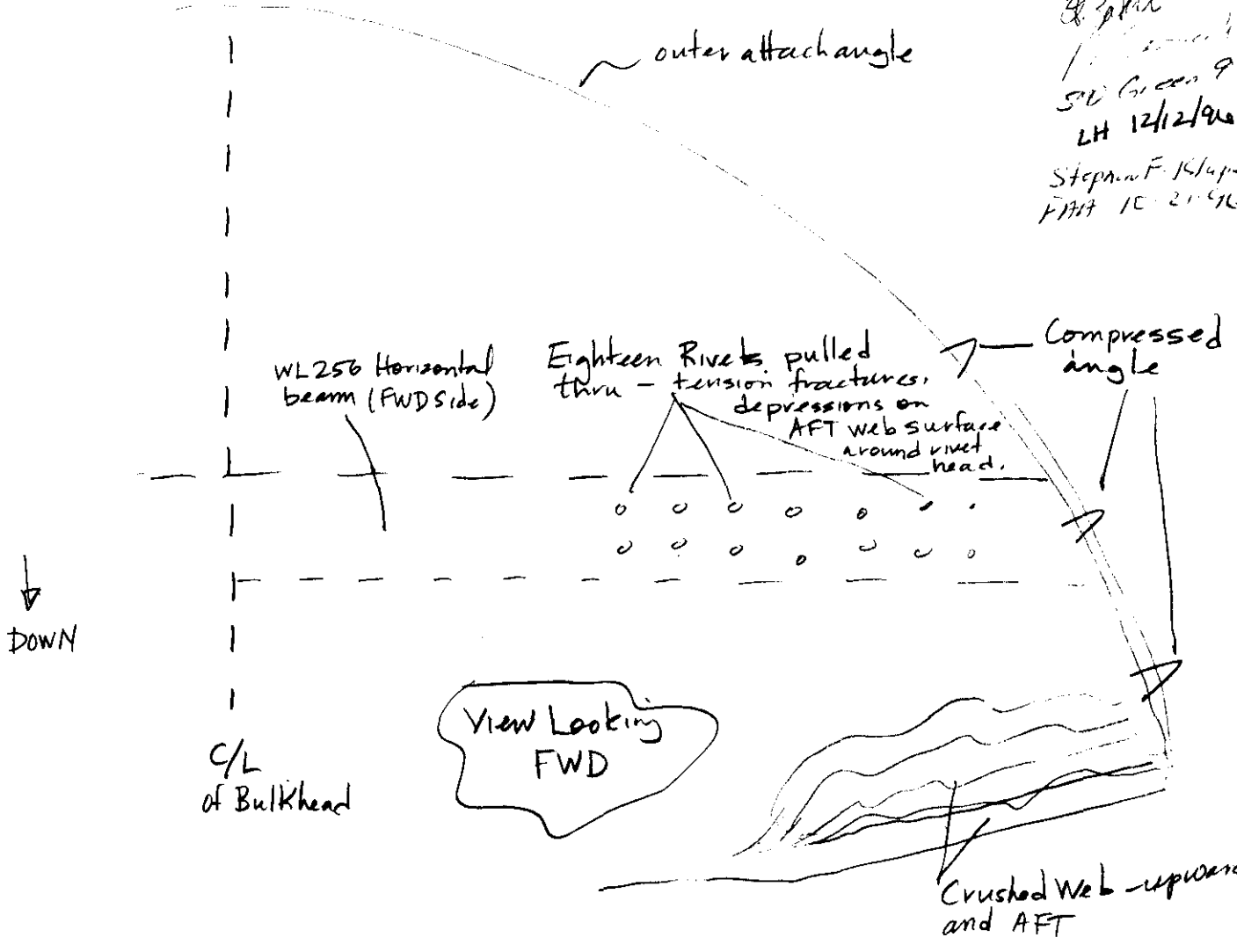
Yellow Zone

-observations made when looking FWD

LF8 - Sta. 140 Bulkhead, Upper Section (piece A).

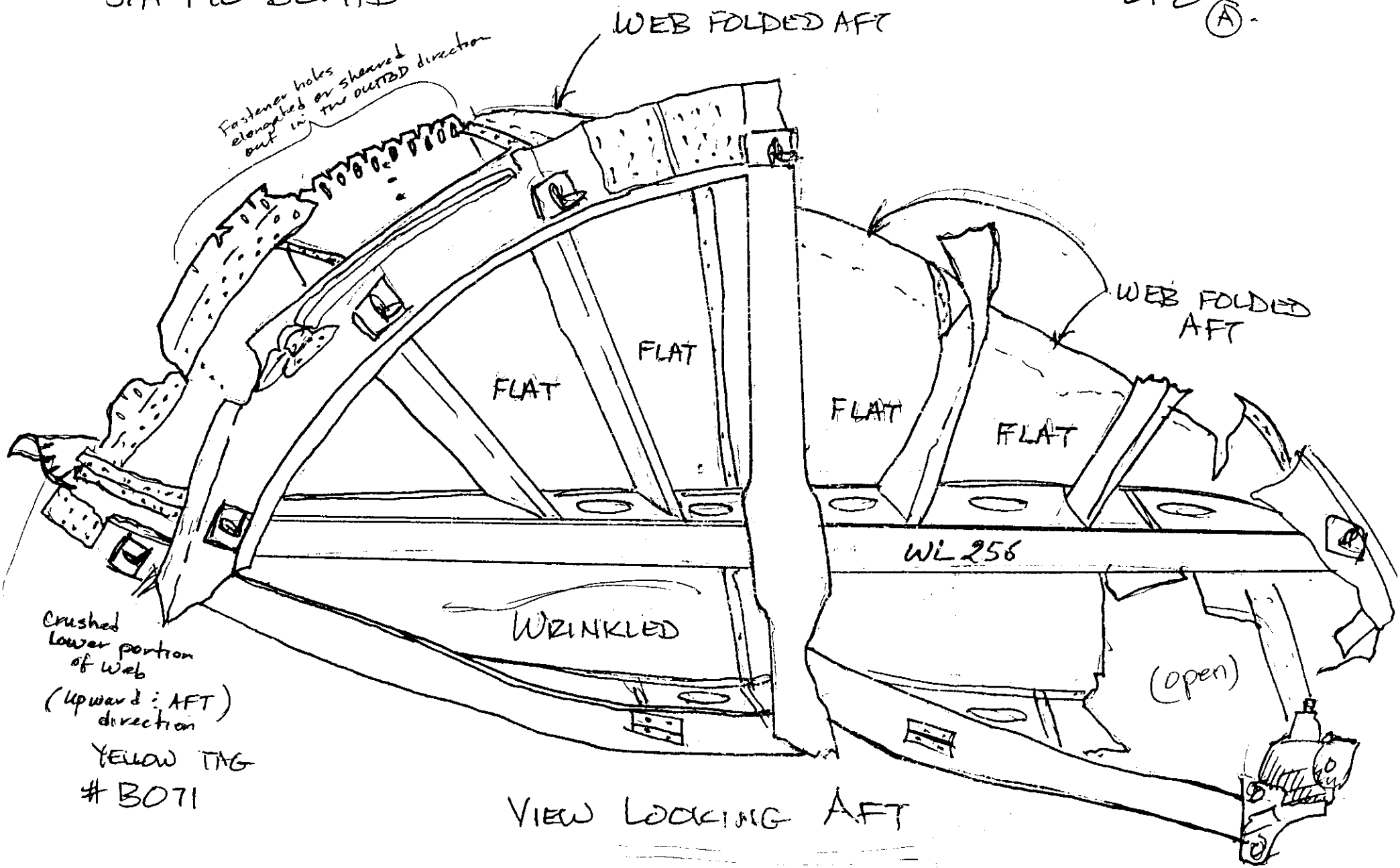
The upper left to center portion of the web is bent AFT and the bottom right portion is crushed upwards and AFT. Eighteen rivets on the far right side common to the upper horizontal beam (WL256) (above the crushed bottom right portion of the web) were pulled in tension and a dimple depression is seen on the AFT surface of the web. The web in this area is pushed FWD due to the crushing damage in the web below. The circumferential outer attach angle above the noted rivets shows signs of compression damage. The bulkhead web exhibits no obvious signs of overpressurization. Examination of fracture surfaces revealed ductile separation fractures with no evidence of any slow growth mechanisms. Many of the fastener holes in outer right side web are sheared out or elongated in the OUTBD direction.

9/11/96
JR Straus



UPPER PORTION of
STA 140 BLKHD

LF8 (A).



VIEW LOOKING AFT

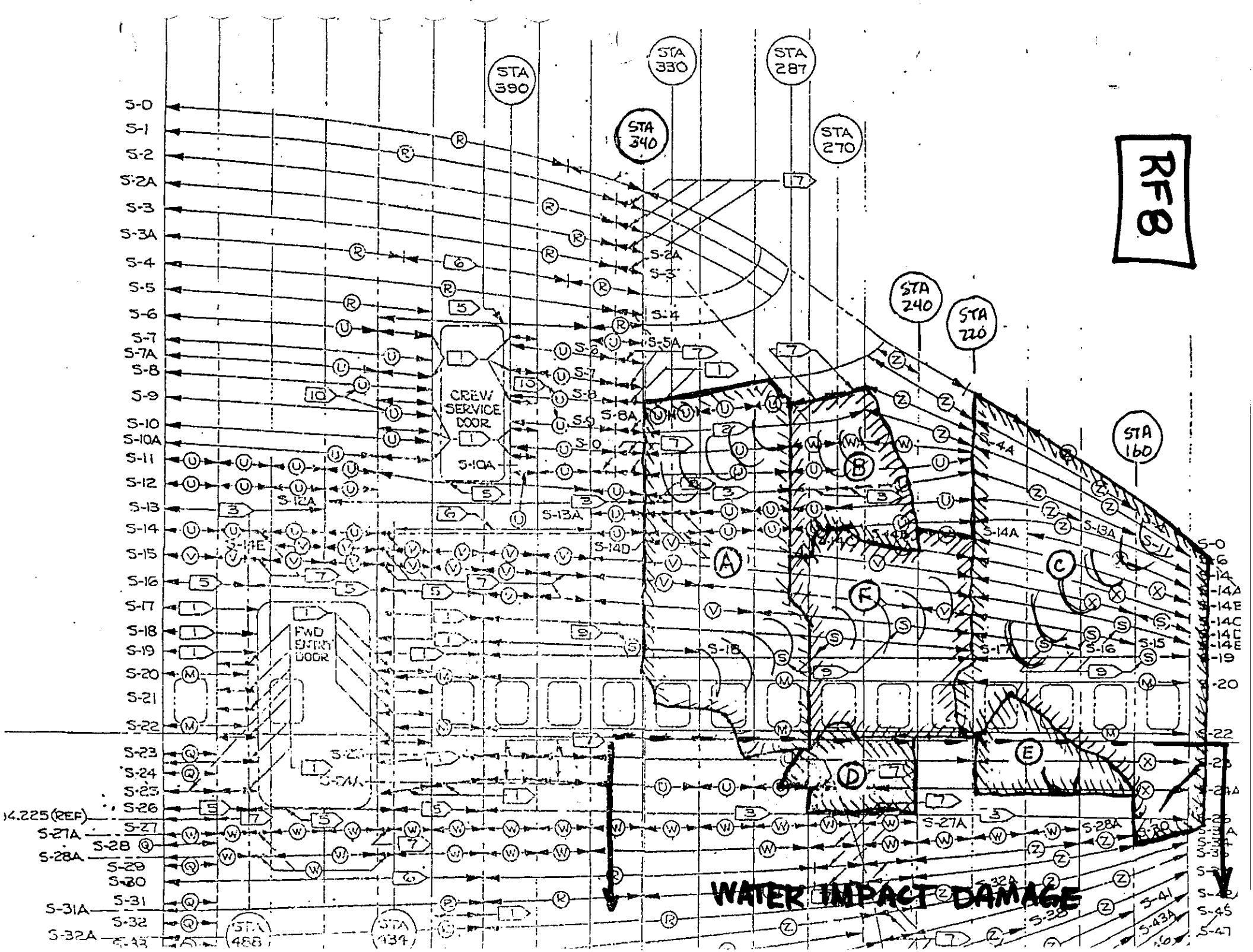
Metallurgical Notes

Yellow Zone

RF8 - RH FWD upper section 41 Skin Assy's.

- All sections below the window line exhibit evidence of water impact damage based on the following observations:
  - Flattened stringers, frames, or shear ties
  - Inward distorted skin
  - Heavy twisting in skin panel
  - Exterior paint badly damaged from skin yielding and impact

JRStraus 9/1/96
G. Zakar
R.T. Sumner 9-11-96
S D Green
LH 12/12/96


RFB
STA 390
STA 330
STA 287
STA 340
STA 270
STA 240
STA 220
STA 160
STA 488
STA 434
CREW/ SERVICE DOOR
FWD CARGO DOOR
S-0
S-1
S-2
S-2A
S-3
S-3A
S-4
S-5
S-6
S-7
S-7A
S-8
S-9
S-10
S-10A
S-11
S-12
S-12A
S-13
S-13A
S-14
S-14E
S-14D
S-15
S-16
S-17
S-18
S-19
S-20
S-21
S-22
S-23
S-24
S-25
S-26
S-27
S-27A
S-28
S-28A
S-29
S-30
S-31
S-31A
S-32
S-32A
S-33
S-2A
S-3
S-4
S-5A
S-6
S-7
S-8
S-8A
S-9
S-10
S-14A
S-13A
S-14
S-17
S-16
S-15
S-18
S-27A
S-28A
S-32A
S-33
S-41
S-43A
S-45
S-47
A
B
C
D
E
F
WATER IMPACT DAMAGE

Metallurgical Notes

Yellow Zone

LF21 - Cock Pit Area

- Right side crushed INBD and UPward below AFT of cockpit window.
- Evidence of skin Peeling outward on left side near the escape hatch.
- Center reinforcement beam between left 1 and right 1 cockpit windows is bent 90° to the left.
- The stringers in the crown of the cab AFT of Sta. 380 exhibit evidence of compression down and FWD as if AFT Portion is pushed FWD.
- Frames at Sta. 380 & 360 show evidence of compression FWD at S-3R and S-3AR, respectively.
- All fractures examined were the result of ductile separation. No evidence of any slow growth (i.e. fatigue)

JR Straus 9/1/96

K. Baker

[illegible]

SD Green 9-11-96

L.H. 12/12/96

Metallurgical Notes — Yellow Zone

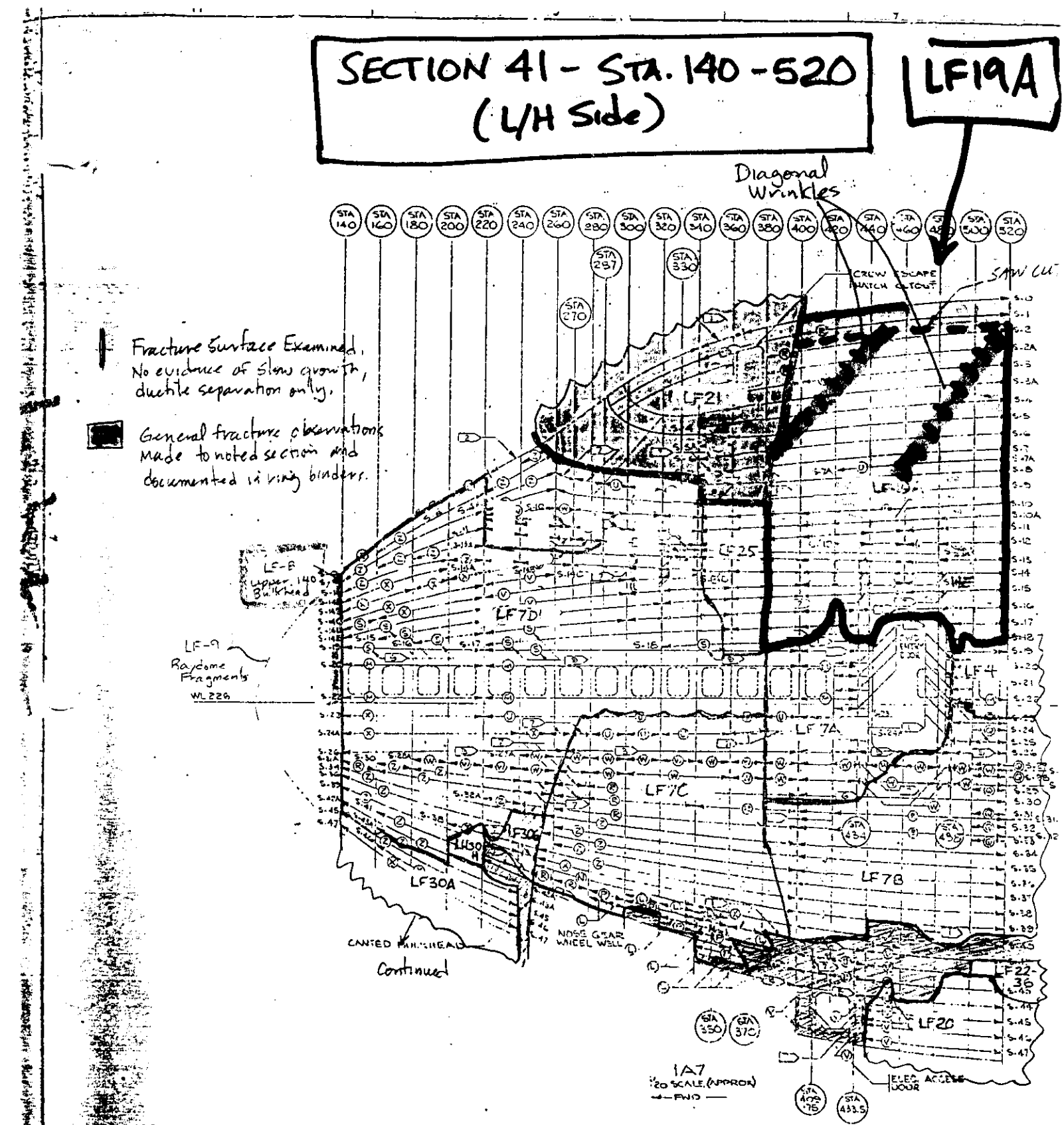
LF19A – LH Fuselage Skin Panel, Sta. 380 – 520, S-18L to S-2R

- A Diagonal wrinkle exists from Sta. 460, S-8L to Sta. 520, S-1L.
- A Diagonal wrinkle exists from Sta. 400, S-5L to Sta. 440, S-1L. The frames coinciding with the wrinkle are fractured.
- Numerous areas of stringer compression damage noted between and at frames.
- Various areas where the stringers are Missing
  - Sta. 460 and AFT – S-5L to top of panel
  - Sta. 460 and AFT – S-10L to S-12AL
  - Sta. 460 and FWD – S-3L to top of panel

JR Straus 9/6/96
[illegible] 9/11/96
SD Green 9-11-96
LH 12/12/96

SECTION 41 - STA. 140 - 520 (L/H Side)

LF19A



[redacted]

Yellow Zone

LF19B – Left hand Skin STA400-520 Stringer 2L – 12R

- Many stringers exhibit compression damage.
- Frames between STA420 and 500 at S-2L adjacent to saw cut line are bent aft.
- Frames STA 420 to 480 between S-4R and S-5R are fractured.
- Frame at STA 420 & S-9R exhibit severe compression damage and skin panel bound. between STA 420 and 460 and between S-10R and S-12R show compression damage

K. Zakar 9-7-96
JR Straus 9/7/96
[illegible] 9/11/96
SD Green 9-11-96
LH 12/12/96

Metallurgical Notes

Yellow Zone

RF6 - RH Skin Panel, Sta. 640 to 741, S-19R to S-27R

- All frames and window frames are severely compressed,
- Below the window belt (S-22R) the panel shows evidence of water impact damage.

JR Straus 9/5/96
[signature]
[signature] 9 11 96
SD Green 9-11-96

- All fracture surfaces were examined and showed no signs of any slow growth cracking (i.e. fatigue). Fracture features were characteristic of ductile separation.

JRStraus 10/11/96
SDGREEN 11/13/96
Stephen F. Klapach Jr
10-10-96 FAA

Metallurgical Notes

yellow zone

RF4 – Fuselage Skin Sta. 520 – 840, S-19R to NTSB Cut-line at S-2L.

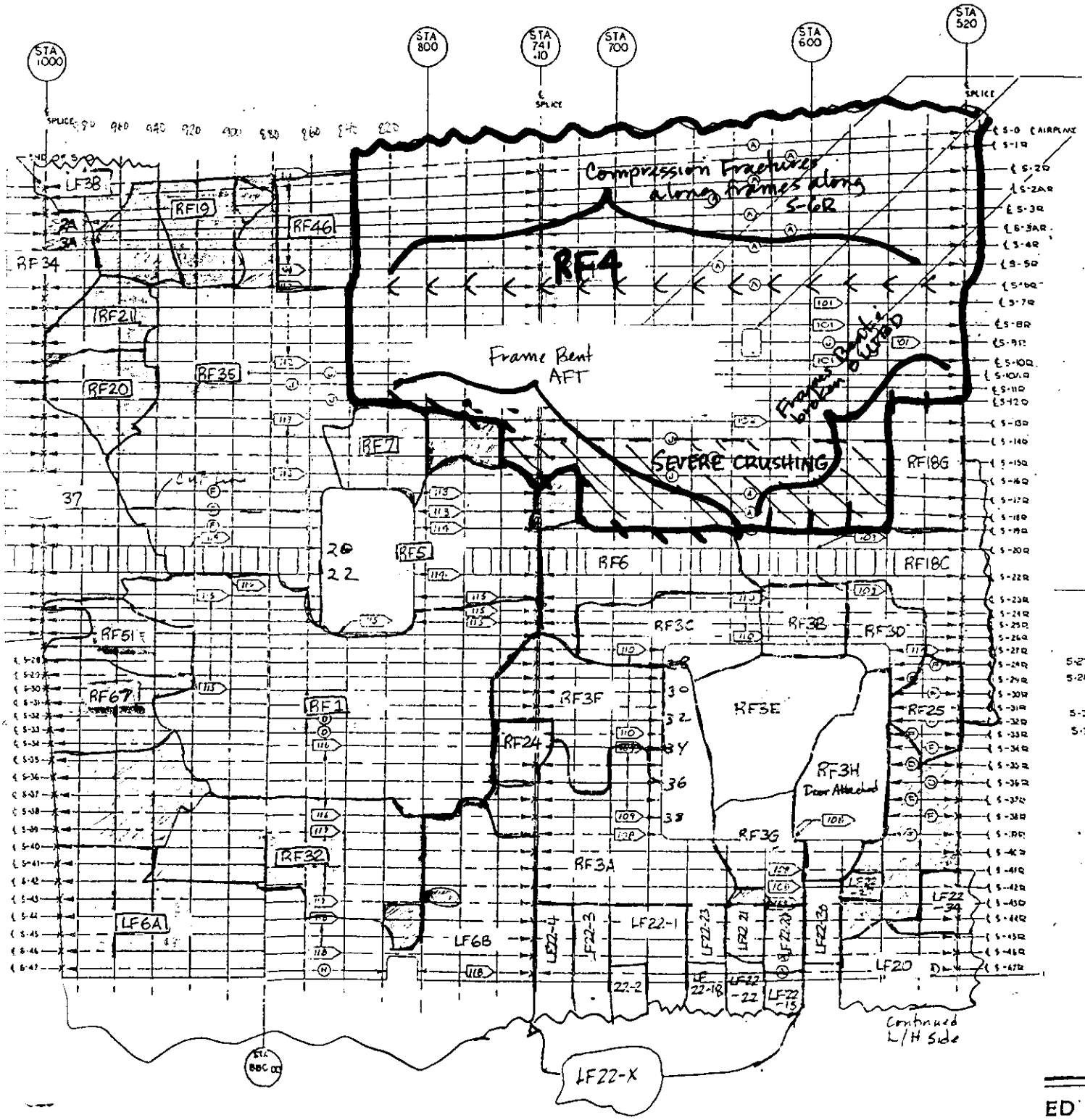
- Severe crushing of the skin panel below S14R from Sta. 560 to 760. The skin was accordioned below the upper deck floor (S-14R) to Stringer S-19R (stringer above passenger window line)
- All frames between Sta. 660 and Sta. 820 exhibited evidence of APT bending on the bottom of the panel.
- Frames on the bottom of the panel from sta. 520-640 were bent and broken OUTBD.
- All frames are broken longitudinally along S-6R. The fractures exhibit evidence of compression.
- Stringer 1R, 0, 1L, 2L, 2AL exhibited evidence of pure tension fracture. Stringer 3L and 4L are bent circumferentially toward S-0. Stringer 2R to 12R are bent circumferentially toward Stringer 0.

JR Straus 9/1/96
H. Zaker.
[illegible] 9-11-96
SD GREEN 9/11/96

- All fracture surfaces were examined and no evidence of any slow growth cracks (i.e. fatigue) were observed. Fracture features were characteristic of ductile separation.

JR Straus 9/11/96

SECTION 42 – STA. 520-1000 (R/H Side)



Metallurgical Notes

Yellow Zone

LF4 - LH Skin Panel, Sta. 520 - 820, S-4L to S-23L

- All frames below the window line exhibits evidence of tensile fractures. Straight-line transverse fractures without any evidence of bending. Mating frames from LF1 exhibit same characteristics
- Frames above the window line were fractured and bent INBD at S-17L.
- Stringers ~~at Sta.~~ S-15L, 14L, 13L and 12L at Sta. 820 exhibit evidence of compression.
- Stringers 6L to 11L exhibit signs of tension fractures (i.e. Straight-line (transverse) fractures with elongated fastener holes in the FWD/AFT direction. at Sta. 820

JR Straus 9/7/96

SO GREEN 9/11/96

LH 12/he/96

Metallurgical Notes

Yellow Zone

LF1 - LH Fuselage Skin Panel, Sta. 580-800, S-23L to 39L

- Evidence of water impact damage below stringer 37L.
- Missing frames below S-33L
- Extensive crushing damage below S-32L AFT of Sta. 680. The extension of this crushing damage can be seen on LF23.
- Frame at Sta. 780 is missing and shear ties are fractured. Stringer 23L, 24L, 26L, 28L, 30L all fractured in a fairly straight (transverse) line. Holes in skin AFT of stringer fracture exhibited evidence of fastener pull out in the AFT direction.
- The following items showed signs of compression:
  - Side-of-Body Shear Webs (level with floor structure)
  - Stabilization Strap
  - Decompression Truss
- FWD stringers at Sta. 580 are relatively straight transverse fractures, however, frame at this location have pulled away from the skin and the shear ties and stringer clips are missing. There are no intact fastener holes in the skin FWD of the fractures available for hole elongation examination (nothing available on mating part either).
- Frames on the top of the panel are relatively straight transverse fractures with no bending indicative of tensile separation. Mating frame fractures on LF4 exhibit same characteristics.

JR Strauss 9/5/96
[signature] 9-11-96
[signature]
SD Green 9-11-96
LH 9/12/96

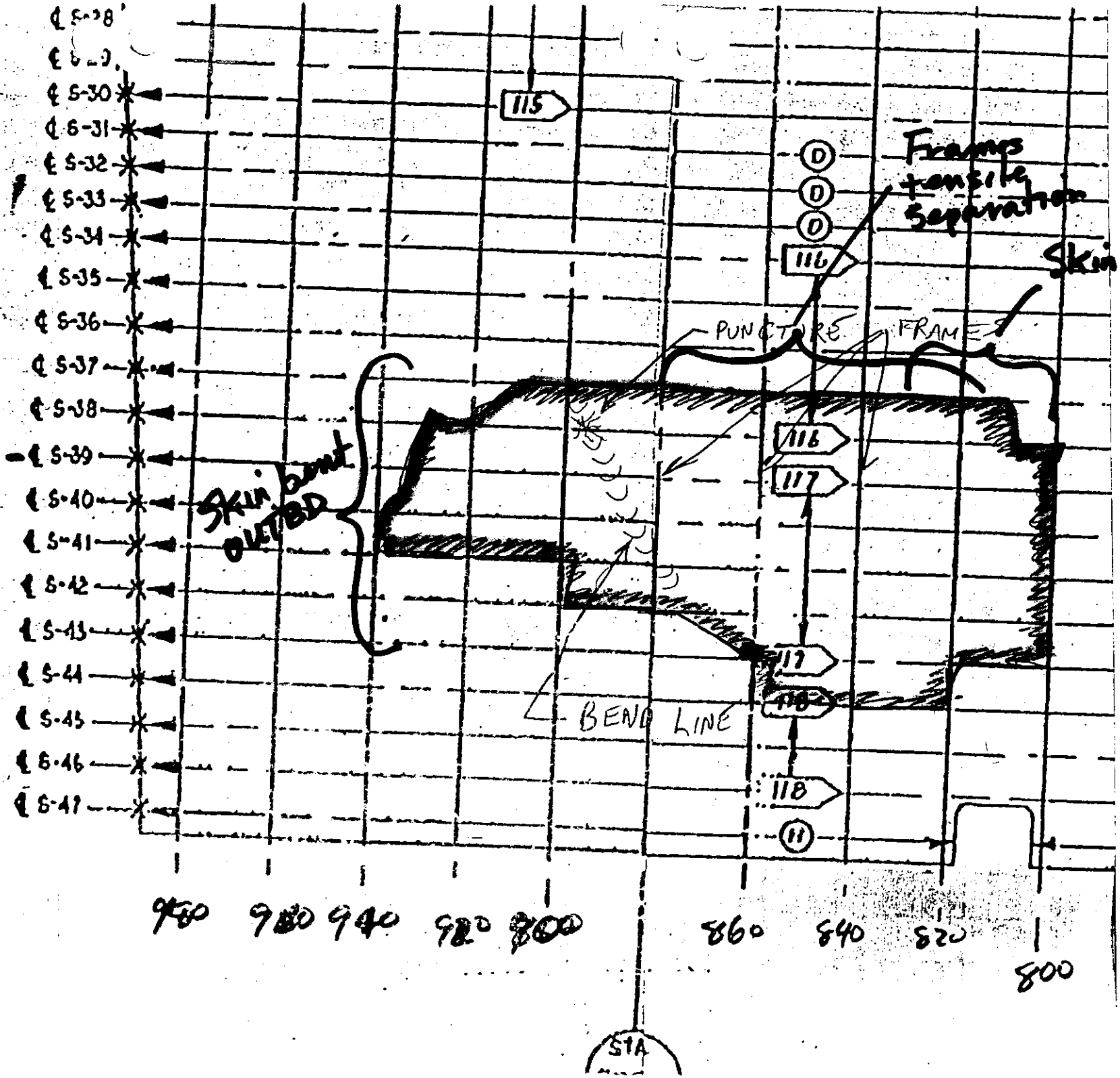
Metallurgical Notes

Red Zone

RF32 - Skin Panel Assy - Sta. 860 to 940, S-37R to S-44R

- Upper and lower fracture surfaces of frames Sta. 820-880 exhibited evidence of tensile separation.
- Cargo deck floor beams integral with frames Sta. 820-880 exhibited tensile fractures.
- Stringers on FWD end of panel (Sta. 860) exhibited evidence of tensile fractures.
- Stringers on AFT end of panel exhibited OUTBD/upward twisting.
- AFT end of skin was bent OUTBD
- FWD end of skin was bent OUTBD.
- No evidence of water impact damage noted.

JR Straus 9/3/96
L. Zuhar
[illegible] 9-4-96
SO Green 9-4-96
LM 12/12/96


Frames transite separation
Skin bent OUTBD
PUNCTURE
FRAMES
Skin bent OUTBD
BEND LINE
115
116
116
117
117
118
118
11
D
D
D
960
940
920
900
860
840
820
800
STA

Metallurgical Notes

Red Zone

RF1 - RH Fuselage Sta. 760-960, S-22R to S-37R

- Stringer fractures AFT of Sta. 900 exhibit evidence of OUTward bending.
- Stringers FWD of Sta. 780 exhibited evidence of tensile fractures.
- The lower fractures of frames Sta. 820-900 exhibit evidence of tensile separation with slight bending on the lower flange.
- Bottom skin from Sta. 760-860 is bent OUTBD. Mating Stringers 34, 35, 36 are bent OUTBD. (at FWD End)
- No evidence of water impact damage noted.

JRStraus 9/3/96
[illegible] 9-11-96
SO G[illegible]
LH 12/12/96
TWA

Supplementary Notes

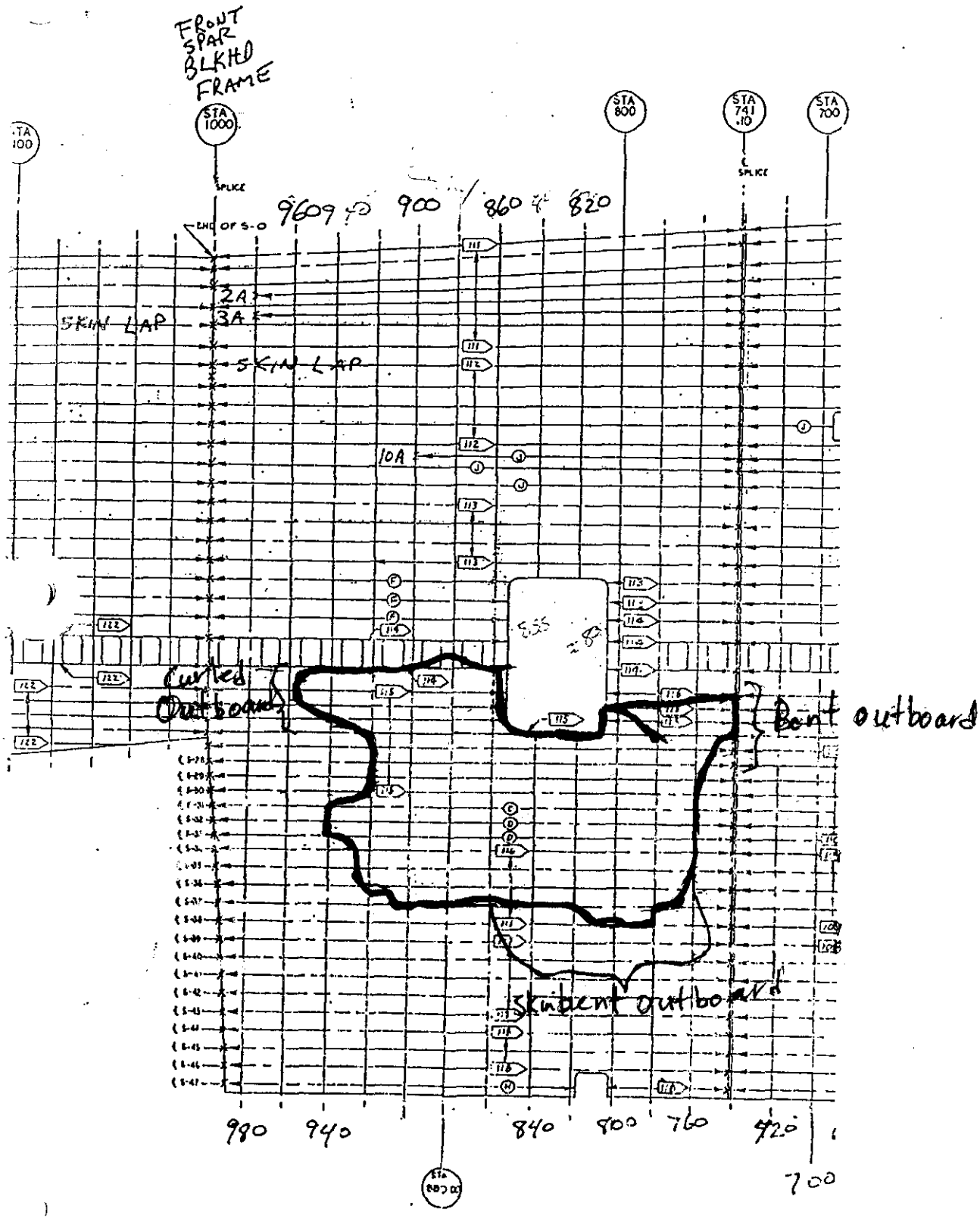
- FWD lower end of skin is bent OUTBD, however, frames have pulled away from skin fracturing stringer clips, shear ties, and some stringers.
- Lower Door Aux. Sill exhibits numerous areas of compression damage located along its length similiar to L/H opposite panel. (LF5).
- Upper section of the panel on the FWD and AFT ends are bent OUTBD.

LH 12/12/96
JRStraus 9/4/96
SDG
[illegible]

SMITH

S TEAM

RFI



RIGHT HAND SKIN PANEL

FWD

65B0000521

6 5

Metallurgical Notes

Red zone

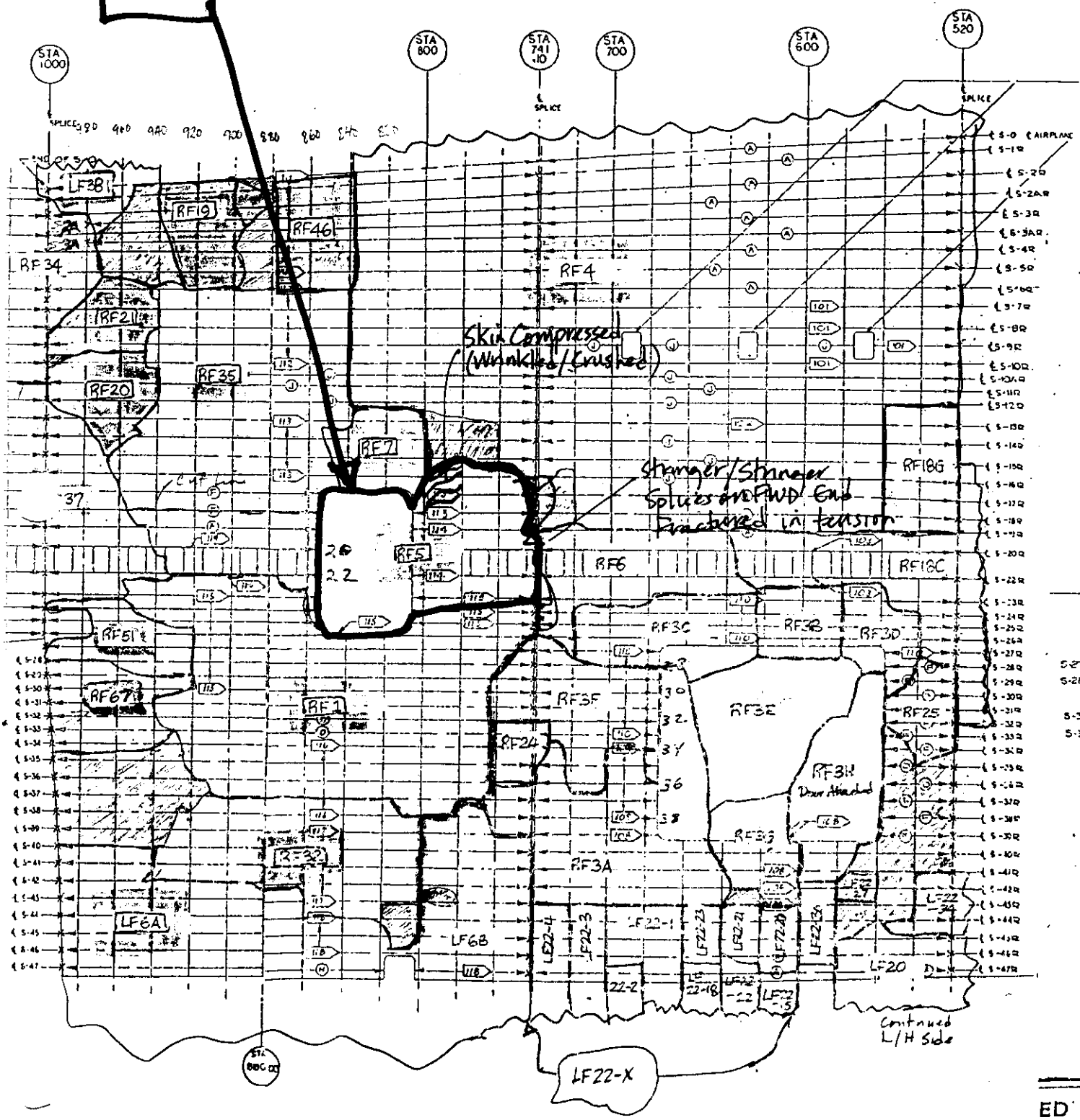
RF5 – RH Fuselage skin from Sta. 740-800, S-15R to S-25R including door R2.

- Stringers 23R and 17R fractured at Sta. 760. Stringer splices 22R, 20R, 19R and stringer 18R fractured at Sta. 740. All FWD fractured stringers exhibited evidence of pure tensile separation.
- At Sta. 740, skin is fractured along rivet line
- At Sta. 780-800, between S-15R to S-17R the skin is bent OUTBD & down with slight FWD directionality. The skin in this bent area shows signs of compression damage (creased/wrinkled skin).

JRStraus 9/11/96
[illegible]
[illegible] 9-[illegible]-96
SD GREEN 9-12-96
[illegible]

SECTION 42 – STA. 520-1000 (R/H Side)

RF5 Section



Metallurgical Notes

Red Zone

RF7 - RH Fuselage Skin Assy, Sta. 800-840, S-13R to S-16R (includes top of RZ door cut-out).

- Stringers 14R to 15R between Sta. 780-800 exhibit evidence of tensile fractures.
- External doubler, skin, and bear strap in FWD upper corner of door RZ cutout is bent OUTBD.
- Skin along total perimeter exhibits evidence of OUTBD bending.

JR Straus 9/2/96

[illegible] 9-11-96

SO Green 9-11-96

LH 12/12/96

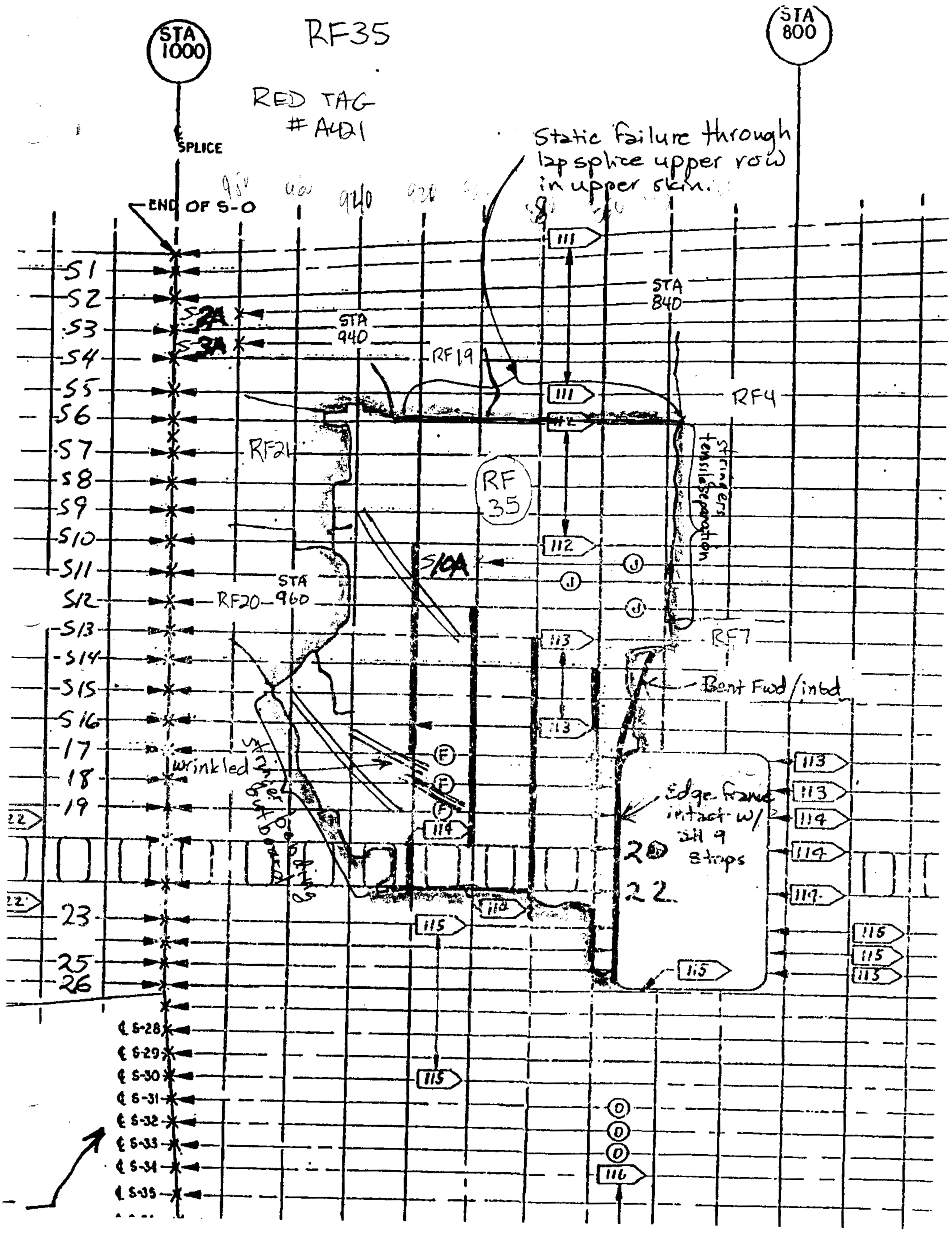
Metallurgical Notes

Red Zone

RF35 – RH Fuselage Skin Panel, Sta. 840 to 960, Window Belt (S-22R) to S-6R.

- Door frame (segment of frame between upper door sill) between S-13R to S-16R is bent forward.
- At Sta. 840–860, stringer 14R, 15R are bent OUTBD. Stringers 11R to 5R exhibit evidence of pure tensile fractures.
- Stringers 5R to 11R have various brakes along their length for entire panel. These brakes exhibit various forms of fracture (tension & compression).
- At Sta. 940-960, stringers 20R to 15R show signs of OUTBD bending. Stringers 14R to 6R are bent and separated in various directions.
- Skin shows 45° (diagonal) wrinkling in the UP and AFT direction at Sta. 900–940 from Stringer 9R to 13R AND at Sta. 920–960 from Stringer 14R to 19R.

JRStrauss 9/2/96
G. Zakar
R.T. Stewar 9-11-96
SD GREEN 9-12-96
LH 9/12/96


RF35
RED TAG
#A421
STA 1000
STA 800
SPLICE
END OF S-0
Static failure through lap splice upper row in upper skin.
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
17
18
19
23
25
26
S-3A
STA 940
STA 840
STA 960
RF19
RF4
RF21
RF20
RF35
RF7
111
112
113
114
115
116
S10A
stringers tensile separation
Bent Fwd/inbd
wrinkled
Edge frame intact w/ all 9 straps
20
22
S-28
S-29
S-30
S-31
S-32
S-33
S-34
S-35

Metallurgical Notes

Red Zone

RF19A & 19B - RH Fuselage Crown Skin FWD of Sta. 940

RF21 - RH Fuselage Skin Sta. 940-1000, S-6R to S-10R

RF20 - RH Fuselage Skin FWD of Sta. 1000 join.

RF46 - RH Fuselage Crown Skin Sta. 840 to 880, S-6R to S-0.

- All fracture faces examined and determined to be ductile separation. No evidence of any slow growth (i.e. fatigue).
- Frames and stringers have separated from the panels except 1' section of S-6R on panel RF21.
- Panels exhibit OUTBD bowing as shown in Structures notes.

JRStrauss 9/3/96
[illegible]
RT Sommer 9-11-96
S D GREEN 9-11-96
LH 12/12/96

Metallurgical Notes

Red Zone

LF12A, B, C

– LH Side Skin Panels Sta. 820-940, S-6L to below window belt (S-22L) (Includes Door L2)

(A)

- The skin is curled OUTBD along its length below S-12L.
- A wrinkle in the skin runs at a diagonal line from the AFT upper edge of the panel (STA 920 S-6L) to Stringer 12L at Sta. 900. The stringers coinciding with the wrinkle damage show signs of compression fractures/damage. The wrinkle coincides with one documented under LF12B.
- All stringers within this panel show multiple signs of compression damage.

(B)

- A wrinkle in the skin runs at a diagonal line from the AFT upper edge of the panel (STA 920 S-15L) to Stringer 20L at Sta. 900. The stringers coinciding with the wrinkle show signs of compression fractures/damage. The wrinkle coincides with that documented under LF12A.
- In addition to their upper and lower fractures at the panel edges, Frame 880 was fractured at S-20L, S-17L and Frame 900 was fractured at S-19L.

(C)

- Door L2 exhibits no signs of water impact damage
- The door is in the locked position
- No signs of any over pressurization were noted.

LH 12/12/ne (TWA)

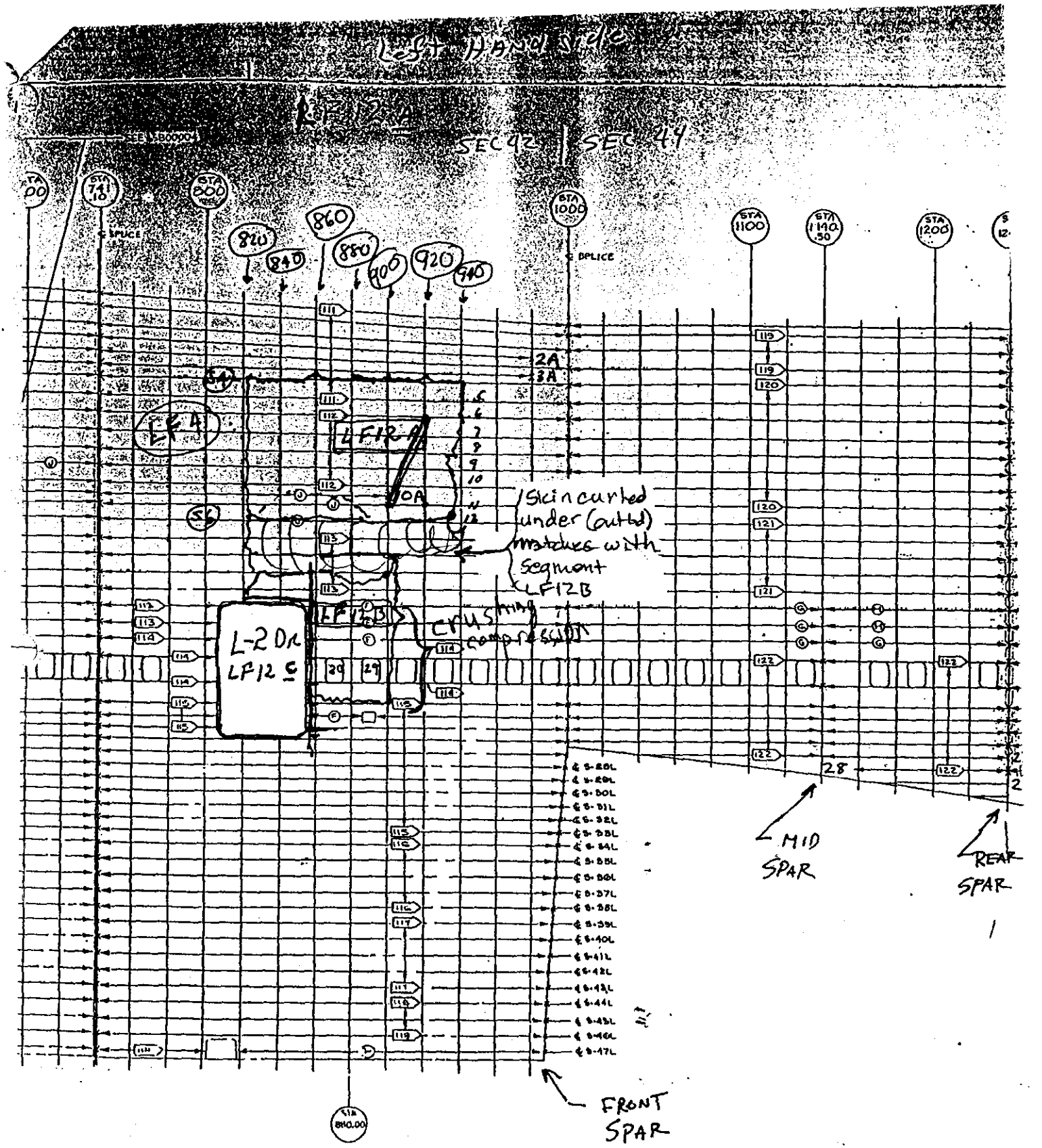
J R Strauss 9/4/96

[signature] Zakar

RT [signature] 9.11.96

SD Green 9.12.96

[signature] - IAM 2-12-97



LF12

Steve K. & Tom T
FAA

25B00005 3

Metallurgical Notes

Red Zone

RF108 - RH Fuselage skin, Sta. 880, S-1R

- No frames or stringers are attached to this piece of skin
- The skin is curled outward along the length of the piece.
- Fracture surfaces were examined and found to be due to ductile separation (no evidence of any slow growth cracking).

J. R. Straus 10/8/96
B. Baker
SD GREEN 11-13-96
LH 12/12/96

Metallurgical Notes

Red Zone

LF74 - LH Skin Piece, Sta. 840 - 940, S-0 to S-6L

Indications of overpressure - see overpressure study

- All stringers and frames are missing from this panel with the exception of S-1L & S-0 which were both partially left in place at the FWD end of the panel (Sta. 900 →).
- The FWD end of the panel (Sta. 840 to fracture zone (≈ Sta. 820) exhibited generally symmetric dimpling of the skin at the fastener holes. In addition, outward uniform pillowing of the skin between stringers and frame at Sta. 840 to the fracture zone (≈ Sta. 820) was observed.
- The AFT end of the panel from Sta. 880 to End (940) exhibited outward curling.
- The fracture profile along S-6L exhibited characteristics of tearing in the AFT direction.
- All fracture surfaces were examined and determined to be absent of any pre-existing cracking or slow growth regions (i.e. fatigue).

LH 12/11/96 10/7/96
JR Strauss
Frank Baker 10-7-96
SD GREEN 11-19-96

The fracture profile at FS 940 between S-2L & S-6L exhibits a pronounced saw tooth pattern.

SD GREEN 11-18-96

Metallurgical Notes

Red Some

LF5 - LH Skin Panel Sta. 780 - 920, S-23L to S-37L.

- Top section of skin is curled OUTBD on both the FWD and AFT ends of the panel. The OUTBD curl on the AFT end also exhibits some FWD directionality.
- Upper skin fracture along stringer 23L exhibits characteristic tearing features in the AFT direction.
- Skin from Sta. 860 FWD along stringer 34L is pulled OUTBD. Some rivets have pulled thru and some are fractured. Some fastener holes in S-34L exhibited pull thru elongation in the OUTBD/AFT direction.
- The Sta. 820 frame at S-36L (lower fracture location) is twisted FWD on the OUTBD side and AFT on the INBD side.
- The FWD lower end of the skin panel is bent OUTBD, however, the frame at Sta. 800 has pulled away from the skin, fracturing stringer clips, shear ties, and some stringers up to the lower Aux. Door Sill (S-30L).
- Stringers 28L, 29L, 30L at the FWD end of the panel (Sta. 780) exhibit evidence of INBD bending.
- The Lower Aux. Door Sill exhibited numerous areas of compression damage along its length. The AFT end exhibited twisting OUTBD at its join with the Sta. 880 frame.

LH 12/12/96 9/4/96
JR Strauss
Y. Zakar
SD Green 9-12-96

Metallurgical Notes

Red Zone

LF24 A & B - LH Lower Skin Panel Sta. 800 - 800, S-44L to 36-L.

(A)

- The FWD / INBD end of the panel is curled inward.
- All frames and stringers are missing except S-40L remains attached from Sta. 820 - 840. The AFT end of S-40L (Sta. 840) exhibits evidence of bending INBD. The FWD end (Sta. 820) is a fairly straight fracture with no evidence of bending. However, the frames on this panel have pulled away from the skin and fractured the shear ties. Based on this observation it could not be determined whether the FWD end of stringer S-40L fractured by tensile separation or shear.
- The AFT fairing attachment bracket at Sta. 840 is undamaged however, the structure attached to the bracket exhibits evidence of AFT bending.

(B)

- The skin at S-37L is bent in a wave along its longitudinal axis.
- The AFT end of S-38L fracture is fairly straight with no evidence of bending. The FWD ends of stringer 38L, 39L, 40L fractures are also fairly straight with no evidence of bending. However, the frames on this panel have been completely pulled away from the skin fracturing all the shear ties. Based on this observation it could not be determined whether these stringer fractures were the result of tension or shear.
- Stringer 39L at Sta. 860 is twisted INBD.

SO Green 9-12-96

9/4/96

LH 12/12/96

[signature] 9-11-96

JRStrauss

[signature]

Red Zone

Metallurgical Notes

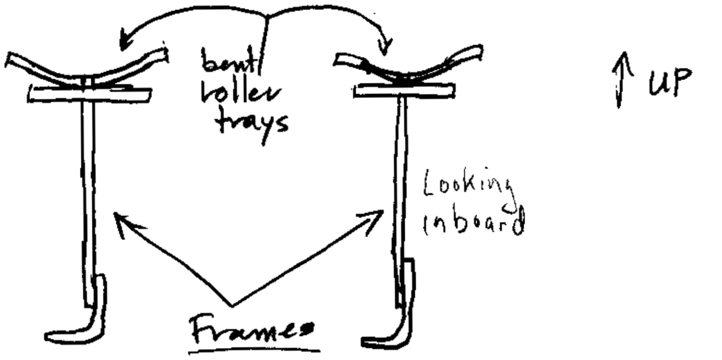
LF6A - Belly skin from AFT end of Sec. 42, Sta. 800-1000

Lower Keel Chords at Sta. 986 fractured due to ductile separation. No evidence of slow growth (i.e. fatigue or SCC). Fracture surface "flow lines" showed some convergence toward the top of the chords indicating origination most likely occurred on the upper surface of the chords. (See Keel Beam Study Notes).

See Rev. A attached JRStraus 10/12/96

~~Lower ring chord at Sta. 1000~~ exhibited predominately ~~tensile separation in the UP/DOWN direction left of stringer 44L and in the FWD/AFT direction~~ for the ~~remainder of the~~ panel.

Roller trays at ≈BL30 fractured due to compression as displayed by the remaining sections of roller tray attached to adjacent frames bent upward (see figure below).



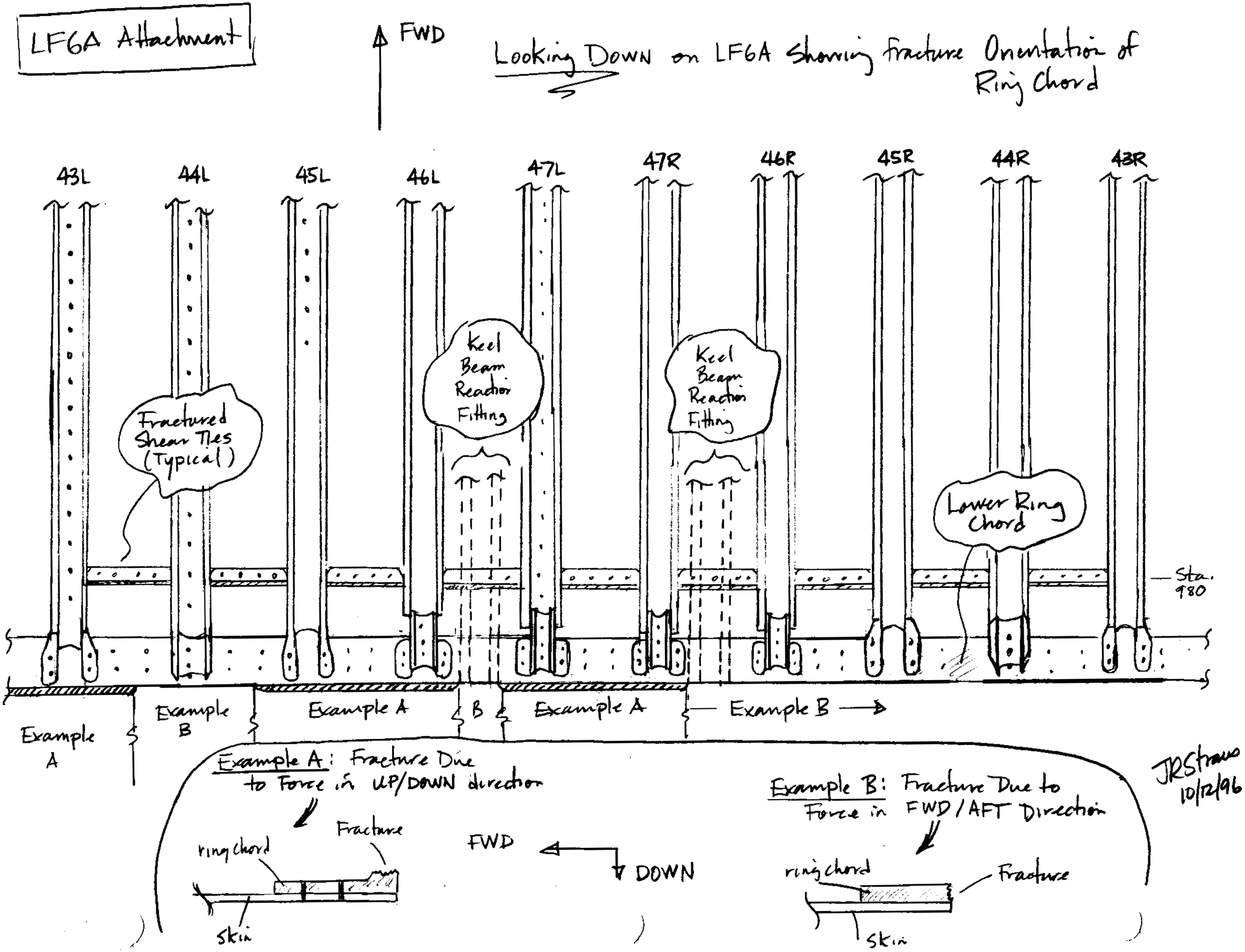
See Rev. A attached JRStraus 10/12/96

~~Lower surface of panel exhibited evidence of bowing INBD along the longitudinal axis.~~

Left side frames (left of S-45L) are completely missing.

The stringers at the FWD end of the panel exhibited evidence of tension fractures with no directional bending.

JRStraus 9/3/96
J. Zakar
[illegible] 9/11/96
SD GREEN 9-12-96
[illegible]



LF6A Attachment
FWD
Looking DOWN on LF6A Showing fracture Orientation of Ring Chord
43L
44L
45L
46L
47L
47R
46R
45R
44R
43R
Fractured Shear Ties (Typical)
Keel Beam Reaction Fitting
Keel Beam Reaction Fitting
Lower Ring Chord
Sta. 980
Example A
Example B
Example A
B
Example A
Example B
Example A: Fracture Due to Force in UP/DOWN direction
ring chord
Fracture
skin
FWD
DOWN
Example B: Fracture Due to Force in FWD/AFT Direction
ring chord
Fracture
skin
JRStraus 10/12/96

Revision A to LFGA

Sta. 990 Join with The Front Spar Underwing Bulkhead

- From the left side reaction fitting OUTBD the panel is flattened out from its original contour with the ring chord. The fracture in the ring chord at this location was due to loading predominately in the UP/DOWN direction but also some in the FWD/AFT direction (see attached Figure).
- The right side from the reaction fitting OUTBD maintained much more of its original contour with the ring chord. The fracture in the ring chord at this location was due to a FWD/AFT direction of loading.
- The remaining portion of the ring chord fractured due to an UP/DOWN direction of loading between the reaction fittings and FWD/AFT direction at the reaction fittings (see attached figure).

JR Straus 10/12/96

SD GREEN 11-13-96

Metallurgical Notes

Red Zone

LF55 A, B, C, D, E - Front Spar Underwing Bulkhead

- The stiffeners on the FWD surface of the bulkhead are bent forward with the most displacement on the upper part of the stiffeners attaching to the Wing Center Section front spar. This observation is consistent with a force being applied in the FWD/DOWNward direction. Significant twisting of the stiffeners is also present typical of compression buckling of a Z-shaped cross section. (per Arnie Reimer).

- The lower wing chord fractured in the radius by tensile separation. The direction of force causing the fracture can be seen in the attached sketch to LF6A.

JR Straub 10/12/96

SO GREEN 11-13-96

LH 12/12/96

<u>Metallurgical Notes</u>

Green Zone

LF 59 - LH Skin Panel, Sta. 910 - 960, S-14L to S-19L

- Frames and stringers are missing from this panel except a small piece of stringer 16L at Sta. 920 and S-19L between Sta. 920-960.

- All fracture surfaces examined exhibited no signs of any slow growth - Ductile separation only.

JRStraus 9/6/96
G. Zakar
RJ Stermer
SD Green 9-12-96
LH 12/12/96

Metallurgical Notes

Green Zone

RF51 - RH Side Panel Sta. 920 to Sta. 1000, S-24R to S-28R

- No frames remain attached to this panel.
- Stringer 26L at Sta. 960 fractured due to OUTBD bending.
- At Sta. 960 the skin panel is bent 180° OUTBD and AFT.
- A small puncture going OUTBD (from inside to outside fuselage) between Sta. 920-940, S-27R to S-28R exists. Area was cut-out for examination by the NTSB and FBI.

J.R. Straus 9/5/96

G Zakar 9-11-96

R.T. Stemmel 9-12-96

S D Green

LH 12/12/96

Metallurgical Notes

Green Zone

RF67 - RH Skin Panel Sta. 920-1000, S-28R - S-34R

- OUTBD and AFT bending at FWD lower portion of panel (See structures Notes)
- Sta. 940 & Sta. 980 frames are missing.
- At Sta. 1000 the ring chord is fractured above S-30R and below S-33R. The fractured ring chord segment still attached is bent INBD.
- All fracture surfaces were examined and found to be ductile separation (No evidence of any slow growth).

JR Straus 9/5/96
G. Zakan
RT Stetmke 9-11-96
SD Green 9-12-96
LH 12/12/96

Metallurgical Notes

Green Zone

RF 95 - RH Fuselage Panel, Sta. 940 - 1000, S-40R to S-35R

- The lower fracture along S-40R (mates to LF6A) exhibited evidence of net area tension from Sta. 1000 to just AFT of Sta. 940.

- Stringers 37R, 36R, 35R exhibited evidence of crushing damage from Sta. 960 FWD.

- At Stringers 38R, 39R, 40R the skin is pulled outward from Sta. 960 FWD.

- The exterior surface exhibits moderate "sooting" pattern.

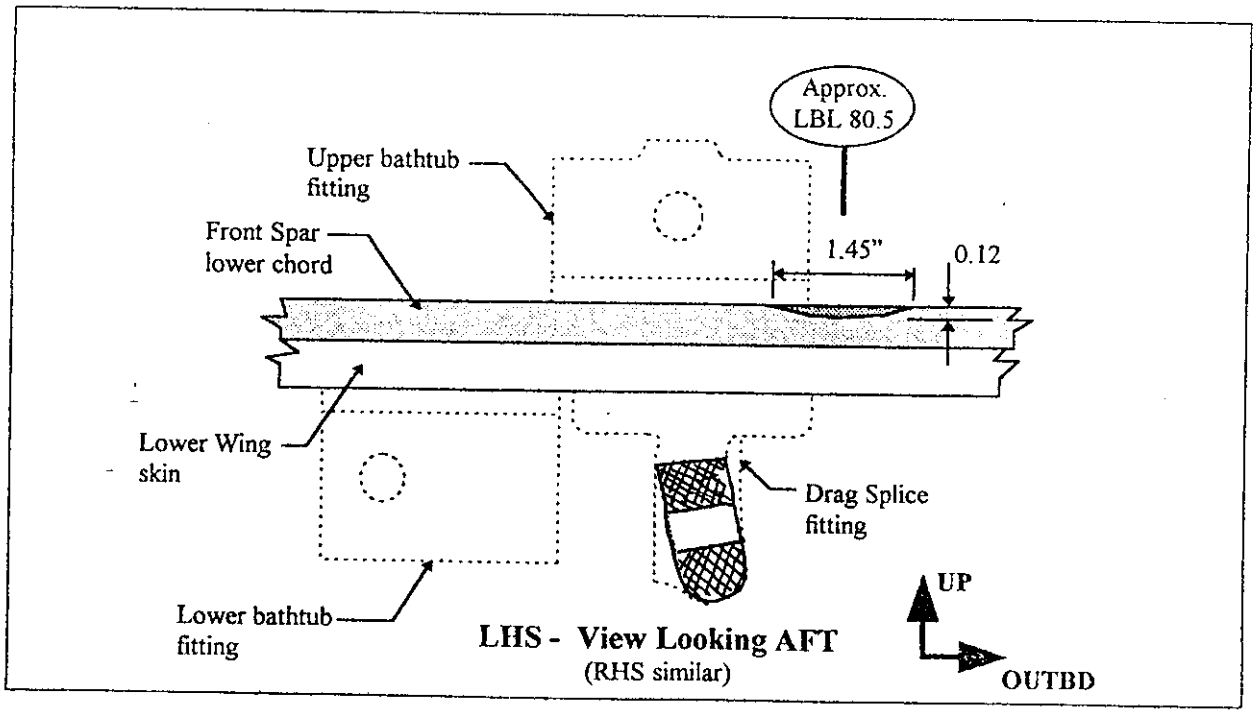
- All fracture surfaces exhibited evidence of ductile separation with no evidence of any slow crack growth mechanisms.

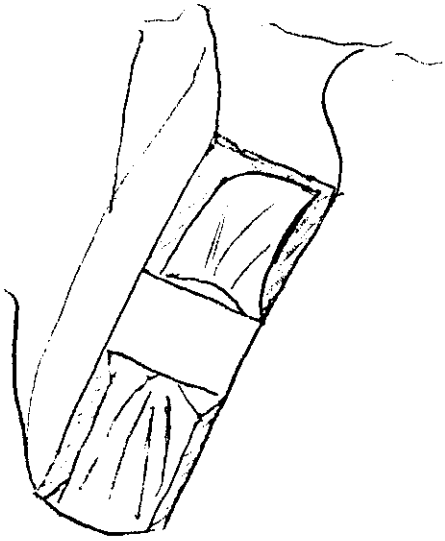
J. R. Straus 10/8/96
D. Zakar
SD GREEN 11-13-96
LH 12/12/96

RF 95
LF 51
(SEE ALSO CW 216 AND CW 221)

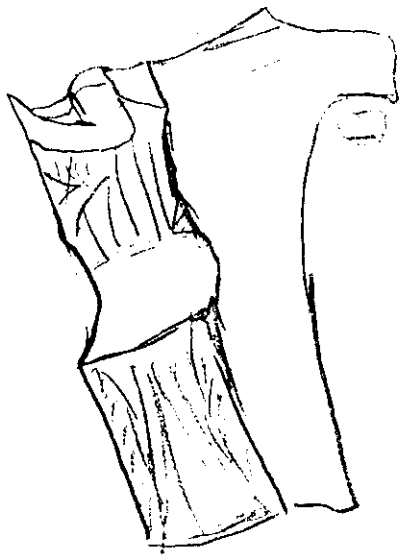
THE DRAG SPLICE BETWEEN THE FUSELAGE AND THE LOWER SKIN OF THE CWT WAS BROKEN AT THE FIRST ATTACHMENT BOLT IN THE FUSELAGE FITTING ON BOTH SIDES OF THE AIRPLANE. ON BOTH SPLICES, THE FRACTURE INITIATED FROM THE UPPER AND LOWER EDGES OF THE BOLT HOLE. OVERSTRESS FRACTURE WAS TYPICAL OF TENSION ~~OR~~ PERHAPS WITH SOME BENDING. DRAG SPLICE IS CROSS HATCHED IN DRAWING BELOW (BORROWED FROM FATIGUE SECTION OF METALLURGY BOOK).

JFW II 1/24/97 John Trgil 1/24/97



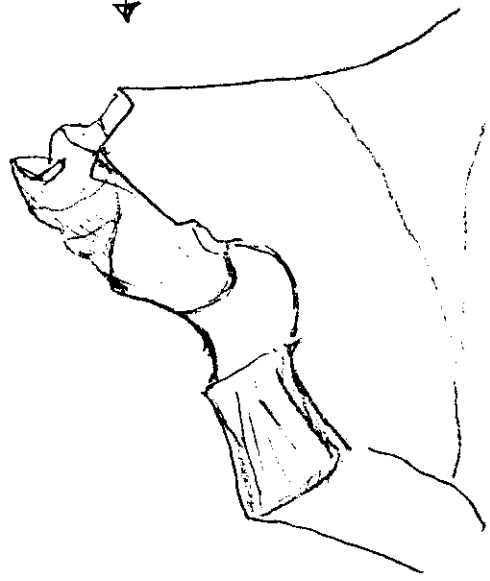


RBL 79
CW 216



SAME; BUT DIFFERENT VIEWS

LBL 79
CW 221



John Taylor
11/24/97

JFWell
1/24/97

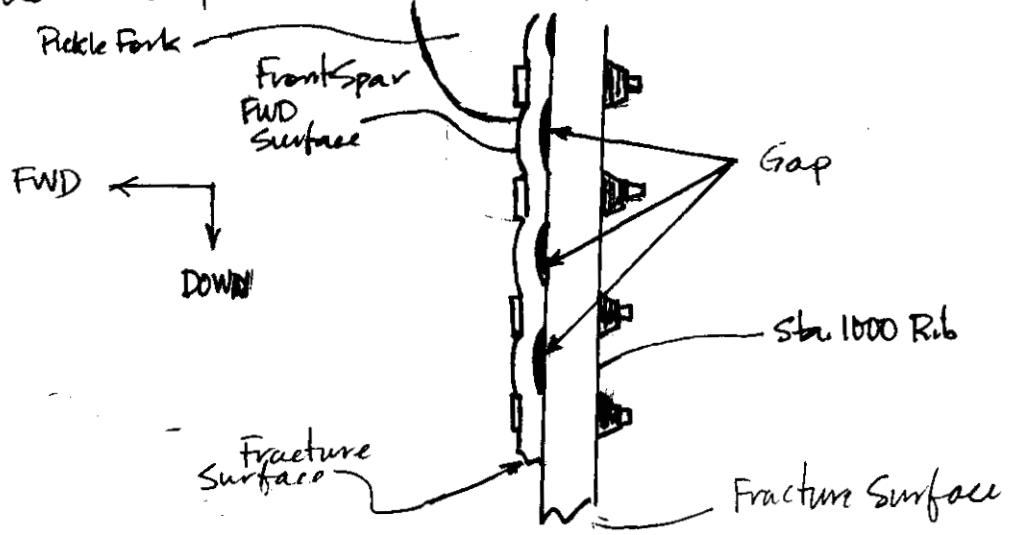
DRAG SPLICE FITTING FRACTURE FACES
(SEE ALSO RF95 AND LF51)

Metallurgical Notes

Green Zone

RF37 - RH Skin Panel, Sta. 930-1065, S-10R to S-27R

- The windows in this panel are no longer present
- Stringers at the FWD end from S-16R to S-20R exhibit signs of OUTBD/downward bending.
- Stringers 13R, 12R at Sta. 980 are bent upward and OUTBD.
- Stringer 19R AFT of Sta. 1020 exhibits multiple signs of compression damage.
- Impact damage is present on the skin and stringer at S-19L between Sta. 960-980.
- The skin and doubler at Sta. 980 on the upper surface of the panel are bent OUTBD.
- Sta. 1020 frame between S-19R and S-18R is bent AFT and shows compression damage at S-16R.
- Sta. 1000 bulkhead (frame) at S-11R, S-10R is twisted AFT. The joining skin is twisted as well.
- Center wing tank front spar adjacent to the pickle fork shows signs of AFT bending as a result of impact damage (Multiple witness marks). Remainder of front spar in this area is bent FWD.
- A gap in the FWD direction between fasteners exists on the front spar and rib at Sta. 1000 (See Sketch)



- No evidence of any slow growth (i.e. fatigue) exist on the Sta. 1000 bulkhead fractures (pickle fork, front spar, sta. 1000 rib). Most fractures are covered in soot.

- The upper longeron fitting at S-26R at Sta. 960 is bent upward. The mating surface on RF51 is bent in the same direction and shows signs of compression.

JRStraus 9/5/96
Frank Baker 9/1/96
R.J. Stettner 9/1/96
LH 12/12/96

Impact damage at S-196, FS 960-980 needs to be qualified.

SD Green ALPA 09-12-96

- APPROXIMATELY 1 in^2 PUNCTURE EXISTS IN STRINGER AND SKIN AT STATION 970 AND STRINGER 19R. DIRECTION OF PENETRATION IS OUTBOARD AND AFT, SLIGHTLY DOWNWARD.

9/13/96

- All remaining fracture surfaces were examined and no evidence of any slow crack growth (fatigue) existed. All fractures exhibited ~~ductile~~ features characteristic of ductile separation.

J.R. Straus 10/11/96
LH 12/12/96

Metallurgical Notes

Green Zone

LF 51 - LH Side Panel Segment, Sta. 940-1000, S-35L to 39L.

- Frames are missing from the panel segment
- Heavy crushing damage was noted from S-38L to S-35L
- The piece of the Sta. 1000 underwing bulkhead attached to the panel was bent FWD.
- The lower spar longeron reaction fitting at S-38L is bent INBD.
- Examination of fracture surfaces of the lower spar longeron fitting lug (still between the clevis of the reaction fitting) showed only ductile separation. Flow lines indicated fracture initiated at the fastener hole.

JR Straus 9/5/96
J Zakar 9.11.96
R.T. Sarrmel
SD Green 9-12-96
LH 12/12/96

Metallurgical Notes

Green Zone

LF38 - LH Fuselage Skin Panel, Sta. 940-1350, S-28L to S-2AR

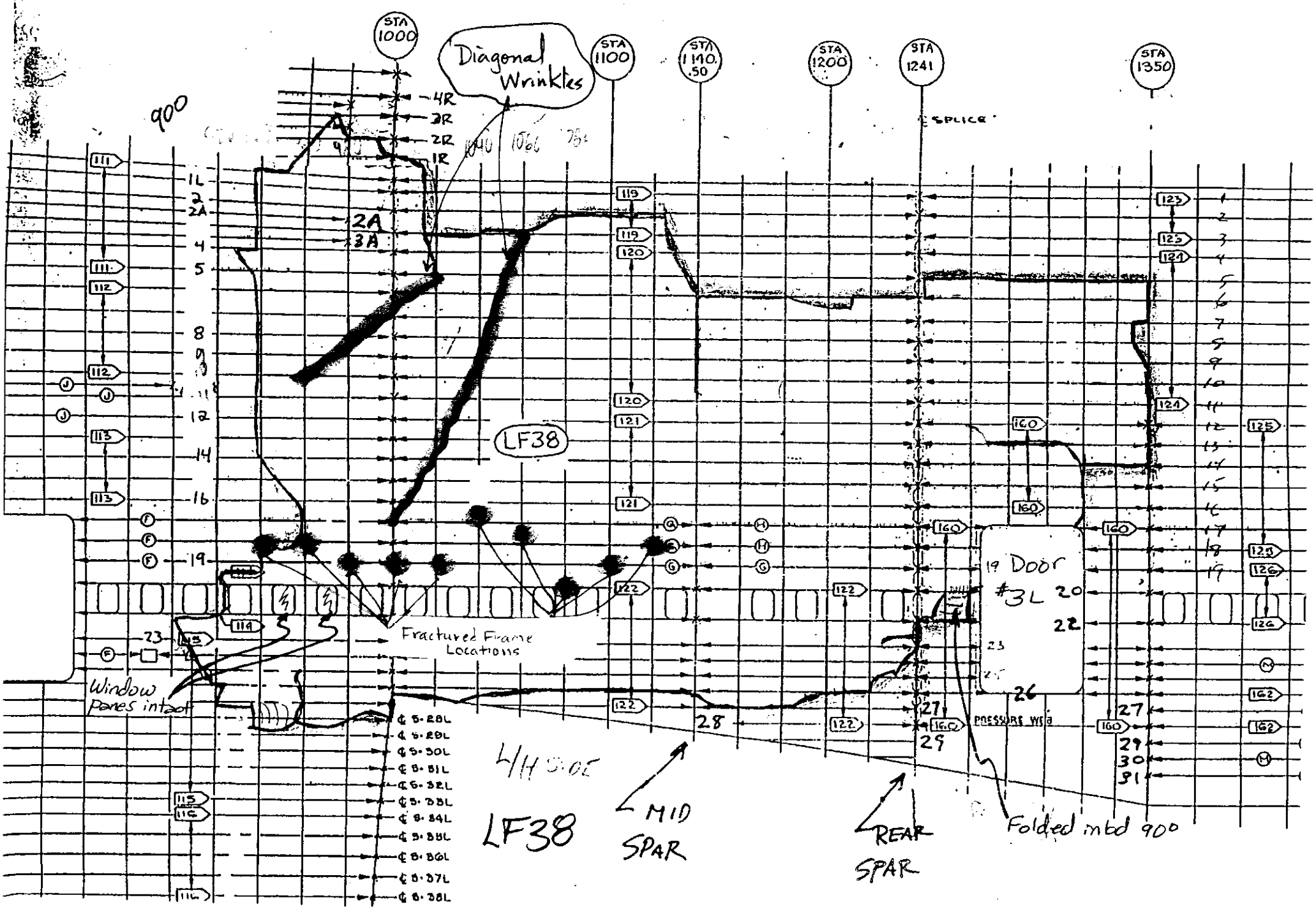
★ Note - This panel may have exhibited some damage as a result of handling during recovery.

- The frames were fractured as shown in the attached sketch.
- The frames are missing in many areas AFT of Sta. 1020 and above S-17L.
- A diagonal wrinkle exists in the panel from Stringer 3L at Sta. 1060 to Stringer 17L at Sta. 1000. The stringers in this area fractured by compression in line with the wrinkle,
- A diagonal wrinkle exists in the panel from stringer 10L at Sta. 960 to Stringer 5L at Sta. 1020, The stringers in this area fractured by compression in line with the wrinkle.
- The skin at Sta. 940 lap splice is pulled or torn off in the OUTBD direction. The rivet heads are pulled out and some skin pieces are still attached to the rivet heads.
- All fracture surfaces examined were ductile separation.

J. R. Strauss 9/4/96
Y. Zakar
R. J. [illegible] 9-11-96
SD Green 9-12-96
LH 12/12/96

SEC 42 | SEC 44

LF38



Metallurgical Notes — Green Zone

RF34 - RH & LH Skin Panel, Sta. 980-1160, S-11R to S-3L

- Sta. 1000 Bulkhead (Frame)
  - upper surface and mating skin splices exhibit evidence of OUTBD bending. Mating surfaces in LF38 exhibited the same features.
  - Lower surface fractures were documented under RF37.
  - No evidence of any fatigue cracking were present on these fractures.
- Frames from Sta. 1040-1160 are missing
- Crease beam shows multiple areas of compression damage.
- Stringers AFT of Sta. 1140 are missing except for random pieces: S-10R, S-3R, S-1L.
- Multiple compression fractures exist on the majority of stringers.
- A diagonal OUTward bend exists between Sta. 1000 at S-2R to Sta. 1160 at S-6R.
- AFT lower corner of skin panel S-7L to S-11L exhibits evidence of OUTBD/FWD bending.

J.R. Straus 9/5/96
K. Zakar
R.T. Slattery 9-11-96
SO Green 9-12-96
LH 12/12/96

- All fracture surfaces were examined and showed no signs of any slow growth cracking (i.e. fatigue). Fracture features were characteristic of ductile separation.

J.R. Straus 10/10/96
S) GREEN 11-18-96

Metallurgical Notes

Green Zone

RF23 - RH Skin Panel, Sta. 1020 - 1240, S-11R to S-19R

- AFT end of panel is bent OUTBD and FWD
- The frames FWD of Sta. 1100 are missing
- A diagonal wrinkle exists from Sta. 1060 at S-19R to Sta. 1080 at S-12R. Compression damaged stringers coincide with the wrinkled area.
- The stringers between Sta. 1140 and Sta. 1160 are compression damaged. A wrinkle following the contour of the frames coincides with the compressed stringers.

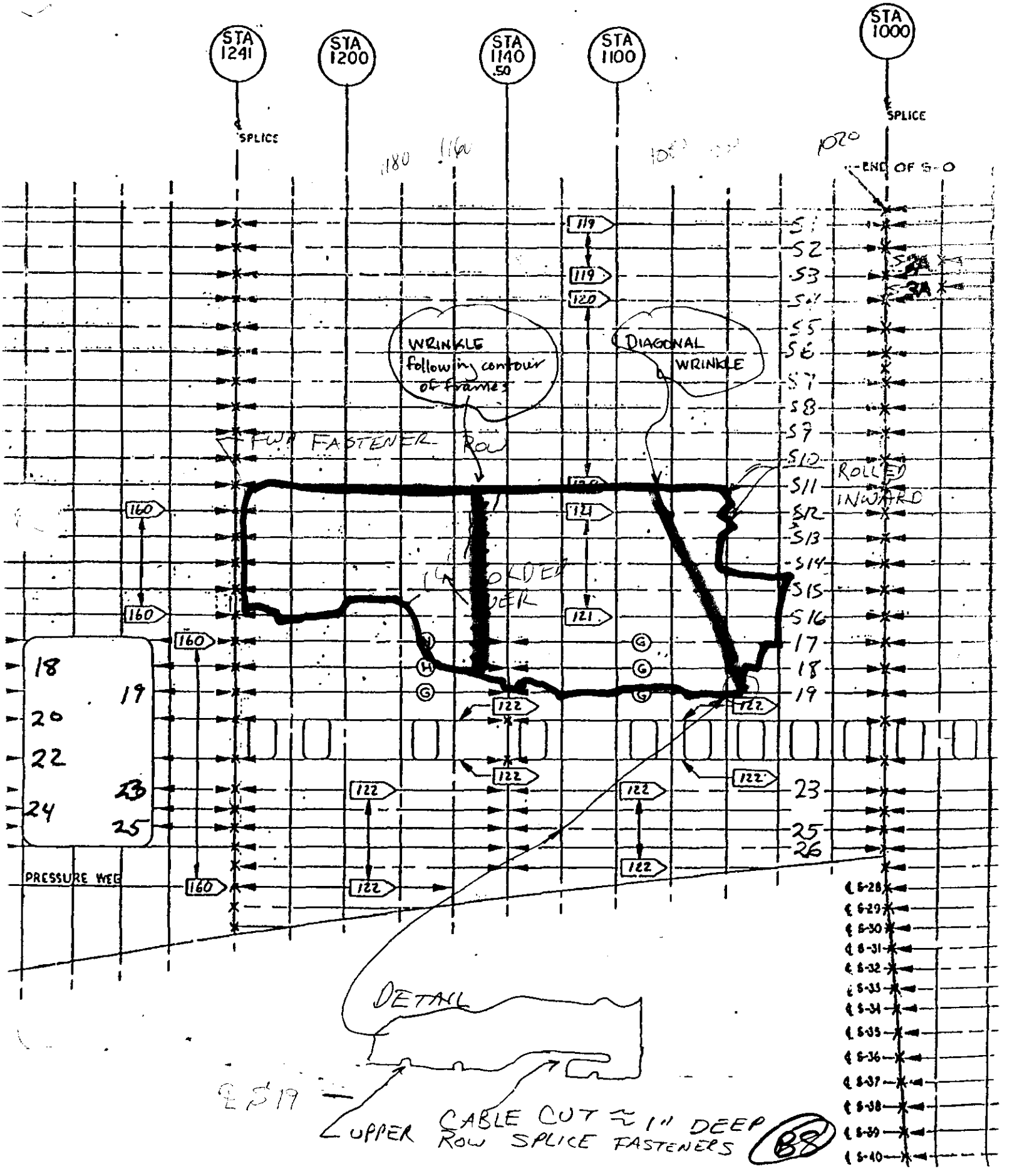
JRStrauss 9/5/96
G. Zakar
R.I. Stettner 9-11-96
SO GREEN
LH 12/12/96

- All fracture surfaces were examined and showed no signs of any slow growth cracking (i.e. fatigue). Fracture features were characteristic of ductile separation.

JRStrauss 10/16/96
SO GREEN 11-18-96

SIDE **RF23** RIGHT

RF-23



Metallurgical Notes

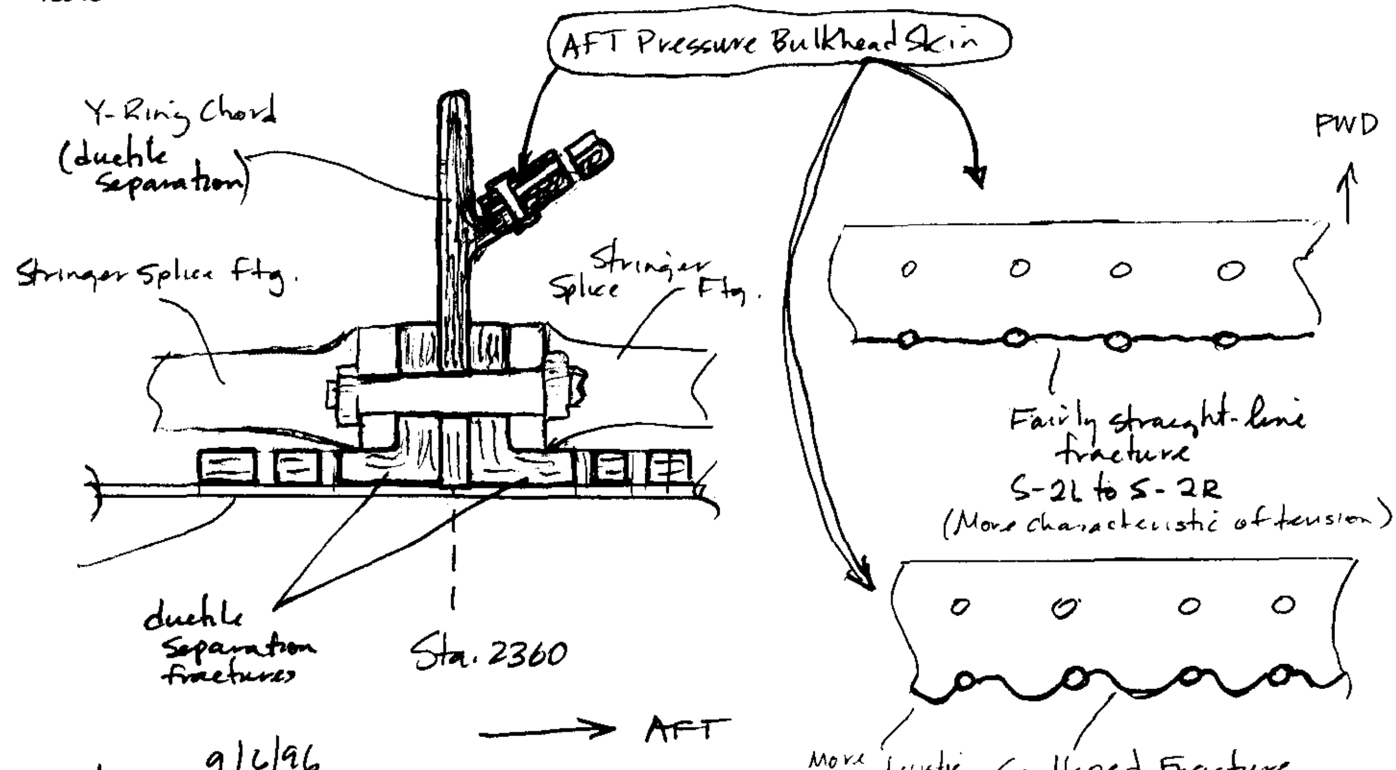
Green Zone

RF27 - RH Aft Body Skin, Sta. 2340-2360, S-8R to S-4R

&

LF26 - LH Aft Body Skin, Sta. 2285 to 2360, S-8L to S-24L

- All stringers on the FWD end of the panel fractured in tension based on the following observations:
  - fairly straight transverse fractures
  - elongated fastener holes in the FWD/AFT direction in the skin
  - No evidence of bending
- The Y-ring chord at Sta. 2360 is compressed below S-12L and at least below S-12R (Missing section from S-12R to S-7R). The Y-Chord fractured by ductile sepation in 4 places at S-4L, between S 4R & S 3R, S-9L & S-12L.
- AFT Pressure bulkhead skin is fractured along the AFT-most rivet line at Sta. 2360. See below for description of fracture line.



JR Strauss 9/6/96

[signature]

RJ Spencer 9-11-96 SD Green 9-12-96

LH 9/12/96

Metallurgical Notes

Green Zone

RF41 - RH & LH Skin Panel, Sta. 1135-1280, S-6L to S-11R

- The frames have separated from the panel except Sta. 1220, 1200, 1180 from Stringer S-1R to S-4R.
- The skin and Stringers FWD of Sta. 1220 from S-1L to S-5L, exhibit evidence of compression damage.

J.R. Straus 9/5/96
G. Zakar 9.11.96
R.T. Swaim 9.11.96
S O GREEN 9-12-96
[illegible]

Metallurgical Notes

Green Zone

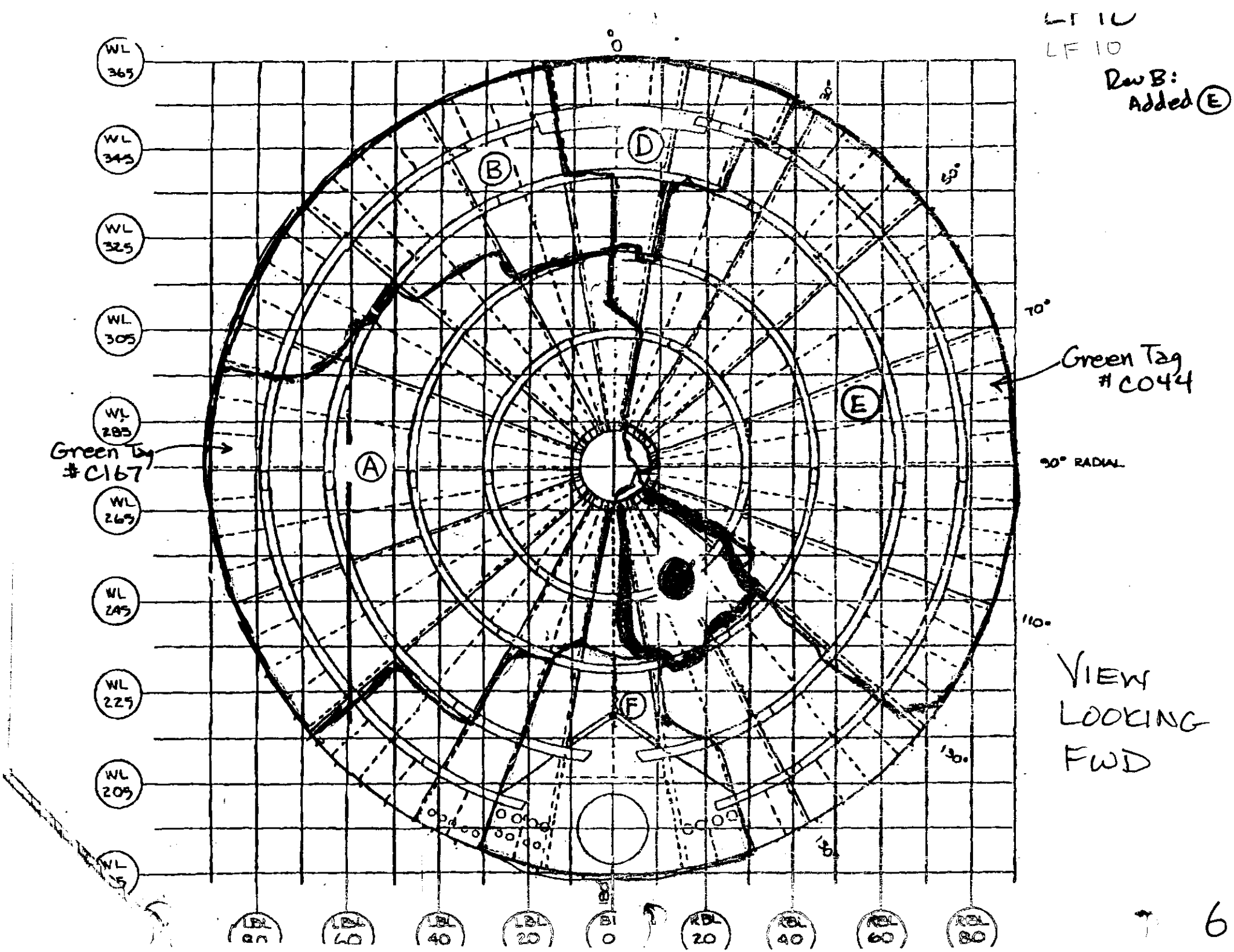
LF10 - AFT Pressure Bulkhead

- Extensive water impact damage on the bottom of the dome below transition from green primer to white enamel, (white enamel is on the bottom).

RF 55A - Tail Cone

- No evidence of compression damage on the bottom of the tail cone.
- Water Impact damage is on the right / AFT side
- Right side APU door support is bent in the OUTBD direction (RF 55C),

JRStrauss 9/6/96
[illegible] 9-11-96
R ISETTNER 9-11-96
S D GREEN 9-12-96
LH 12/12/96


LF 10
LF 10
Rev B:
Added (E)
WL 365
WL 345
WL 325
WL 305
WL 285
WL 265
WL 245
WL 225
WL 205
WL 5
0°
30°
50°
70°
90° RADIAL
110°
Green Tag #C044
Green Tag #C167
A
B
D
E
F
LBL 60
LBL 40
LBL 20
BL 0
RBL 20
RBL 40
RBL 60
RBL 80
VIEW LOOKING FWD

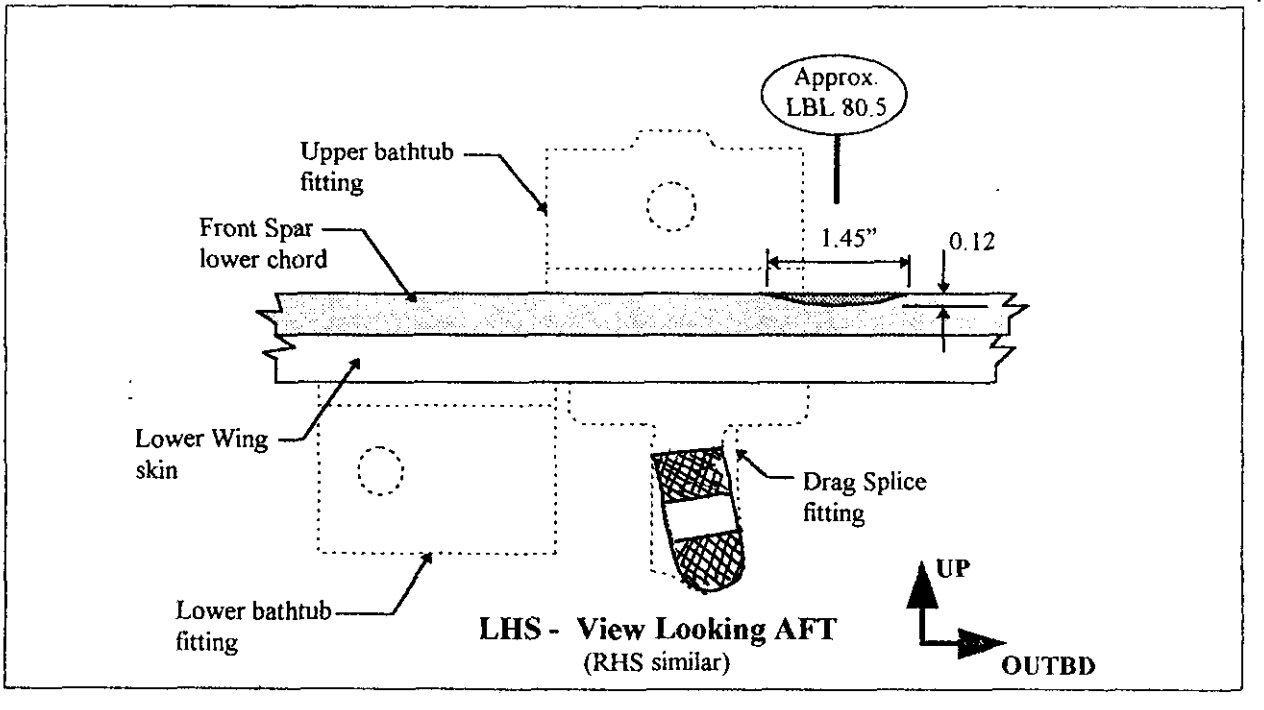
GREEN

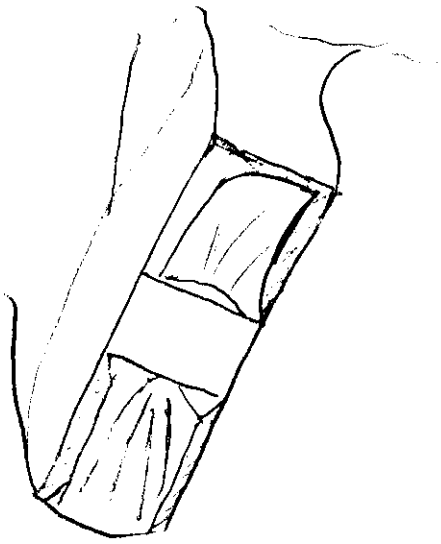
LF 51

RF 95
LF 51
(SEE ALSO CW 216 AND CW221)

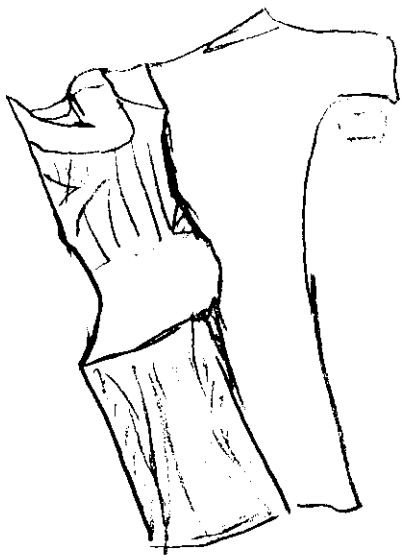
THE DRAG SPLICE BETWEEN THE FUSELAGE AND THE LOWER SKIN OF THE CWT WAS BROKEN AT THE FIRST ATTACHMENT BOLT IN THE FUSELAGE FITTING ON BOTH SIDES OF THE AIRPLANE. ON BOTH SPLICES, THE FRACTURE INITIATED FROM THE UPPER AND LOWER EDGES OF THE BOLT HOLE. OVERSTRESS FRACTURE WAS TYPICAL OF TENSION ~~OF~~ PERHAPS WITH SOME BENDING. DRAG SPLICE IS CROSS HATCHED IN DRAWING BELOW (BORROWED FROM FATIGUE SECTION OF METALLURGY BOOK).

JFW II 1/24/97 John Trail 1/24/97



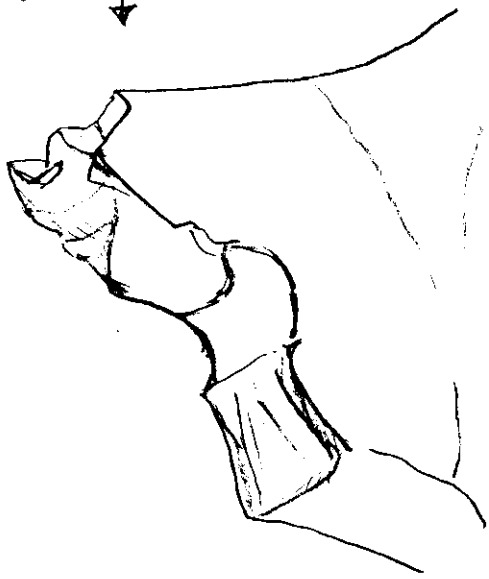


RBL 79
CW 216



SAME; BUT DIFFERENT VIEWS

LBL 79
CW 221



John T-J
11/24/97

JFWell
1/24/97

DRAG SPLICE FITTING FRACTURE FACES
(SEE ALSO RF95 AND LF51)

Metallurgy Group Notes - Keel Beam Study

October 9, 1996

Examined the keel beam consisting of LF14A , LF 14B, and LF14C to determine the mode of separation from the airplane. The lower chord fractures at Sta. 990, Sta. 1151.95 and Sta. 1255 were the result of downward/forward bending. (A)

Section LF14A and deformation of the attach bolts at spanwise beam 3, 2 and mid spar

The ductile fractures of the two lower chords of the forward portion of the keel beam at the front spar exhibited deformation flow marks indicative of a fracture originating at the top surface due to downward bending.

All the bolts on the upper surface of the keel beam that attach the front spar, spanwise beam no. 3, 2 , and the midspar, remained attached to the keel beam. Examination of the four bolts attaching the front spar chord to the keel beam revealed no evidence of bending deformation, whereas, the exposed bolts for spanwise 3, 2, and the midspar showed bending deformation in the aft direction.

The ductile fractures of the two lower chords of the aft portion of the keel beam (STA 1151.95) exhibited deformation flow marks converging toward the upper surface of the fracture indicative of downward bending.

The top of the web on each side of the center line was bowed outward 9.5" ~~approximately 1 foot~~ forward of SWB 2 location and contained a diagonal wrinkle that starts from the top of the keel beam and extends down and forward ~~halfway down the box~~. one stiffener bay. The outward bow and diagonal wrinkle were characteristic of compression buckling. (A)

Section LF14B & 14C

The keel beam at the rear spar location contains two vertical stiffeners that are attached to the rear spar structure. The left vertical stiffener was twisted INBD and AFT above the lower wing skin. The right vertical stiffener above the lower wing skin contained a fragment of the rear spar web which was bent in the AFT direction.

A portion of the lower skin for the wing center section at the rear spar remained attached to the right side of the keel beam. This portion of skin was bent AFT.

The fracture at Sta. 1255 (left side of lower chord) initiated at the top surface of the left chord and was due to ductile separation due to downward bending.

The AFT fracture of the keel beam at Sta. 1338 was due to ductile separation typical of a over stressed condition. The direction of fracture/deformation was not clear.

See the attached Figure for a graphical representation of the noted conditions.

Frank P. Zakar 10-9-96

Frank Zakar, NTSB Metallurgist

James R. Straus 10-9-96

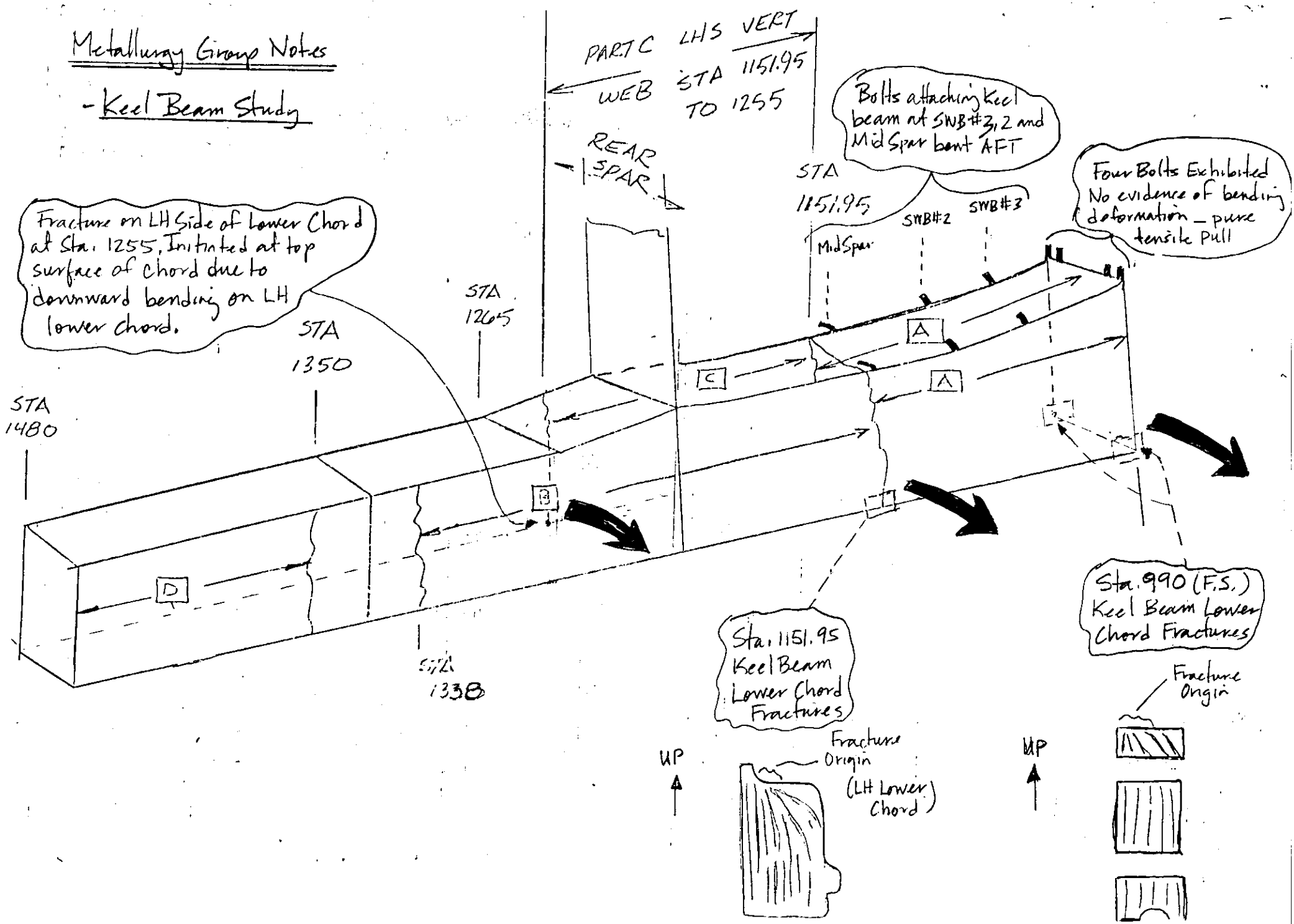
James Straus, Boeing Metallurgist

reviewed 10-27-96
SO Green ALPA

Rev. (A) - J.R. Straus 10/12/96

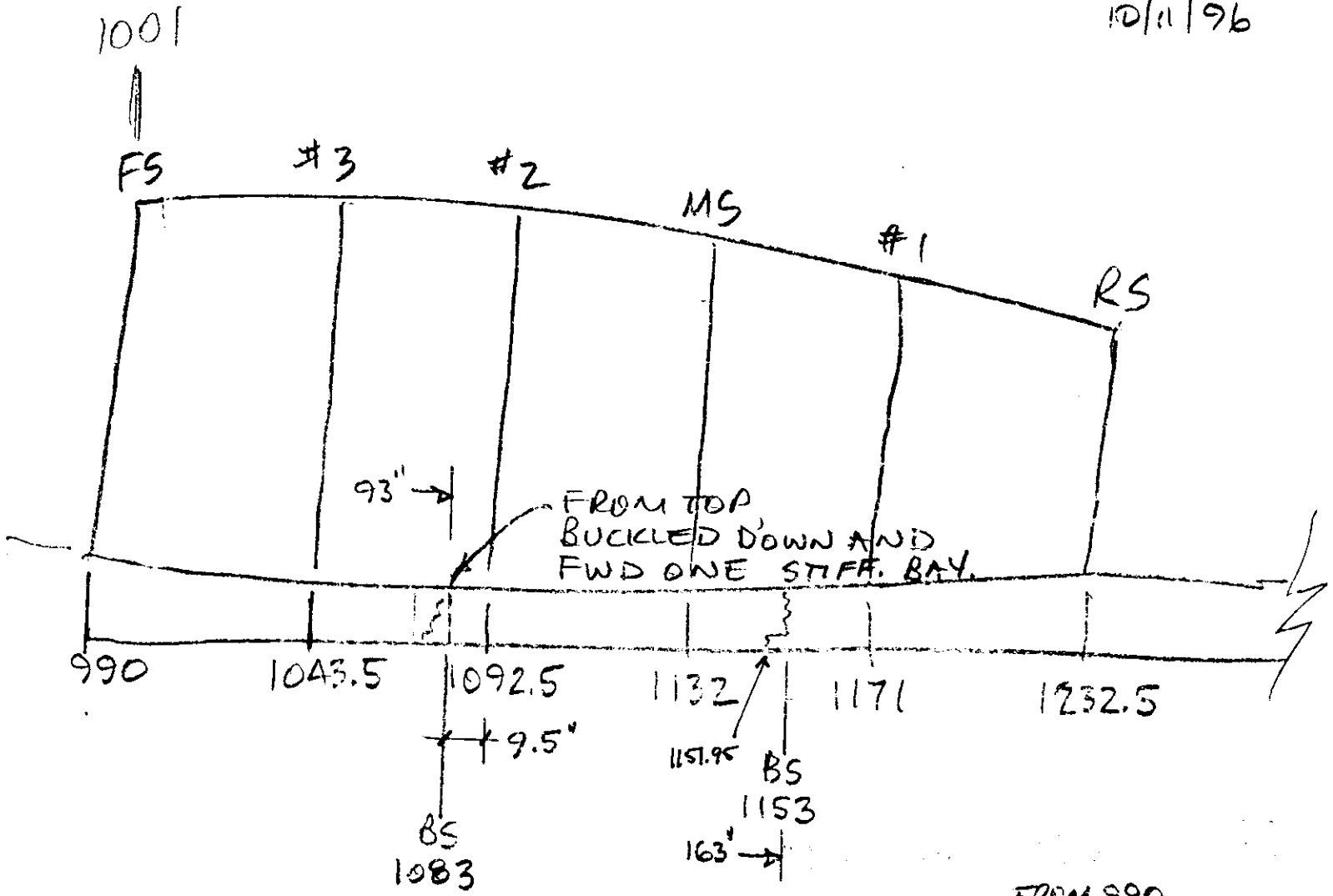
Metallurgy Group Notes

- Keel Beam Study



LF.4

A REIMER
10/11/96



		FROM 990
RH	UPR KB CHORD SKIN LEG FRACTURED	90 → 96" (6")
LH	" " " "	77 - 96 (19")
RH	BUCKLE 3/4" DEEP } BOTH OUTWARDS @ TOP	
LH	" 1" " }	