NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety

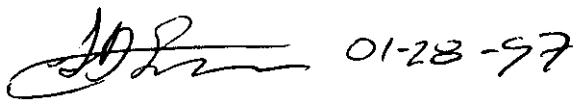
Washington, DC 20594

January 20, 1997

STRUCTURES GROUP

WING CENTER SECTION SHEAR TIE FACTUAL SUMMARY

ACCIDENT	:	**DCA96MA070**
Location	:	**East Moriches, New York**
Date	:	**July 17, 1996**
Time	:	**2031 Eastern Daylight Time**
Airplane	:	**Boeing 747-131, N93119**
		Operated as Trans World Airlines (TWA) Flight 800

GROUP	Name/Organization	
Chairman	Deepak Joshi NTSB Washington, DC	
Member	Arnie Reimer Boeing Commercial Airplane Group Seattle, WA	
Member	Steve Green Air Line Pilots Association (ALPA) Herndon, VA	
Member	Dan Rephlo Trans World Airlines (TWA) Kansas City, MO	

SHEAR TIE STUDY FACTUAL SUMMARY

A study was conducted to determine the motion of the frontspar, mid spar, and spanwise beams No. 3, 2, and 1, relative to the upper and lower skins. Where applicable, the shear tie bolt holes were examined for deformation or witness marks, deformation to bolts attaching shear ties to the chords or skins, and deformation to the chord fastener holes. Of 213 shear ties and 48 tension fittings associated with the spanwise beams, 124 shear ties and 41 tension fittings were recovered. While a number remained attached to the stiffeners, the majority remained attached to the chord or skin, as appropriate.

In addition, the bolts and bolt holes associated with the vertical (web) faces of the tension fittings installed on the upper skin beneath the floor beams were evaluated for deformation.

UPPER SKIN

Front Spar

Of the twenty nine shear ties associated with the front spar upper section, twenty seven were recovered. Those at LBL 114.93 and RBL 114.93 were not recovered. The upper spar chord horizontal flange at LBL 114.93 was missing. The shear ties at LBL 106.72 and 98.48 remained attached to the upper skin with all the bolts. No direction or deformation was observed. Between LBL 95 to the center of the center fuel tank, all of the shear ties were accounted for; several remained attached to the stiffeners while the remainder fractured and remained with the skin. The upper chord bolt holes associated with the shear ties exhibit evidence of forward deformation in nearly all the shear tie locations and the bolts that remained with the shear ties at LBL 57.40, 49.60, 41.77 and 18.13 exhibit evidence of aft bending. The shear tie chord attachment flange at LBL 75.82, 57.40, 33.89 and 11.31 remained attached to the skin with the flange lifted away from the chord on the aft side. One or more aft bolts of the shear ties from LBL 66.65 to LBL 41.77 and LBL 26.03 and LBL 18.13 exhibit tensile pull-out and there is no lateral deformation on the bolts.

The shear ties remained with the stiffeners between RBL 11.31 and RBL 49.60, and at RBL 66.65. One or more forward bolt holes in the upper chord exhibited deformation in the forward direction between the center of the tank and RBL 26.03, as

well as at RBL 41.77, 49.60 and 66.65. The aft pair of bolts at RBL 18.13 and 26.03 exhibit no deformation. At RBL 33.89 all four bolts remained with the shear tie that is attached to the stiffener and the bolts exhibit no deformation. The shear ties at RBL 57.40 and between RBL 75.82 to RBL 106.72 remained with the upper skin and the aft edge is lifted off the chord except for RBL 106.72. The shear tie at RBL 114.93 is missing and all of the three fasteners are fractured with stubs remaining in the upper chord. Witness marks are evident forward of these bolt holes. The outboard half of the shear tie at RBL 91.14 remained attached to the stiffener. The forward hole in the stiffener shear tie was elongated aft; the aft bolt was bent aft and inboard.

Spanwise Beam #3

In spanwise beam #3 the shear ties are attached to the upper and lower chords by two bolts, with the exception that on the upper chord along the passenger floor beam locations a tension fitting, with one large diameter bolt is used to attach the stiffener to the chord. There are nineteen shear ties and ten tension fittings associated with the upper skin. All of the tension fittings were recovered. The associated stiffeners where a tension fitting is used, remained attached to the skin and had separated approximately 6" below the inside surface of the upper skin. No deformation of the bolt or the bolt hole was observed.

With the exception of that at LBL 25.26, no shear ties were found which corresponded to specific upper skin locations. At least one shear tie which corresponded to spanwise beam no. 3 was found, but could not be associated with a specific position. Generally, the bolt holes in the upper chord which correspond to the shear tie between LBL 83.24 to RBL 106.20 exhibited deformation in a forward direction. Two upper chord bolt holes of the shear tie at RBL 112.39 exhibit no deformation on the bolt holes.

At the lip of the upper chord vertical flange, which remained after the chord had fractured, witness marks were noted forward of several shear ties. These marks were caused by the shear tie fasteners after they had withdrawn from the holes in the upper chord skin flange. Often, no evidence of continuous contact between the bolt and the skin flange was exhibited on the flange material between the bolt hole and the witness marks. Generally, these marks indicated that the shear ties near BL 0 had translated forward with no lateral movement, and those farther outboard of BL 0, on either side, had translated forward and slightly inboard. On the right side at LBL 66.65 and 83.24, the witness marks show bolt translation approximately 30 degrees inboard from the original position.

Spanwise Beam #2

Spanwise beam #2 uses nineteen shear ties and ten tension fittings in the upper surface. Of these, nine shear ties and nine tension fittings were recovered. From LBL 112.39 to LBL 91.14, all the shear ties are missing and the direction of the hole deformation could not be determined. Bolt holes at LBL 83.24, 49.60, and 41.77 of SWB2 exhibit evidence of forward outboard or forward inboard deformation. At LBL 17.27, the shear tie remained with the stiffener and retained both bolts. The forward hole on the upper chord associated with this shear tie exhibited no deformation. The aft bolt hole exhibited aft outboard deformation. The tension fittings at RBL 33.97 and RBL 57.48, along with the shear ties at RBL 41.77 and RBL 49.60, remain attached to the upper chord and to a considerable length of stiffener. These stiffeners comprise the "curtained" area of spanwise beam #2. All of the remaining shear ties on the right side are attached to the upper chord. The shear tie at RBL 112.39 is lifted away from the upper chord on the inboard side. Three of the six bolt holes between BL 0 and RBL 25.26 exhibited no deformation, except RBL 25.26 shows forward inboard deformation.

Mid Spar

Of eight shear ties and ten tension fittings associated with the mid spar, only seven shear ties and nine tension fittings were recovered. Of these, one (LBL 17.27) exhibited evidence of gapping from the upper chord at the aft end. Two tension fittings remained attached to the stiffeners at RBL 34.00 and RBL 57.51. The upper chord bolt hole at RBL 34.00 is elongated inboard. The hole in the tension fitting at RBL 57.51 is elongated forward and outboard. The shear tie at LBL 44.65 and the tension fitting at LBL 34.00 are missing. The skin hole at LBL 34.00 for tension fitting was elongated forward.

Spanwise Beam #1

Along SWB1, eight of sixteen shear ties and all of the ten tension fittings were recovered. All of the recovered tension fittings remained attached to the upper skin with the stiffeners fractured below the tension fitting. The inboard skin attachment flange bolt holes associated with the shear ties at LBL 106.20 and 83.24 exhibit forward elongation/aft motion of shear tie. The bolts holes at LBL 91.14 exhibit no deformation. The bolts in the upper skin associated with the shear ties at LBL 66.65, 49.60 and 41.77 exhibit slight aft bending. At LBL 17.27, the bolts are retained by the stiffener and exhibit no deformation, and the bolt holes in the skin exhibit aft deformation. The bolt holes in the upper skin associated with the shear tie at RBL 17.27 exhibit straight aft

elongation. The holes at RBL 49.60 exhibit no deformation. The bolts at RBL 41.77 exhibit no deformation. The outboard bolt hole at RBL 83.24 exhibits aft and slightly outboard deformation. The inboard bolt hole at RBL 91.14 exhibits straight aft deformation. The outboard bolt hole at RBL 91.14 exhibits forward outboard deformation.

UPPER SKIN TENSION FITTINGS

The vertical faces of the tension fittings associated with spanwise beams 3 and 1 were evaluated for deformation. The tension fittings are only installed on the upper skin at locations common to the floor beams. The bolt holes exhibited deformation which was consistent with vertical and/or lateral loads applied simultaneously with the longitudinal loads which resulted in the bolts withdrawing from the shear ties. The vertical face of the tension fittings on spanwise beam #3 face forward to mate with the web; thus the bolt withdraw occurred as the beam web moved forward. The vertical face of the tension fittings on spanwise beam #1 face aft to mate with the web; thus the bolt withdraw occurred as the beam moved aft.

Generally, the bolt holes on the vertical faces of those fittings recovered from spanwise beam #1 exhibit downward deformation with somewhat random lateral deformation. The holes on the vertical faces of the fittings recovered from spanwise beam #3 exhibit downward deformation with no lateral component at BL 0, and an outboard component to the downward deformation which becomes more pronounced with distance from BL 0 (except for RBL and LBL 98).

LOWER SKIN

Front Spar

Of twenty five shear ties associated with the front spar lower section, all but those at BBL 0, inboard half of RBL 18.13, and RBL 91.14 were recovered. Portions of the shear ties at LBL 66.65, 57.40, 49.60, RBL 26.03, 57.40 and 66.65 remain attached to the stiffeners; the remainder of these shear ties, as well as all other recovered shear ties, are attached to the lower chord. The aft edges of shear ties between LBL 98.48 and RBL 8.94, with the exceptions of those at LBL 91.14, 83.24, and 49.60, have lifted away from the chord. Those at RBL 41.77, 49.60, and the inboard half of 57.40 have also lifted away from the lower chord. The fastener holes associated with the chord attachment flange on the portions of shear ties remaining attached to the stiffeners at LBL 66.65, and 57.40 exhibited deformation in the aft direction. The fastener holes associated with

the chord attachment flange on the portions of shear ties remaining attached to the stiffeners at RBL 57.40 and 66.65 exhibited deformation in the forward direction. One or more fasteners at RBL18.13, 26.03, and 66.65 exhibit no deformation.

Spanwise Beam #3

Sixteen of twenty seven shear ties associated with spanwise beam #3 were recovered; of these, all remained attached to the stiffeners except those at LBL 98.56 and 49.60, and at RBL 98.56. The two tension fittings at LBL/RBL 8.94 remained attached to the stiffener and were separated from the skin The shear ties at LBL 98.56 and RBL 98.56 exhibit a gapping of the aft edges away from the chord. The shear ties which were retained by the stiffeners did not retain any bolts; however, the deformation of the bolt holes in the chord attachment flanges is in the forward direction. The lower chord retained the shear tie attachment bolts at LBL 112.39, 106.20, 91.14, and 83.24. These bolts are bent aft and slightly inboard (lower shear tie moved aft, top of beam moved forward). The lower chord also retained three of six shear tie attachment bolts at RBL 106.20, and 112.39. The bolt deformations at these sites are aft and inboard. The three empty bolt holes at these sites exhibit deformations that was also aft and inboard. The bolt holes on the lower chord from LBL 8.94 and RBL 8.94 exhibit no deformation.

A portion of the web from approximately LBL 120 to 30, approximately RBL 20 to 55, and approximately RBL 110 to 120 remained attached to the lower skin at SWB3. The web was generally deformed in the forward direction.

Spanwise Beam #2

A total of eight shear ties out of twenty seven and both tension fittings were recovered which were associated with the lower portion of spanwise beam #2. Of these, six were still attached to the lower chord. Those located at LBL 83.24 and 66.65, RBL 25.26 and 112.39, and the tension fitting at LBL 8.94, exhibited no deformation below the stiffener flange fracture. The tension fitting at RBL 8.94 has lifted away from the lower chord at the aft edge. The shear ties at LBL 112.39, 106.20, 75.90, and 57.48 remained attached to the stiffeners. The bolt holes in the chord attachment flanges of the shear tie at LBL 57.48, and the outboard hole at LBL 75.90 exhibit deformation in the aft inboard direction. The outboard bolt hole in the lower chord at LBL 112.39 shows outboard forward deformation; the inboard hole shows aft inboard deformation. The outboard hole in the lower chord at LBL 106.20 shows aft outboard deformation; the inboard hole shows forward inboard deformation. The one surviving bolt hole in the lower chord at LBL 17.27 exhibits no deformation. The inboard bolt hole at RBL 17.27

exhibits aft deformation. At RBL 33.97, the inboard bolt hole exhibits no deformation; the outboard bolt hole shows forward inboard deformation. The bolt holes at BBL 0 exhibit no deformation.

Mid Spar

Of sixteen shear ties and two tension fittings associated with the lower mid spar, seven complete shear ties, one partial shear tie, and both tension fittings were recovered. Those at LBL 98.59, 87.26, 66.65, 57.51, 44.65 and 34.00 remained attached to the lower chord. The shear tie at LBL 17.27 is fractured through the chord attachment flange and only the aft inboard portion remains. The tension fitting at LBL 8.94 remains attached to the stiffener, but the bolt hole has damage at inboard forward side. The tension fitting at RBL 8.94 is also attached to the stiffener and shows no deformation in the bolt hole. A bolt hole in the lower chord at RBL 17.27 exhibits no deformation. The inboard bolt hole in the lower chord at RBL 44.65 is elongated aft and outboard. The bolt holes in the lower chord at RBL 57.51 are deformed forward and inboard. The inboard bolt hole at RBL 66.65 is similarly deformed; the outboard hole at this station exhibits no deformation. The shear tie at RBL 98.48 remains attached to the lower chord.

Spanwise Beam #1

Eighteen of twenty seven shear ties associated with spanwise beam #1 were recovered. Both tension fittings at LBL/RBL 8.94 were recovered. The shear ties at LBL 75.93, 112.39 and RBL 17.27, 25.26, 34.00, ~~48.59~~, 106.20, and 112.39 are still attached to the lower skin and exhibit no directionality. The tension fitting at LBL 8.94 also remains attached to the lower skin and also shows no directionality. The shear ties at LBL 106.20, 98.59, 91.14, 83.24, 57.51, 49.60, 41.77, 25.26, 17.27, and RBL 41.77 all remain attached to the respective stiffeners. The bolt holes in the skin attachment flanges all exhibit deformation in the aft direction with varying and slight inclinations either inboard or outboard. The bolt holes in the lower skin at LBL 66.65, 34.00, RBL 57.51 through 75.93 all exhibit forward deformations or no deformations at all. The shear tie at LBL 17.27 remains attached to the stiffener, and the bolt hole in the chord attachment flange exhibit aft deformation. However, the outboard bolt is retained by the lower skin, and this bolt is bent more than thirty degrees in the outboard and slightly aft direction. A similar bend is seen in the outboard bolt at RBL 49.60, which is retained in the lower skin. This bolt is bent inboard and slightly forward. The shear ties at LBL 75.93, RBL 98.59, and the tension fitting at RBL 8.94 all are lifted away from the lower skin at the forward edge. The shear tie at LBL 49.60 is retained by the stiffener, and the associated bolts are fractured mid shank. The fracture directions are aft. From approximately LBL 127 to RBL 40, a portion of the beam web remains attached to the lower chord.

ARROW ORIGINATING AT THE BOLT/BOLT HOLE INDICATES THE DIRECTION THAT THE SHEAR TIE MOVED RELATIVE TO THE SKIN. THE COLOR OF THE ARROW INDICATES THE STRUCTURE FROM WHICH THIS DIRECTION WAS DERIVED.

BLUE IDENTIFIES FEATURES ASSOCIATED WITH AND/OR INFORMATION DERIVED FROM THE INDIVIDUAL STIFFENER.
MAGENTA IDENTIFIES FEATURES ASSOCIATED WITH AND/OR INFORMATION DERIVED FROM THE CENTER TANK SKIN.

RED ARROW (NOT SHADED IN) INDICATES A FAILURE DIRECTION DERIVED FROM EXAMINATION OF THE BOLT SHANK FRACTURE.

GREEN ARROW (SWB #3 ONLY) INDICATES A FAILURE DIRECTION DERIVED FROM WITNESS MARKS ON LIP OF CHORD VERTICAL FLA

ARROW POINTING TO A SHEAR TIE INDICATES THE DIRECTION THAT THE SHEAR TIE WAS OBSERVED TO BE LIFTED OFF OF THE SPAR CHORD.

LARGE CIRCLE INDICATES NO DIRECTIONAL INFORMATION COULD BE DERIVED FROM THE BOLT/BOLT HOLE.

SQUARE INDICATES A SHEAR TIE CHORD FLANGE. MAGENTA SQUARE –> SHEAR TIE CHORD FLANGE AND RESPECTIVE SPAR CHORD ARE ATTACHED; BLUE –> ENTIRE SHEAR TIE ATTACHED TO STIFFENER; BLUE AND MAGENTA CONCENTRIC SQUARES –> SHEAR TIE ATTACHED TO RESPECTIVE SPAR CHORD AND COMPLETE STIFFENER. PORTIONS OF THE SQUARE MAY BE OMITTED TO ILLUSTRATE MISSING SHEAR TIE CHORD FLANGE STRUCTURE. MISSING SHEAR TIE STIFFENER FLANGE INFORMATION NOT SHOWN.

SMALL CIRCLE INDICATES A BOLT HOLE. IF IT IS COLORED, THEN THE BOLT IS STILL PRESENT IN THE STRUCTURE IDENTIFIED BY THE COLOR. IF IT IS NOT FILLED IN, THEN THE BOLT IS MISSING.

INDICATES A FRACTURED FASTENER WITH PORTIONS STILL PRESENT IN THE STRUCTURE. THE COLOR INDICATES WHICH STRUCTURE EACH PORTION IS FOUND IN.

INDICATES BOLT FAILURE UNDETERMINED

SOLID LINE PARALLEL TO THE SPAR INDICATES SURVIVING SPAR WEB STRUCTURE.
SMALL ARROW INDICATES THE DIRECTION THAT THE SURVIVING SPAR WEB STRUCTURE IS BENT.

FOOTNOTE:

1. BOLT HEADS LIFTED OFF FLANGE
2. BOLT SHANK BENT MORE THAN APPROX. 30 DEGREES

Center Fuel Tank Area
Shear Tie Separation Patterns

Key

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1. 

THIS SHEAR TIE USES TWO BOLTS TO ATTACH IT TO THE SKIN FLANGE. IN THIS CASE, BOTH BOLTS STILL ATTACH THE SHEAR TIE TO THE SKIN, AND NO DIRECTIONALITY IS EVIDENT.

2. 

THIS SHEAR TIE USES FOUR BOLTS TO ATTACH IT TO THE SKIN FLANGE. ALL ARE PRESENT. THE ARROW INDICATES THAT, WHILE THE SHEAR TIE IS STILL PRESENT ON THE SKIN, THE EDGE TO WHICH THE ARROW POINTS IS LIFTED AWAY FROM THE SKIN FLANGE (GAPPED).

3. 

THIS FOUR-BOLT SHEAR TIE IS ATTACHED TO THE STIFFENER AND RETAINS THREE OF THE BOLTS WHICH WOULD ATTACH IT TO THE SKIN FLANGE. A FOURTH BOLT REMAINS EMBEDDED IN THE SKIN FLANGE. THE BLUE ARROW INDICATES THAT DIRECTIONALITY WAS DERIVED FROM THE BOLT DEFORMATION. THE RED ARROW INDICATES THAT, WHILE THE BOLT IS PRESENT IN THE SHEAR TIE, DIRECTIONALITY WAS DERIVED FROM THE BOLT HOLE IN THE SKIN FLANGE. THE CIRCLES INDICATE TENSILE PULL-OUT. AGAIN, THE COLOR INDICATES WHICH SURFACE WAS EVALUATED TO GET THE INFORMATION.

4. 

IN THIS EXAMPLE, THE SHEAR TIE IS ATTACHED TO THE STIFFENER AND RETAINS THE TWO BOLTS USED FOR ATTACHMENT TO THE SKIN FLANGE. DIRECTIONALITY WAS DERIVED FROM HOLE DEFORMATION IN THE SKIN FLANGE. HOWEVER, ONE BOLT IS DEFORMED IN A DIRECTION NOT CONSISTENT WITH ITS RESPECTIVE HOLE ELONGATION. THE BOLT DEFORMATION IS SHOWN BY THE BLUE ARROW, THE HOLE DEFORMATION BY THE RED ARROW. THE SECOND BOLT EXHIBITS DEFORMATION CONSISTENT WITH BUT NOT AS SPECIFIC AS THE HOLE ELONGATION IN THE SKIN FLANGE. SO THE SKIN FLANGE HOLE IS USED AS THE PRIMARY SOURCE OF INFORMATION, SHOWN BY A RED ARROW, AND THE ABSENCE OF A BLUE ARROW INDICATES THAT THE BOLT DEFORMATION AGREES.

5. 

IN THIS EXAMPLE, THE SHEAR TIE REMAINS ATTACHED TO THE STIFFENER BUT DOES NOT RETAIN ANY BOLTS. DIRECTIONALITY IS OBTAINED FROM BOLT HOLE ELONGATION ON THE SHEAR TIE. NO BOLTS REMAIN IN THE SKIN FLANGE.

6. 

IN THIS EXAMPLE, THE SHEAR TIE IS MISSING. HOWEVER, THE SKIN FLANGE BOLT HOLES HAVE YIELDED DIRECTION INFORMATION.

Center Fuel Tank Area
Shear Tie Separation Patterns
Symbology
Examples

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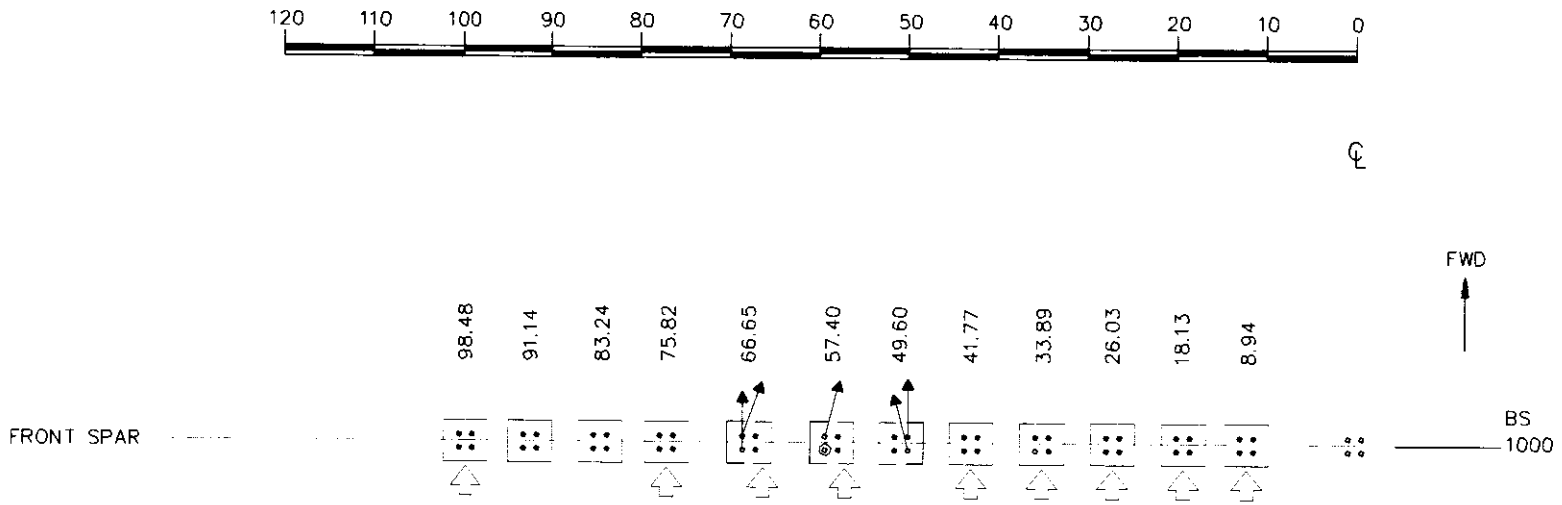

Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Lower Skin, Top View

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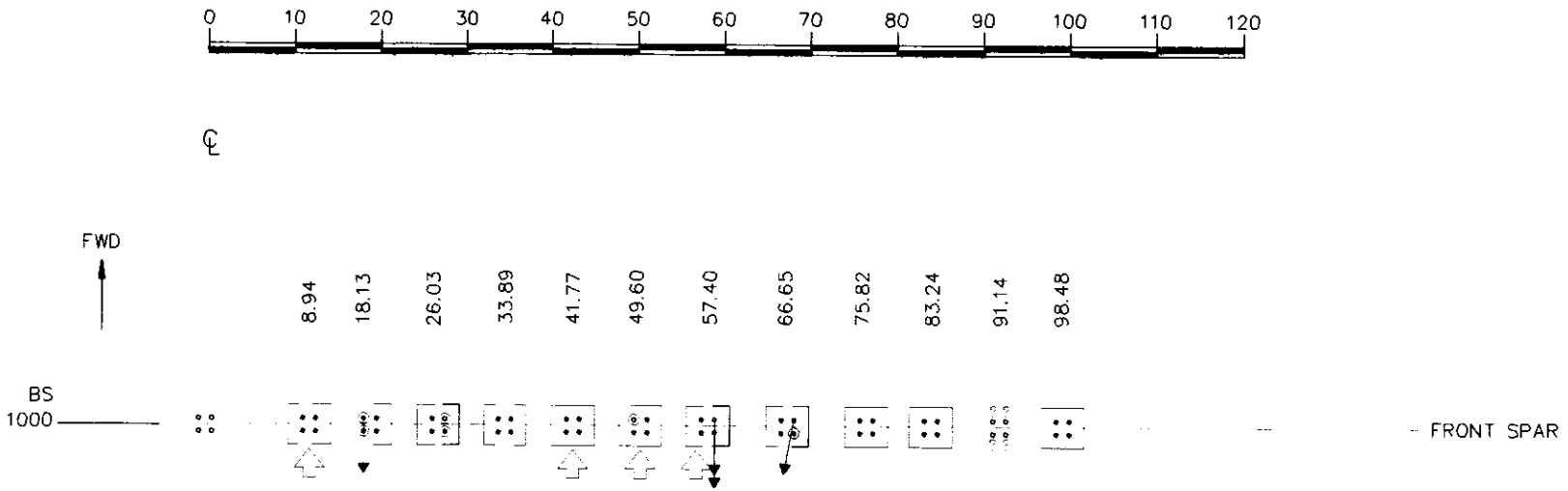

Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Lower Skin, Top View

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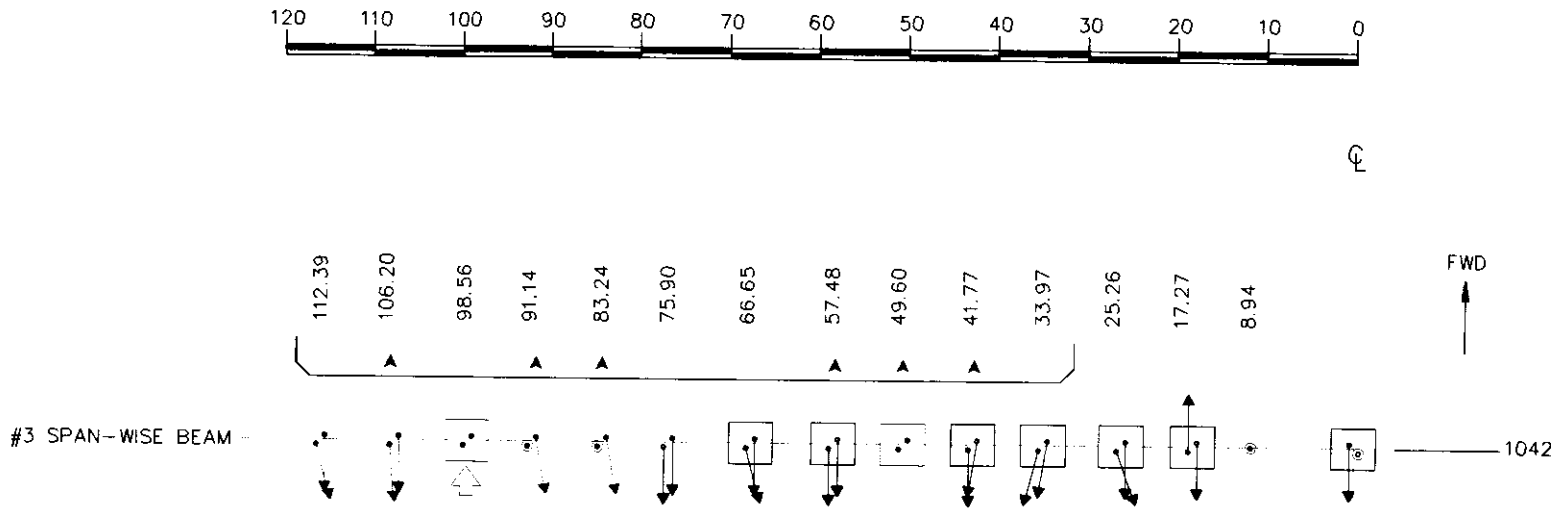

Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Lower Skin, Top View

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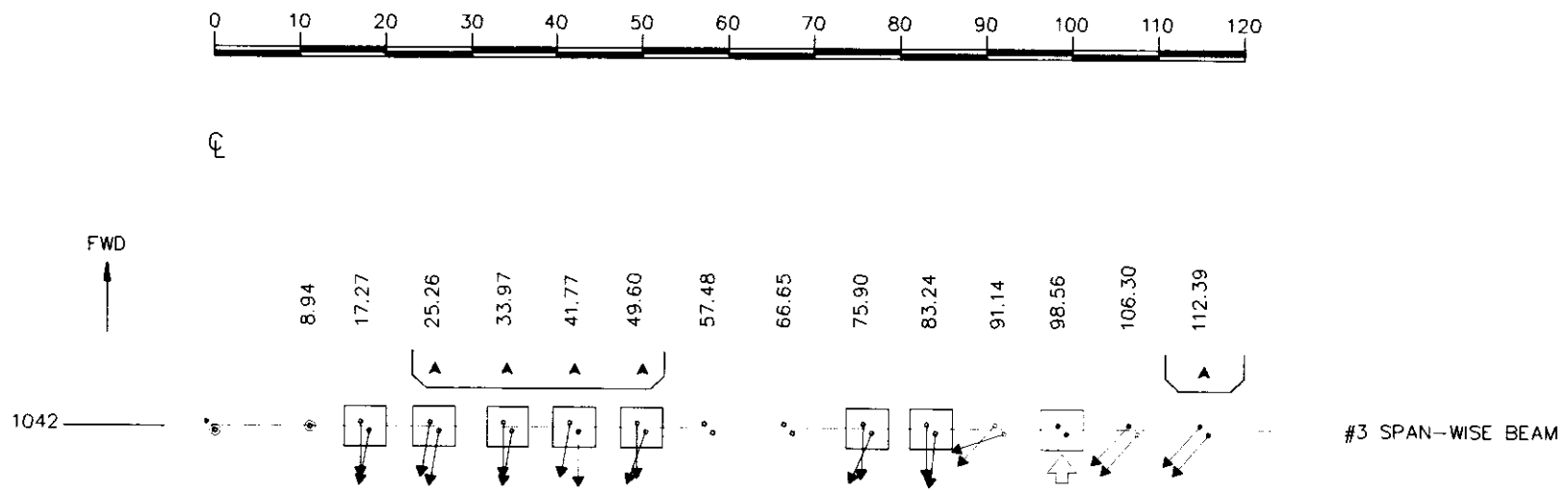

Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Lower Skin, Top View

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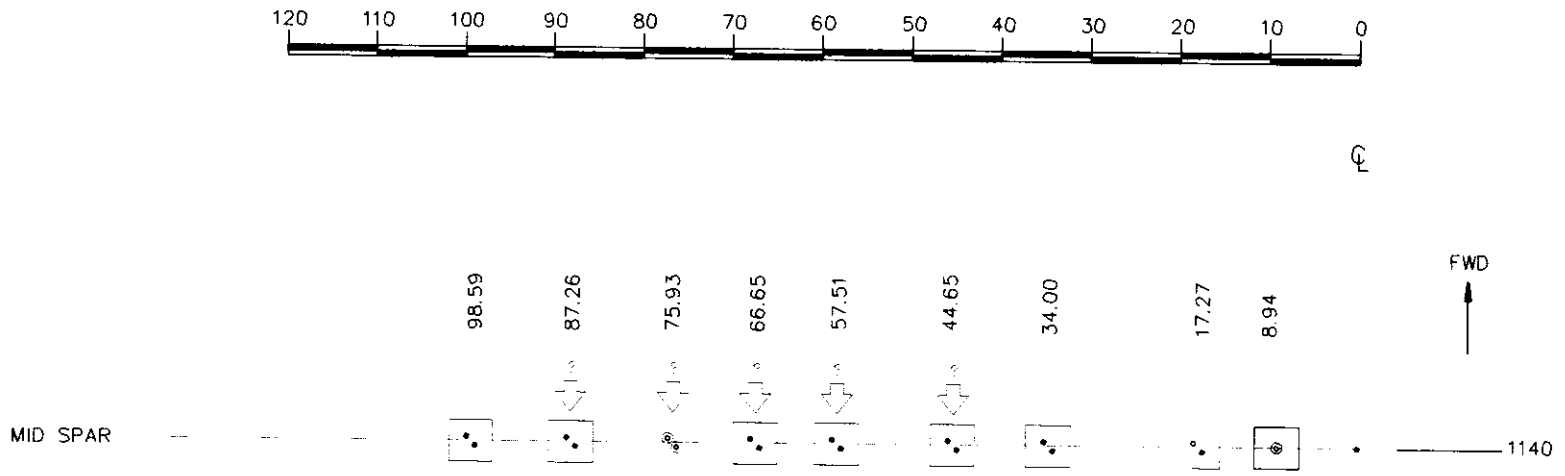

Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Lower Skin, Top View

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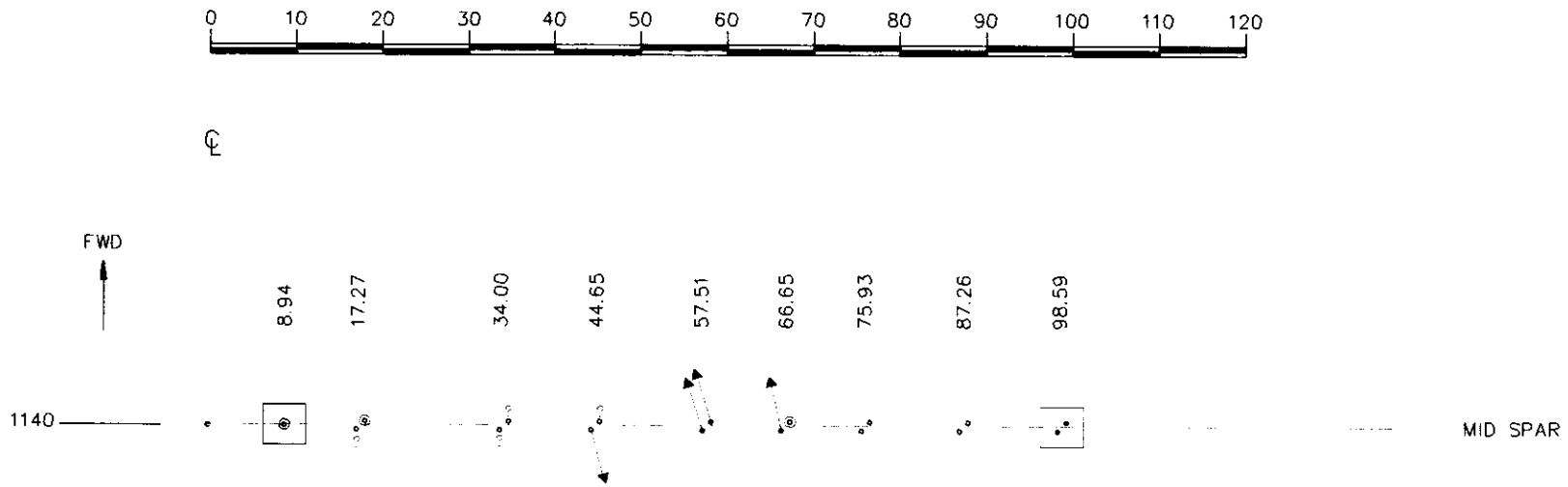

Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Lower Skin, Top View

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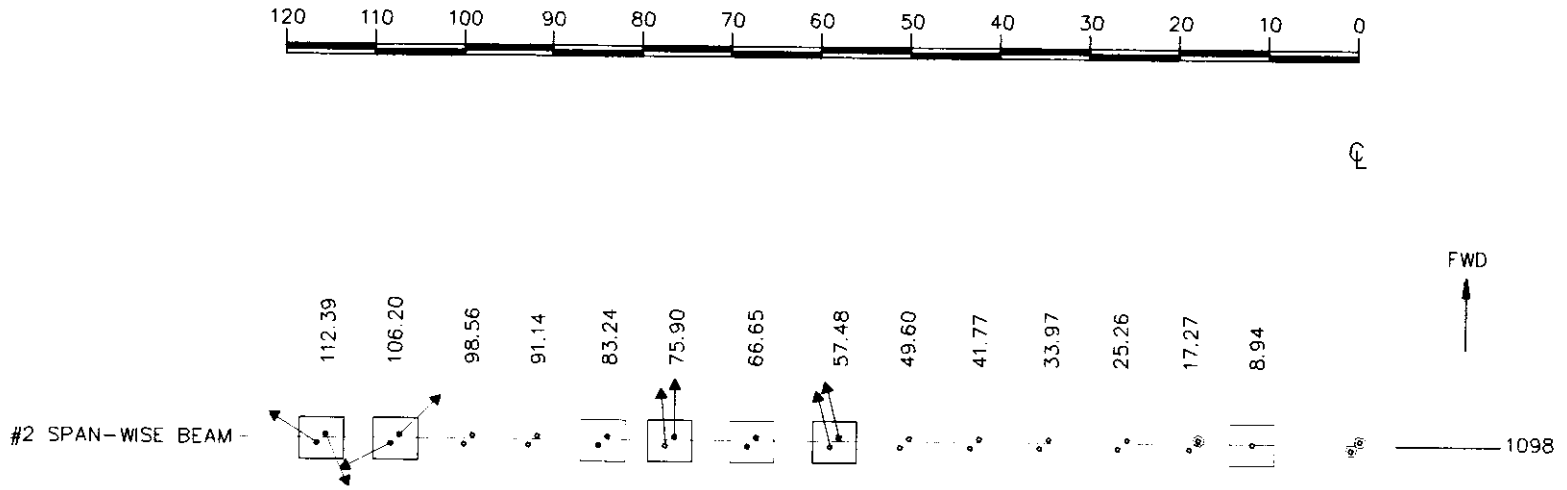

Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Lower Skin, Top View

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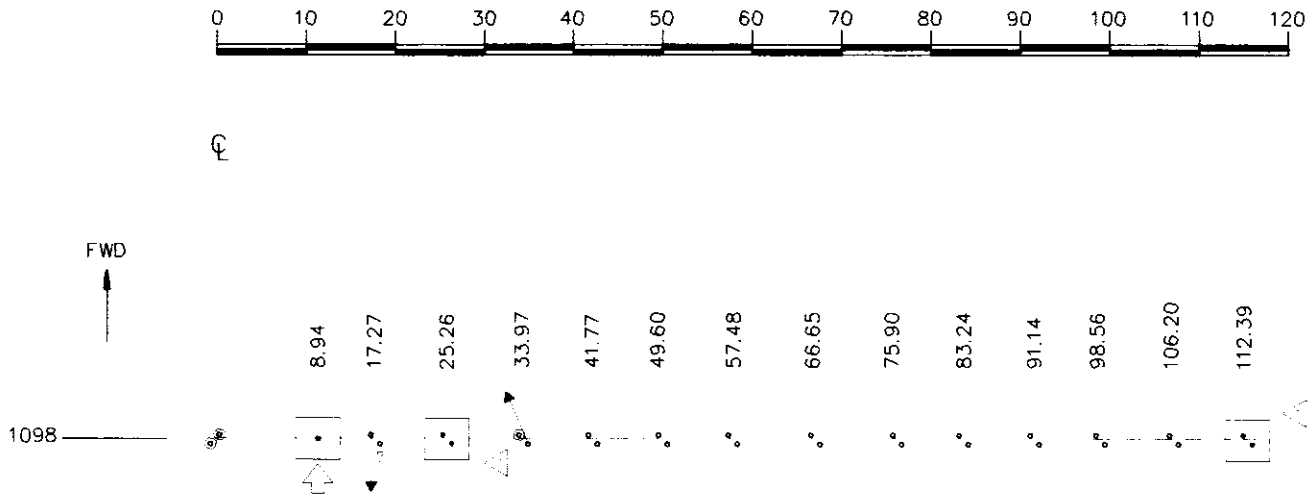

Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Lower Skin, Top View

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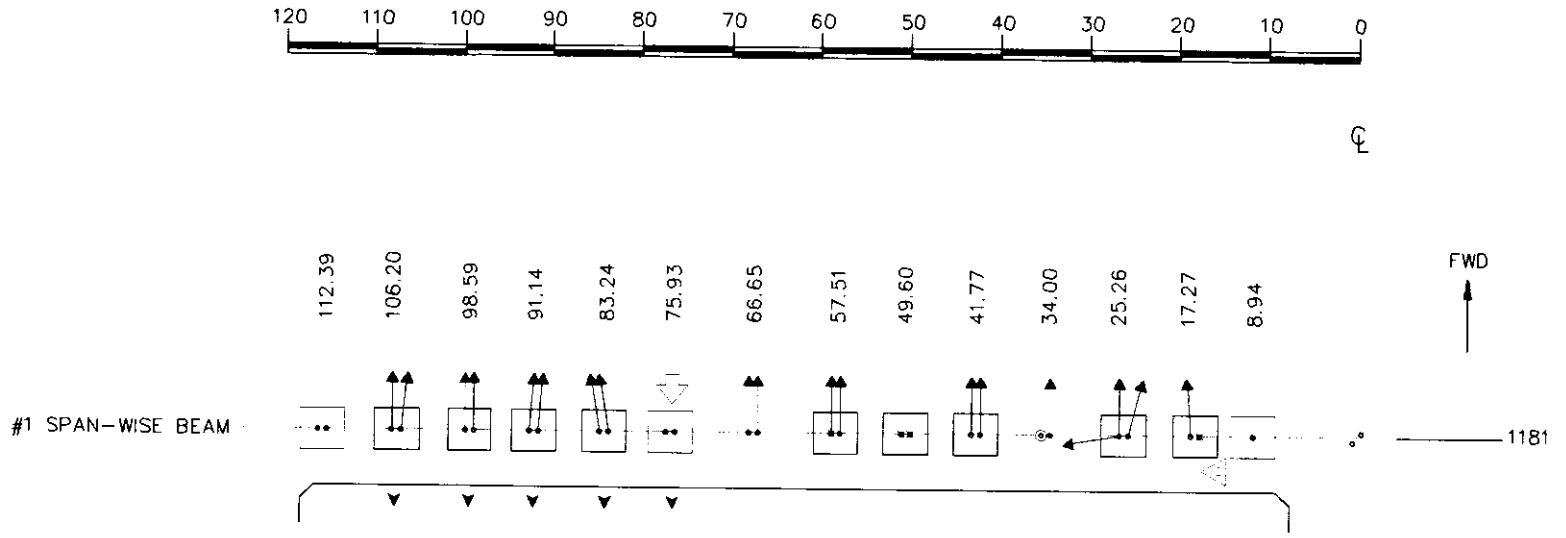

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Shear Tie Separation Patterns
Left Side
Lower Skin, Top View

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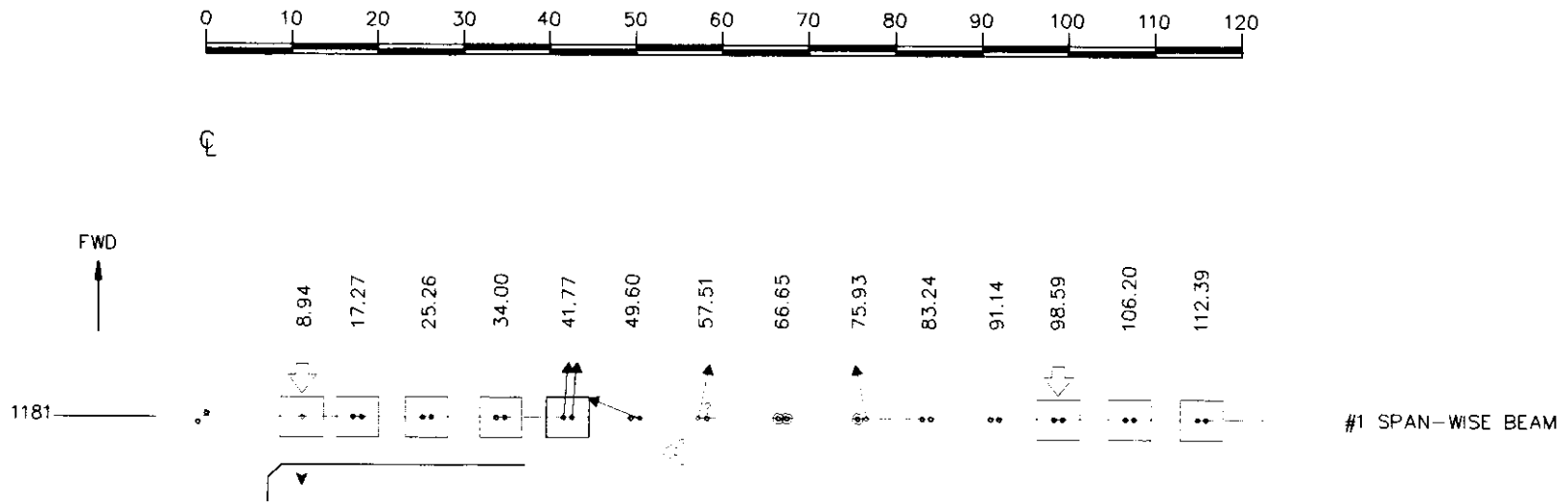

Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Lower Skin, Top View

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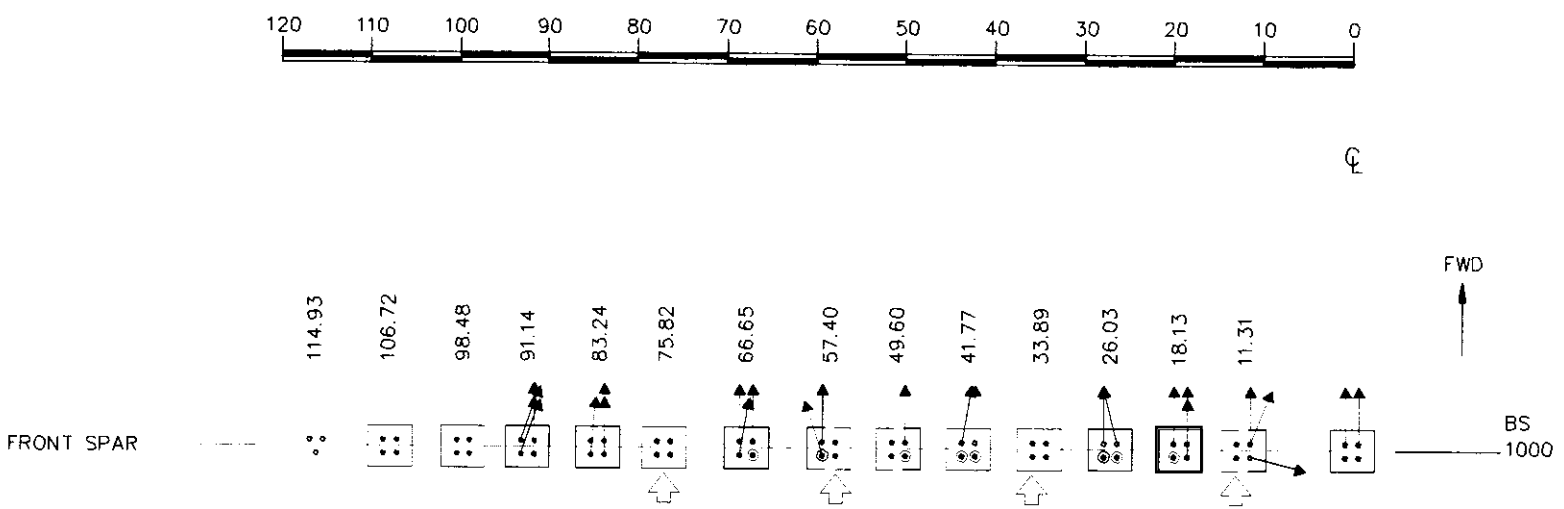

Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Upper Skin, Top View

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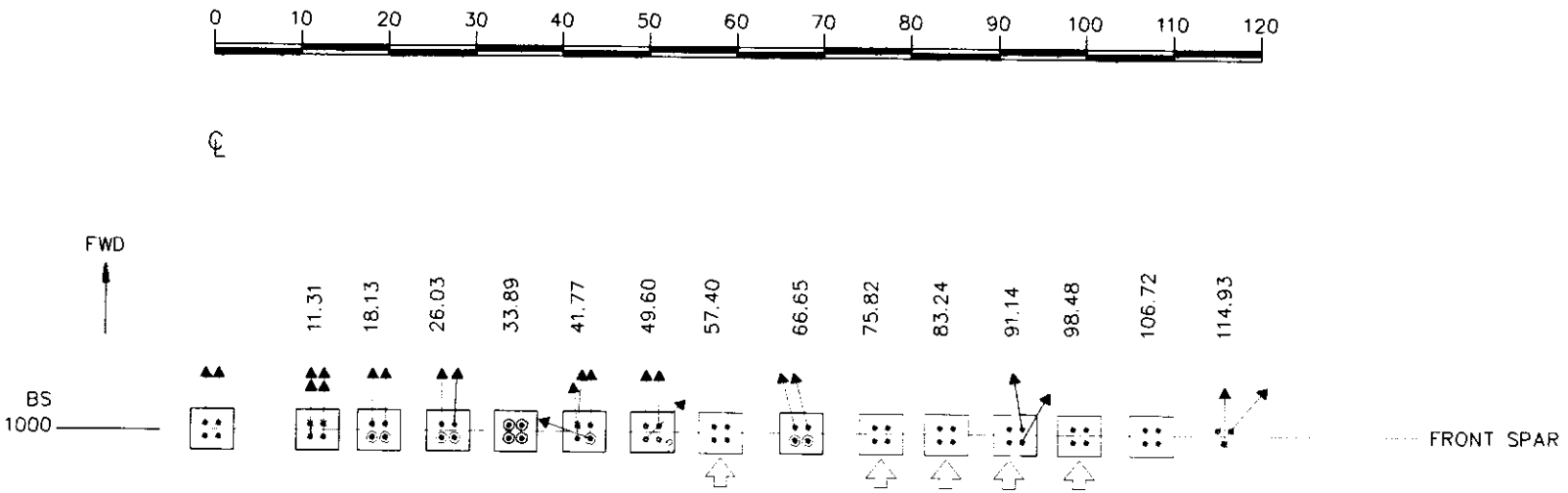

Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Upper Skin, Top View

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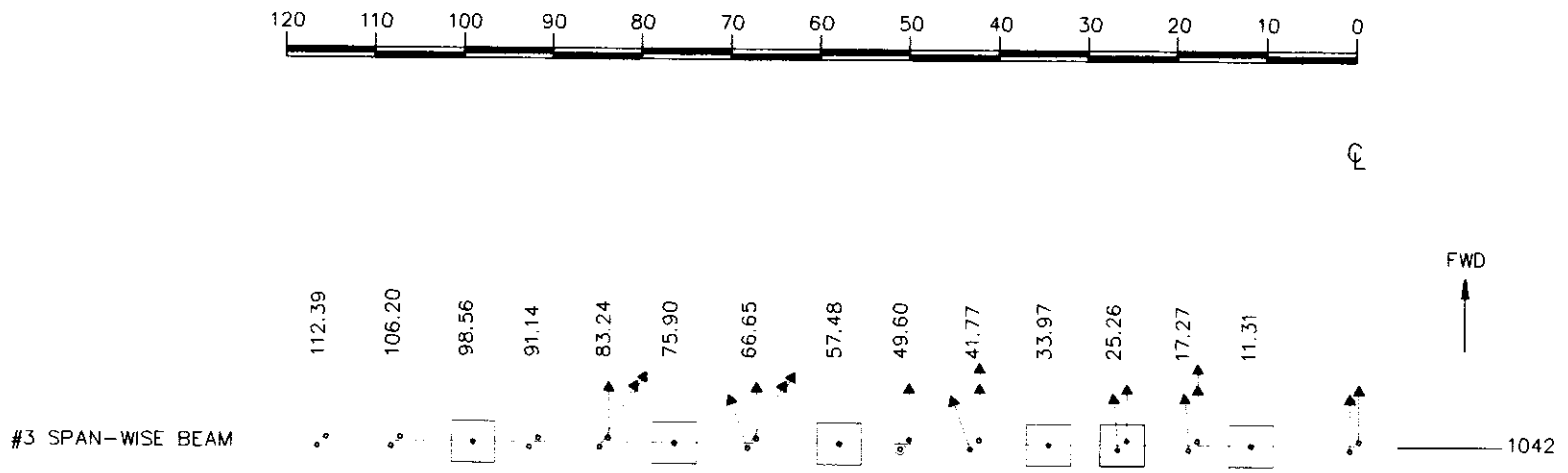

Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Upper Skin, Top View

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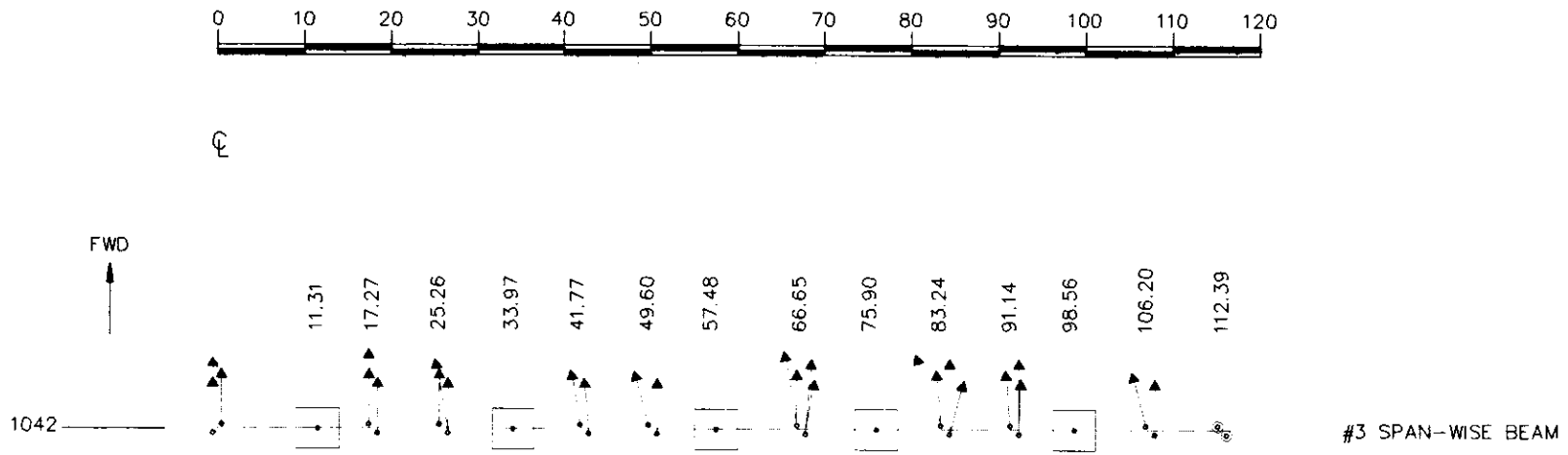

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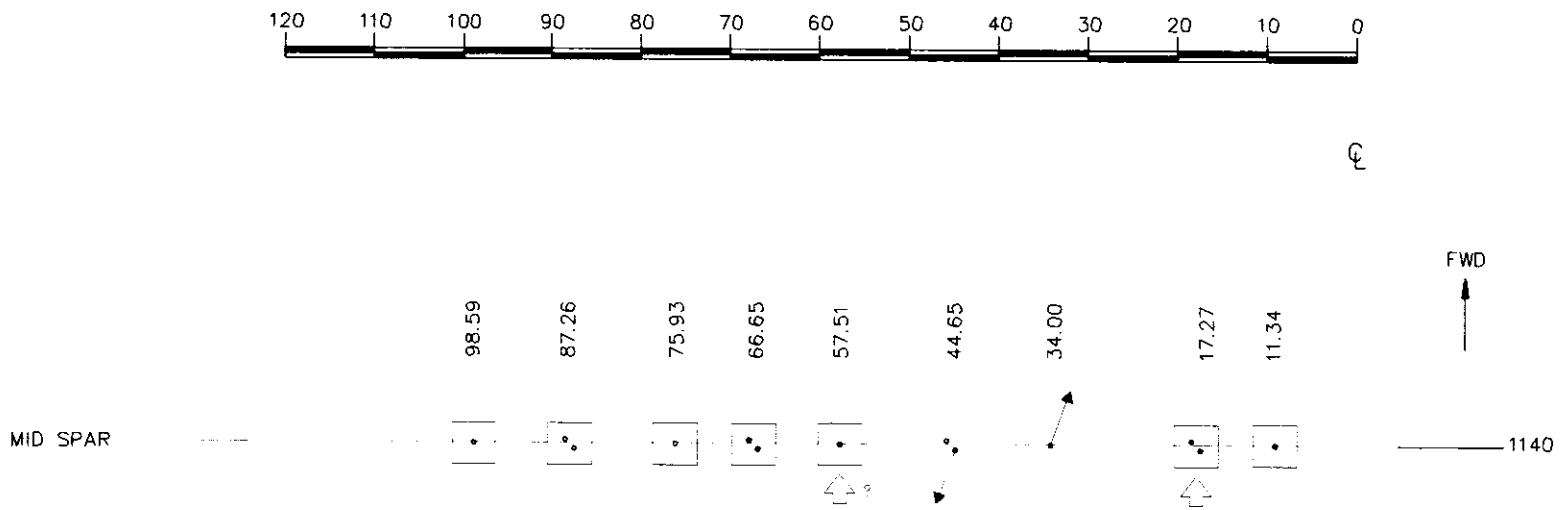


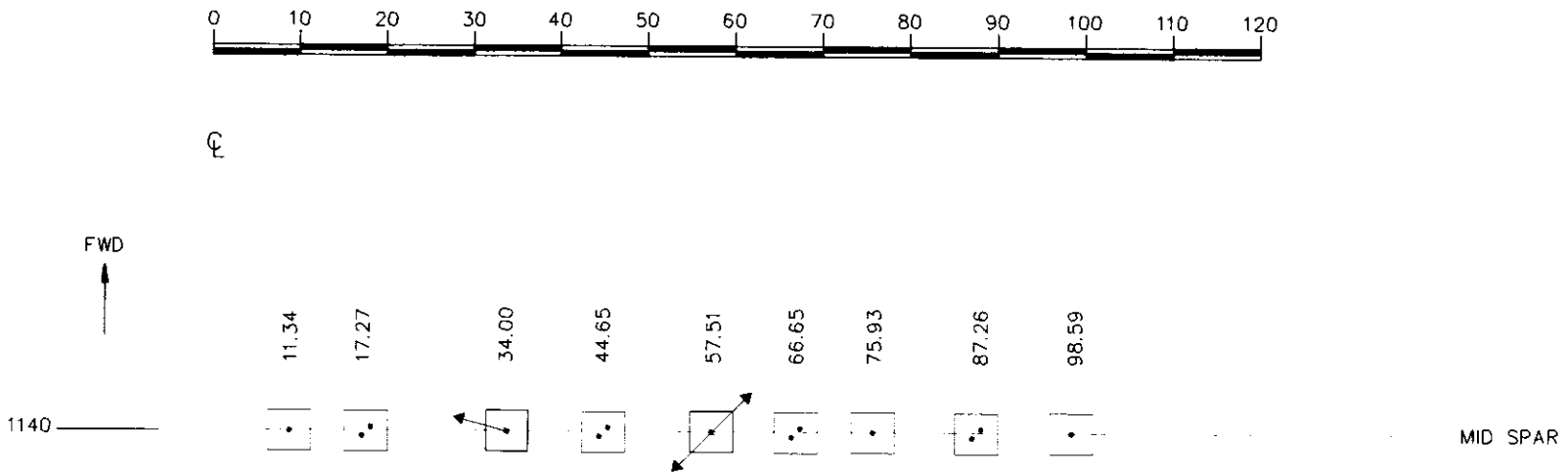
Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Upper Skin, Top View

TWA 800

Supervisor of Salvage, USN

Oceaneering International Inc.
Advanced Technologies Group

January 29 1997



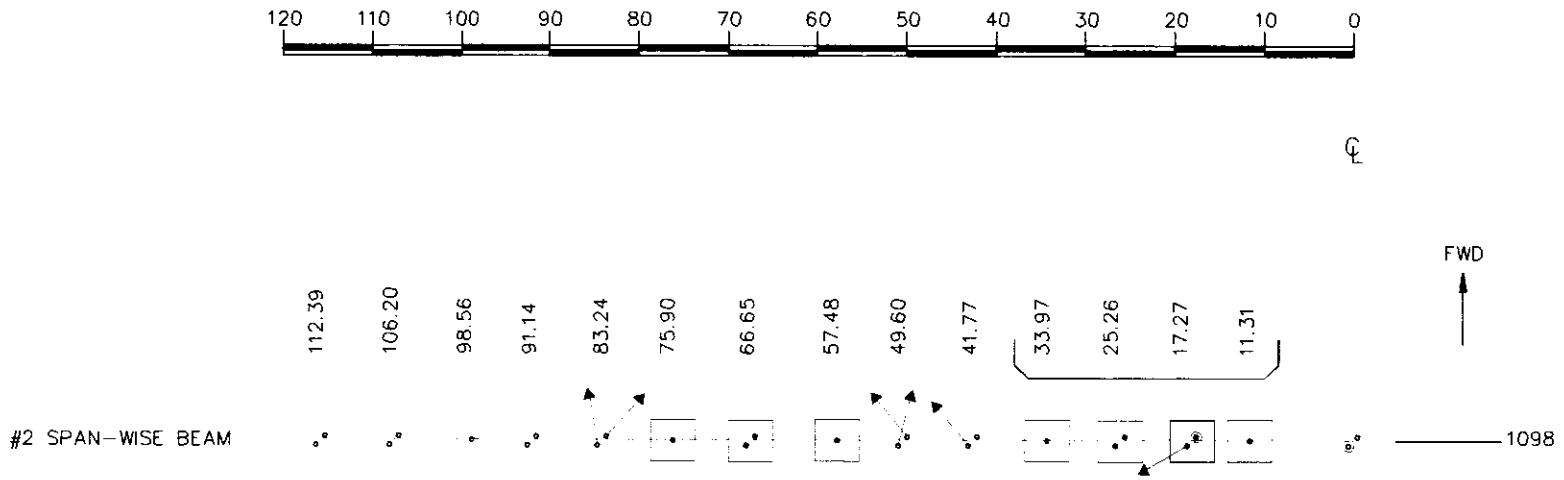
Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Upper Skin, Top View

TWA 800

Supervisor of Salvage, USN

Oceaneering International Inc.
Advanced Technologies Group

January 29 1997



Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Upper Skin, Top View

TWA 800

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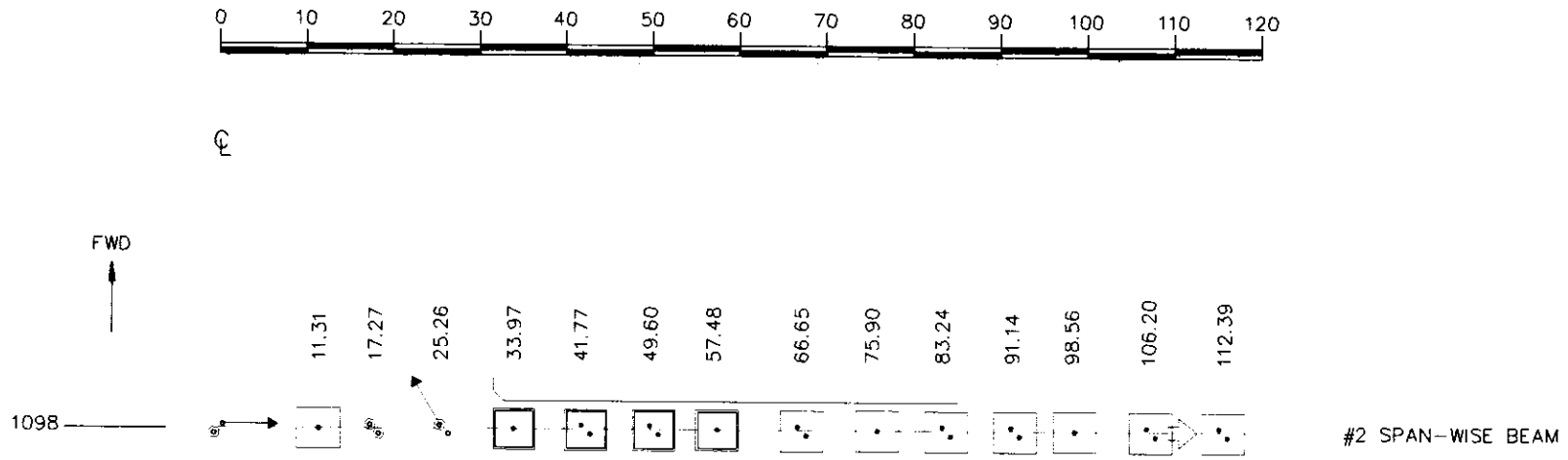
Oceaneering International Inc.
Advanced Technologies Group

January 29 1997



Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Upper Skin, Top View

TWA 800

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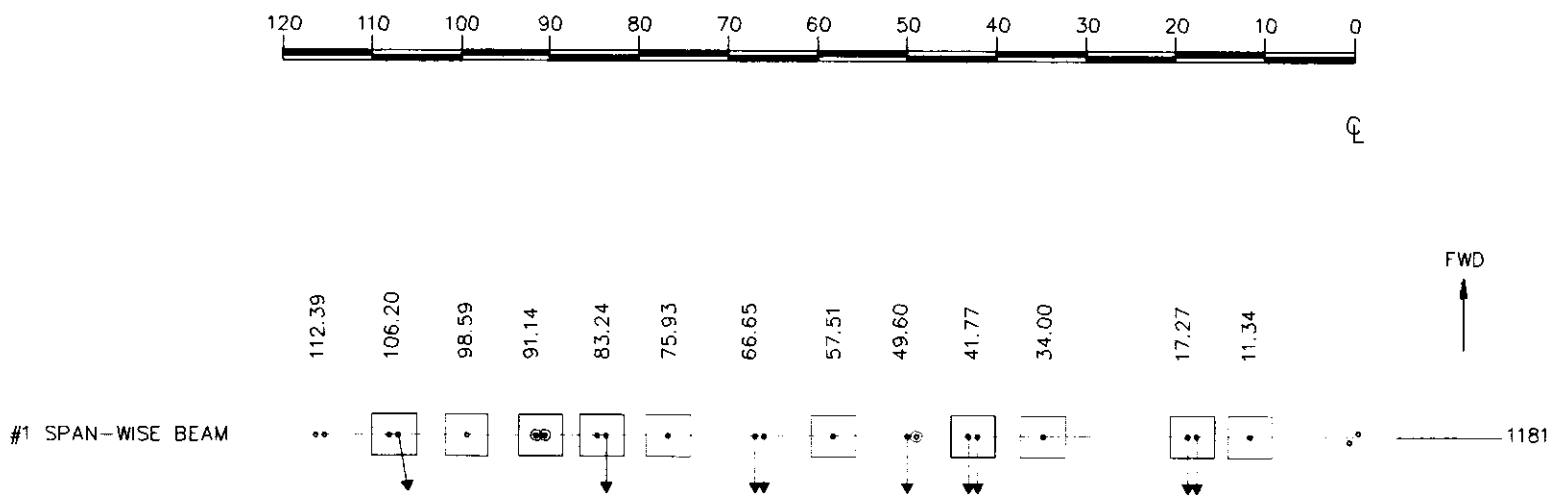

Center Fuel Tank Area
Shear Tie Separation Patterns
Left Side
Upper Skin, Top View

TWA 800

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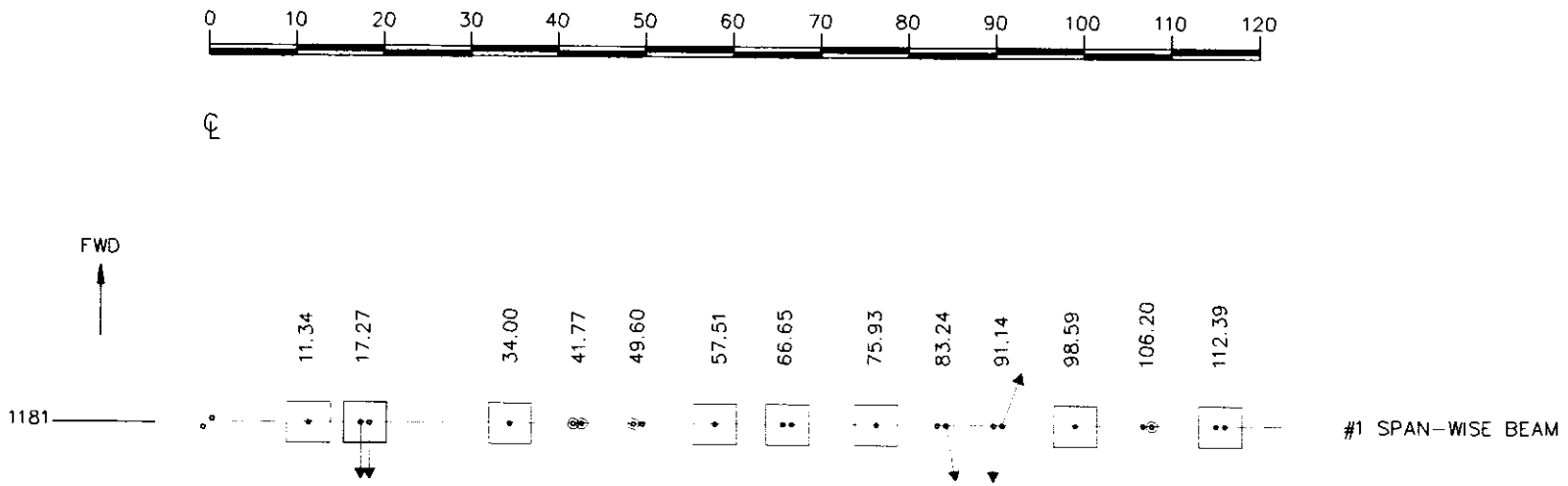

Center Fuel Tank Area
Shear Tie Separation Patterns
Right Side
Upper Skin, Top View

TWA 800

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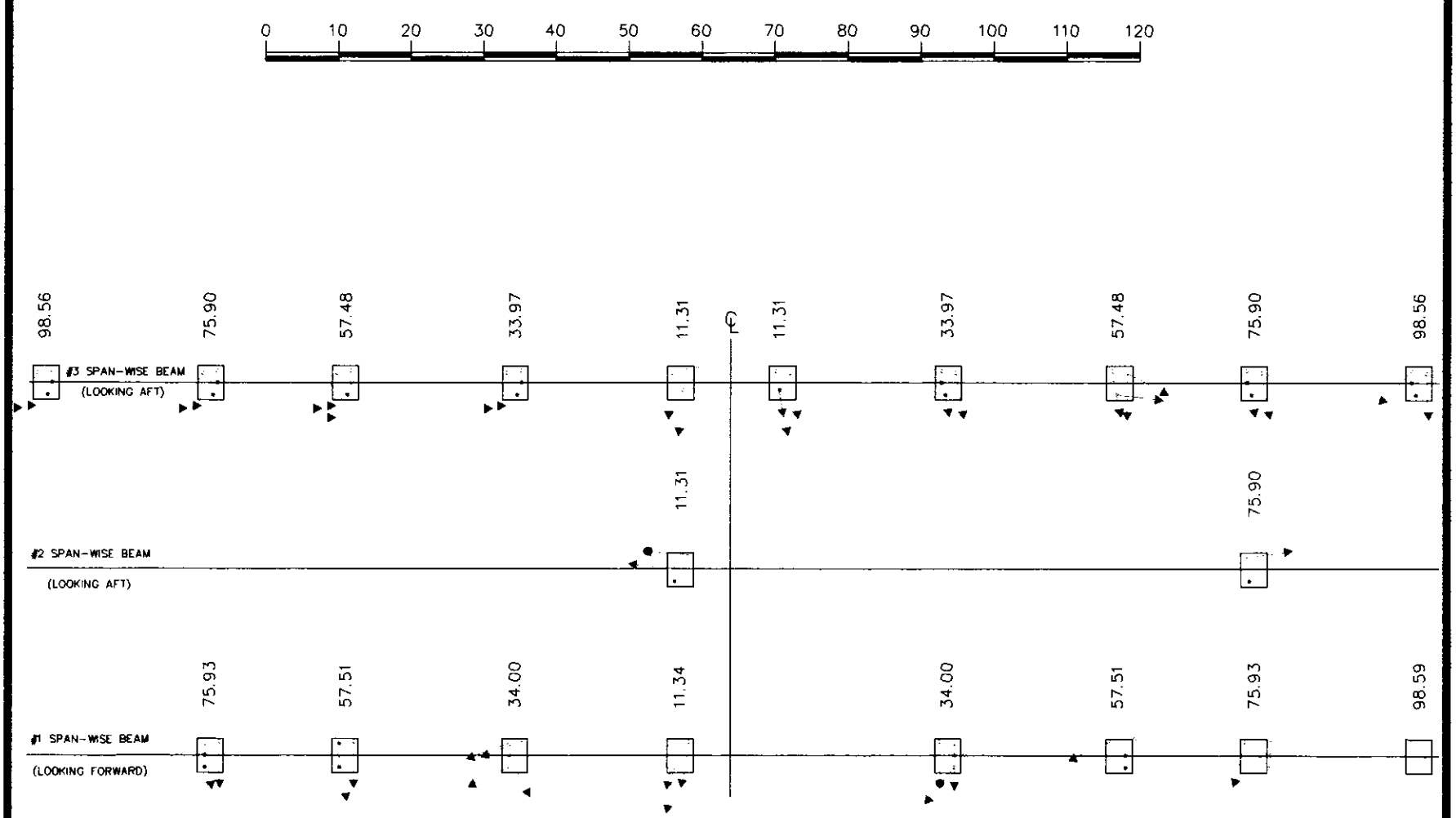
January 29 1997



Center Fuel Tank Area
Shear Tie Separation Patterns

Tension Fitting Vertical Face

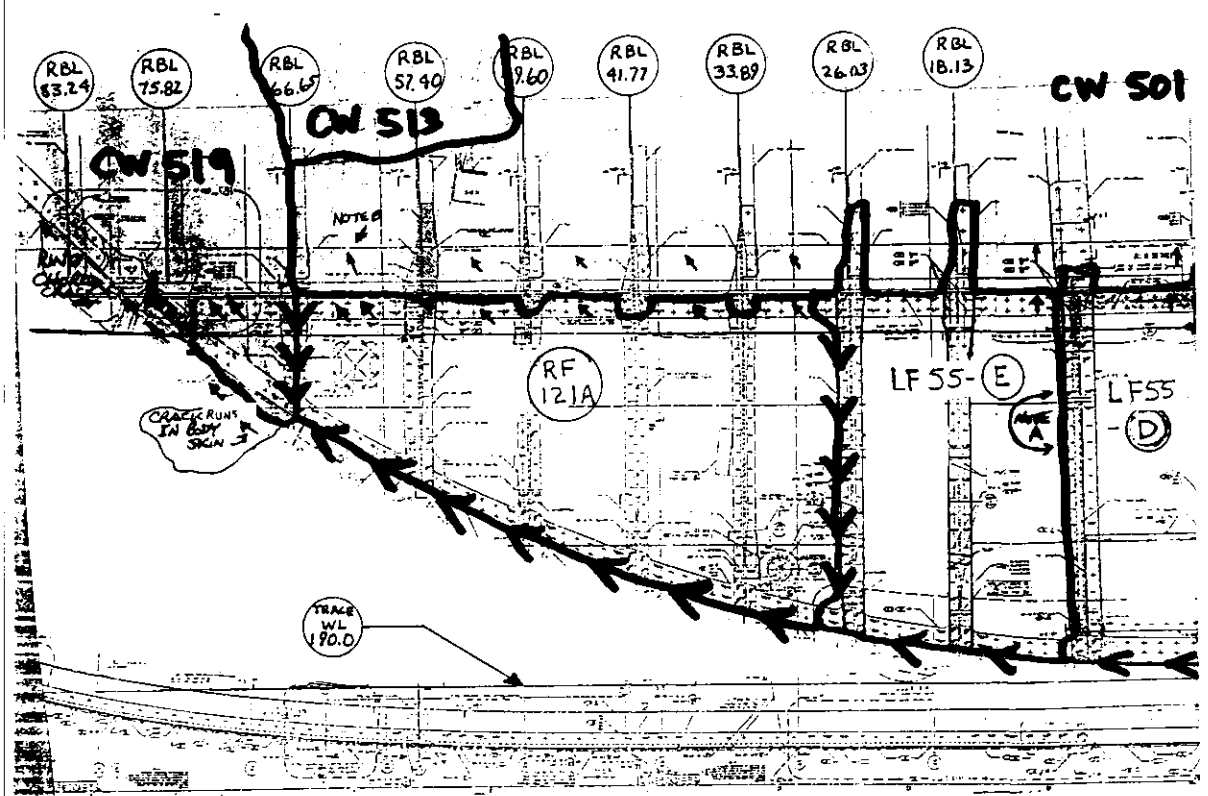
NOTE: ARROWS INDICATE DIRECTION OF HOLE OR BOLT DEFORMATION ON TENSION FITTING VERTICAL FACE.

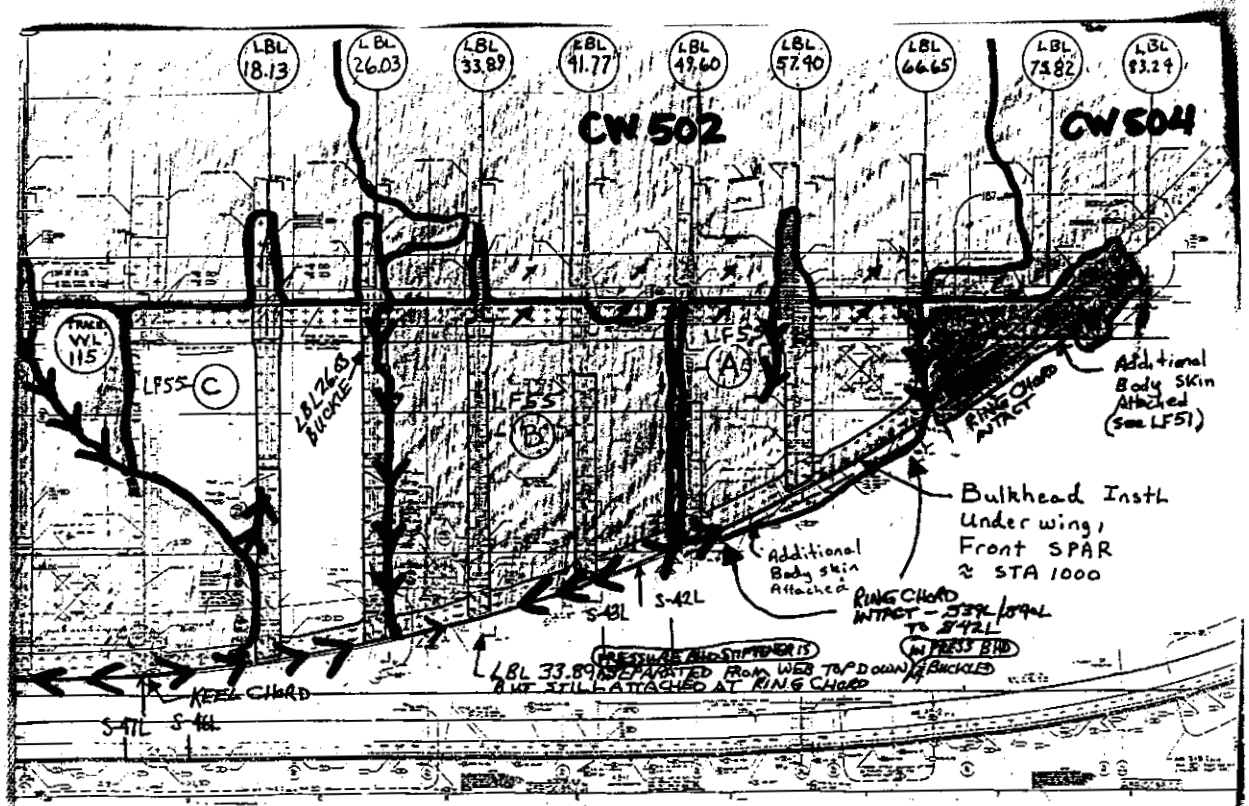
TWA 800

Supervisor of Salvage, USN

Oceaneering International Inc.
Advanced Technologies Group

January 29 1997


RBL 53.24
RBL 75.82
RBL 66.65
RBL 57.40
RBL 49.60
RBL 41.77
RBL 33.89
RBL 26.03
RBL 18.13
CW 501
CW 513
CW 519
NOTE B
RF 121A
LF 55-E
LF 55 -D
CRACK RUNS IN BODY SKIN
TRACE WL 190.0
NOTE A: LF 55 E MOVED FORWARD RELATIVE TO LF 55D, RESULTING IN A VERTICAL SHEAR SEPARATION IN THE WEB
NOTE B: FRONT SPAR UNDER WING BULKHEAD WEB IS LAPPED OVER FRONT SPAR WEB. ARROWS INDICATE DIRECTION OF MOTION OF FRONT SPAR WEB AS RIVETS ARE SHEARED
NOTE C: RING CHORD IS BENT AT ENDS OF LF 55A DOWN AND OUTBOARD
UP
Fror
RF121 & LF



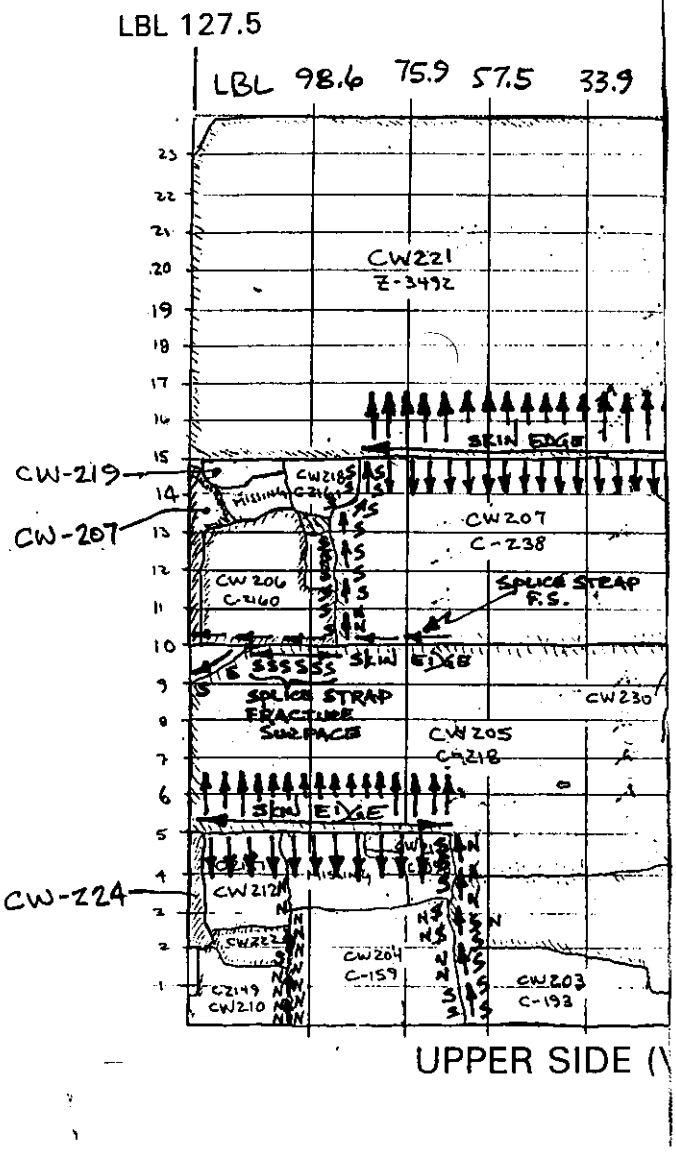
+ View

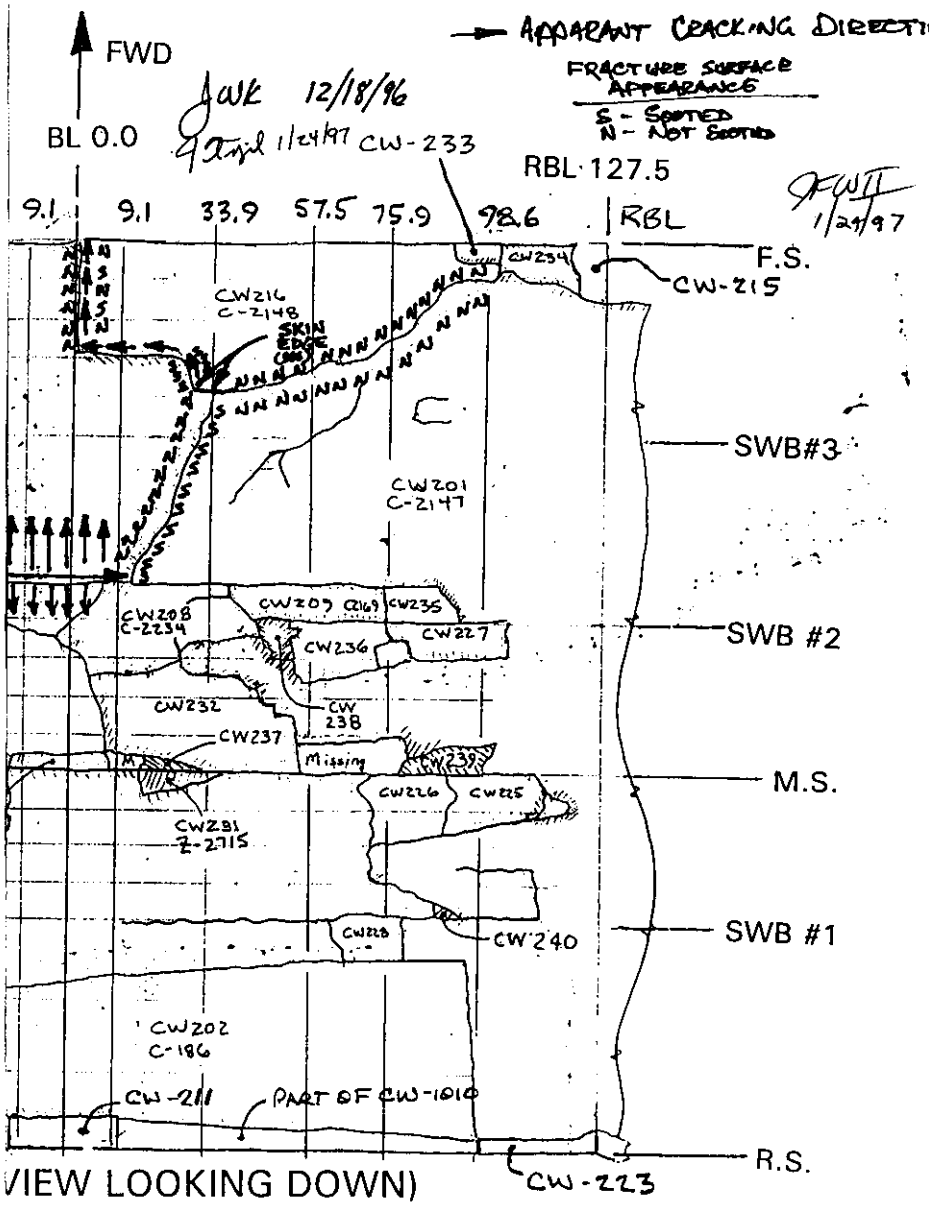
55 Roadmap

JRT 11/21/97 JRS II 1/22/97

Fracture Directions noted on Front Spar Underwing Bulkhead and Ring Chord. JRStraus 11/22/96

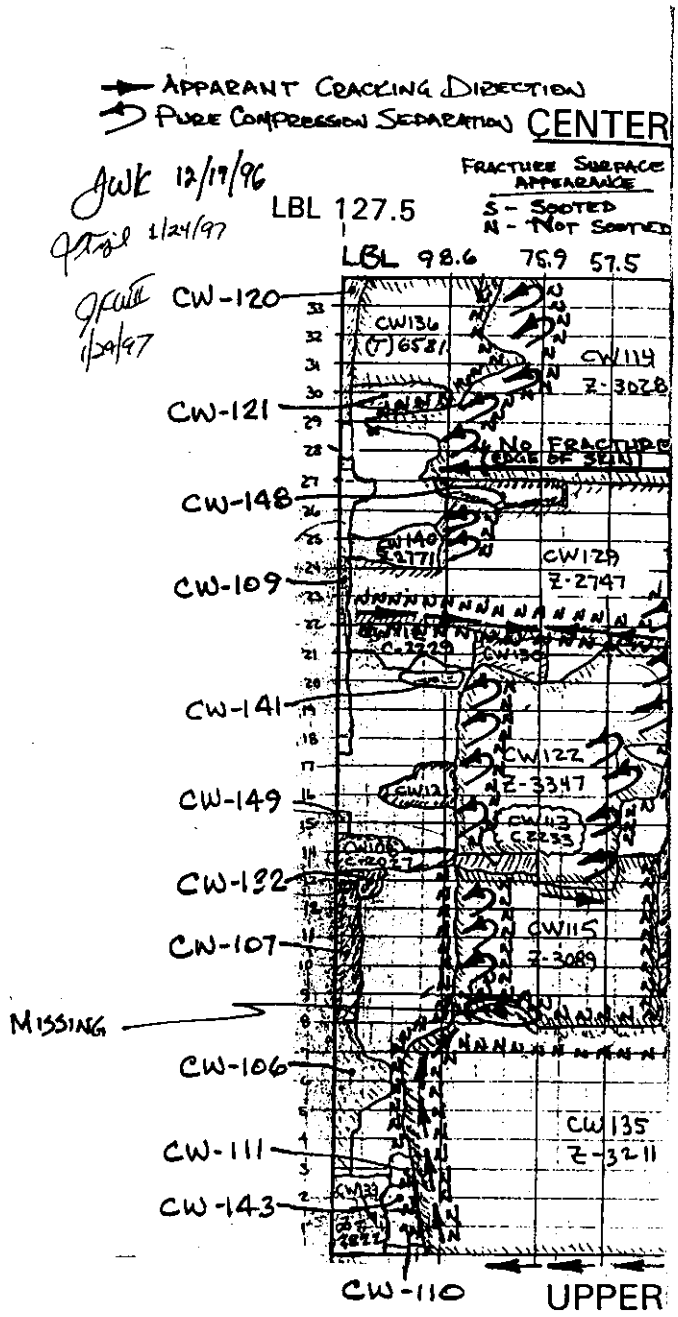
CENTER WING TANK - LOWER SKIN



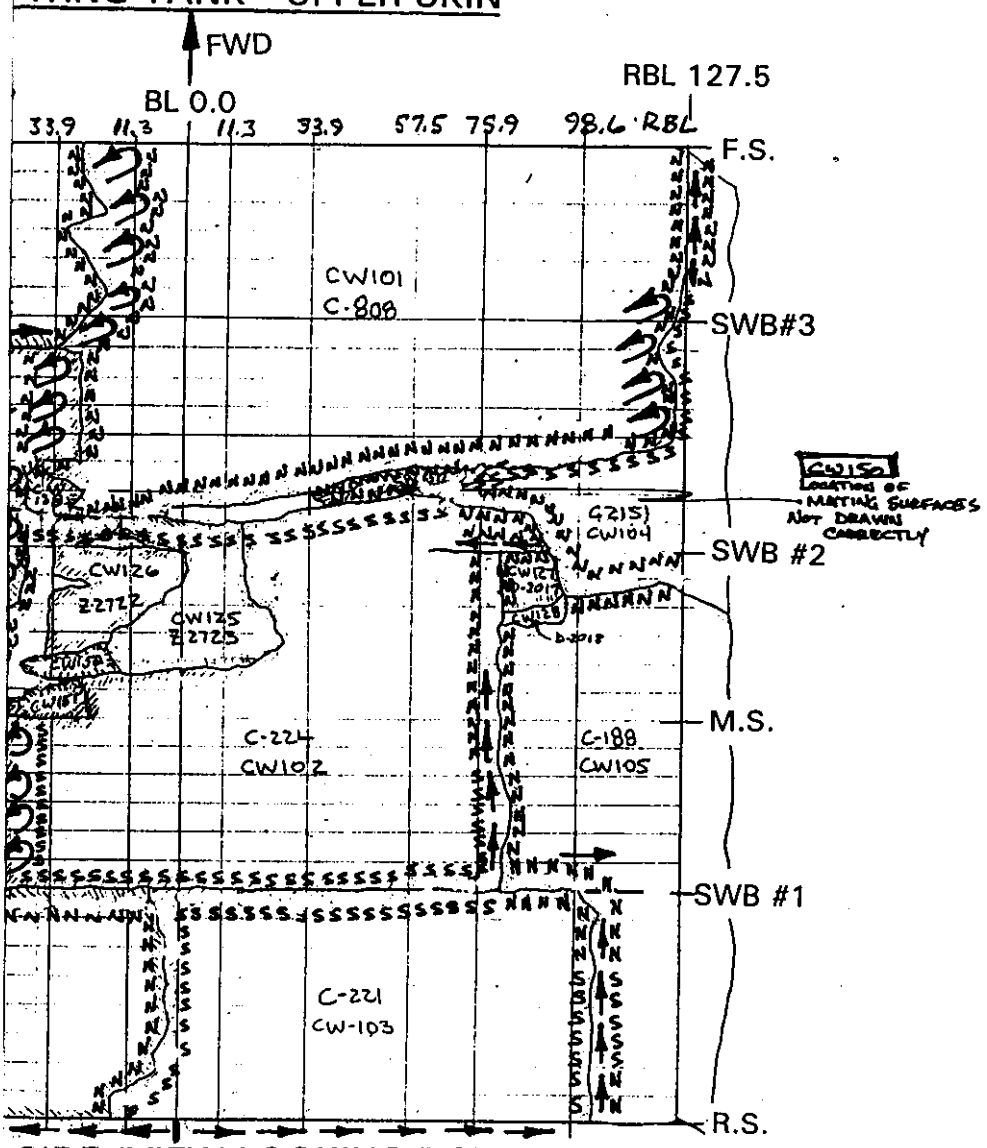


VIEW LOOKING DOWN)

FIGURE B-2

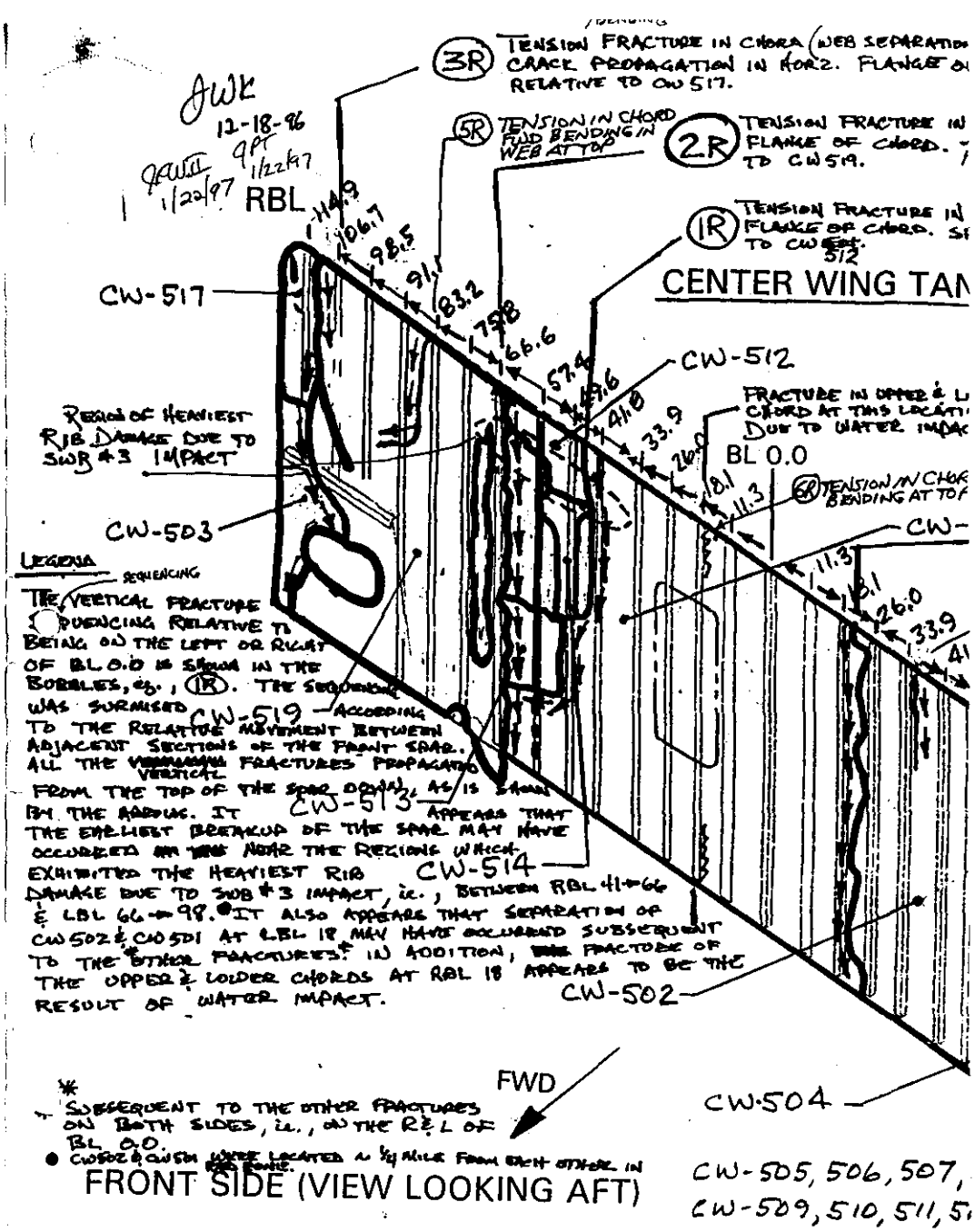

APPARENT CRACKING DIRECTION
PURE COMPRESSION SEPARATION
CENTER
JWK 12/19/96
JWK 1/24/97
JWK 1/24/97
FRACTURE SURFACE APPEARANCE
S - SOOTED
N - NOT SOOTED
LBL 127.5
LBL 98.6
76.9
57.5
CW-120
CW-121
CW-148
CW-109
CW-141
CW-149
CW-132
CW-107
MISSING
CW-106
CW-111
CW-143
CW-110
CW136
Z-6581
CW114
Z-3028
NO FRACTURE
(EDGE OF SEAM)
CW140
Z-2771
CW129
Z-2747
C-3229
CW130
CW122
Z-3347
CW113
Z-2233
C-2027
CW115
Z-3089
CW135
Z-3211
UPPER

WING TANK - UPPER SKIN



SIDE (VIEW LOOKING DOWN)

FIGURE B-3


JWK 12-18-96
9PT 1/22/97
1/22/97
RBL
3R TENSION FRACTURE IN CHORD (WEB SEPARATION
CRACK PROPAGATION IN HOR'Z. FLANGE O
RELATIVE TO CW 517.
5R TENSION IN CHORD AND BENDING IN WEB AT TOP
2R TENSION FRACTURE IN FLANGE OF CHORD.
TO CW 519.
1R TENSION FRACTURE IN FLANGE OF CHORD. SI
TO CW 512
CENTER WING TAN
CW-517
CW-512
CW-503
CW-519
CW-513
CW-514
CW-502
CW-504
CW-505, 506, 507,
CW-509, 510, 511, 5
144.9
106.7
98.5
91.1
83.2
74.8
66.6
57.4
49.6
41.8
33.9
26.0
18.1
11.3
BL 0.0
REGION OF HEAVIEST RIB DAMAGE DUE TO SWB #3 IMPACT
FRACTURE IN UPPER & L CHORD AT THIS LOCATI DUE TO WATER IMPAC
6R TENSION IN CHOR BENDING AT TOP
LEGENDA
THE VERTICAL FRACTURE SEQUENCING RELATIVE TO BEING ON THE LEFT OR RIGHT OF BL 0.0 IS SHOWN IN THE BUBBLES, eg., (1R). THE SEQUENCING WAS SURMISED ACCORDING TO THE RELATIVE MOVEMENT BETWEEN ADJACENT SECTIONS OF THE FRONT SPAR. ALL THE VERTICAL FRACTURES PROPAGATED FROM THE TOP OF THE SPAR DOWN, AS IS SHOWN BY THE ARROWS. IT APPEARS THAT THE EARLIEST BREAKUP OF THE SPAR MAY HAVE OCCURRED IN THE NEAR THE REGIONS WHICH EXHIBITED THE HEAVIEST RIB DAMAGE DUE TO SWB #3 IMPACT, ie., BETWEEN RBL 41 & 66 & LBL 66 & 98. * IT ALSO APPEARS THAT SEPARATION OF CW 502 & CW 501 AT LBL 18 MAY HAVE OCCURRED SUBSEQUENT TO THE *OTHER FRACTURES. IN ADDITION, THE FRACTURE OF THE UPPER & LOWER CHORDS AT RBL 18 APPEARS TO BE THE RESULT OF WATER IMPACT.
FWD
* SUBSEQUENT TO THE OTHER FRACTURES ON BOTH SIDES, ie., ON THE R & L OF BL 0.0
• CW502 & CW504 WERE LOCATED ~ 1/4 MILE FROM EACH OTHER IN THE FRONT.
FRONT SIDE (VIEW LOOKING AFT)

WAS [redacted] BETWEEN RBL 106 & 114). FRACTURE WAS EXTENSION OF L→R CHORD. ~~SHEARING IN ADJACENT~~ WEB MAT'L INDICATES CW519 MOVING FWD FWD BENDING AT TOP OF

CHORD. FRACTURE WAS EXTENSION OF R→L CRACK PROPAGATION IN HORE. ~~SHEARING IN ADJACENT~~ [redacted] MAT'L INDICATES CW512 MOVING FWD RELATIVE TO BENDING AT TOP OF WEB

AND WEB AT TOP. WEB IS PULLED DOWN WITH VERTICAL SHEAR OF CHORD FASTENERS.
CHORD. FRACTURE WAS EXTENSION OF R→L CRACK PROPAGATION IN HORE.
SHEARING IN ADJACENT WEB MAT'L INDICATES CW501 MOVING FWD RELATIVE

K - FRONT SPAR

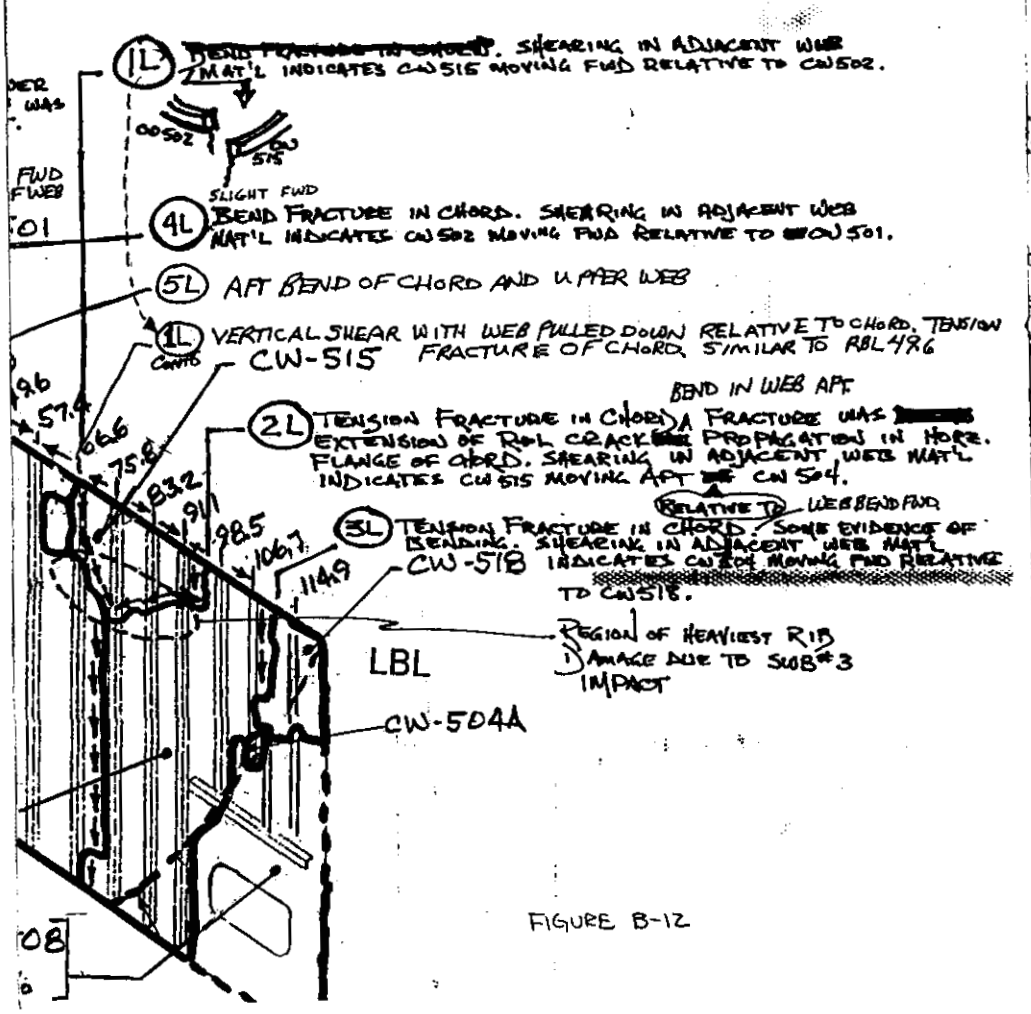
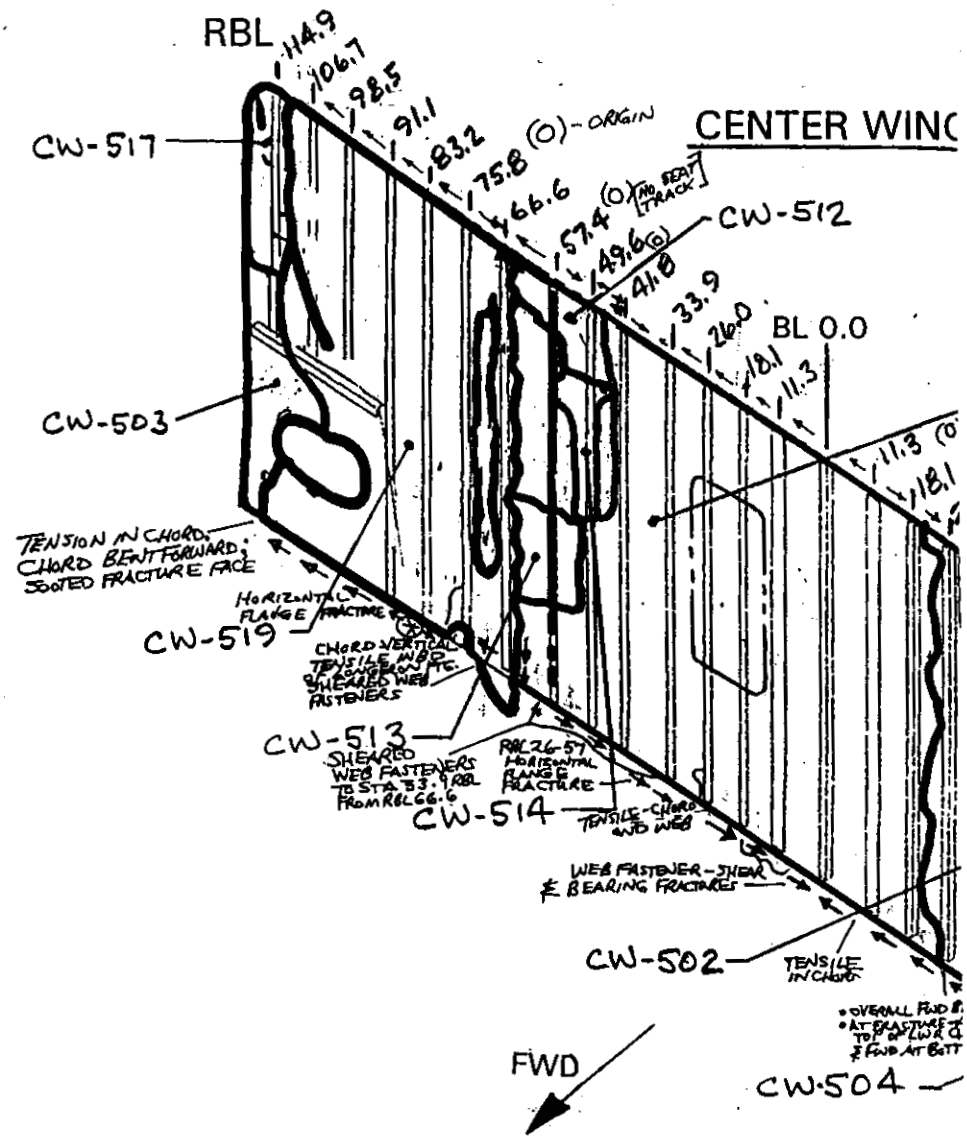


FIGURE B-12

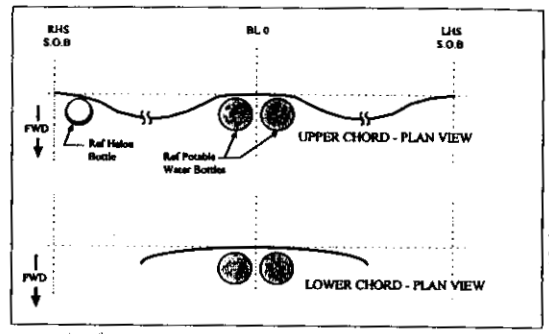


FRONT SIDE (VIEW LOOKING AFT)

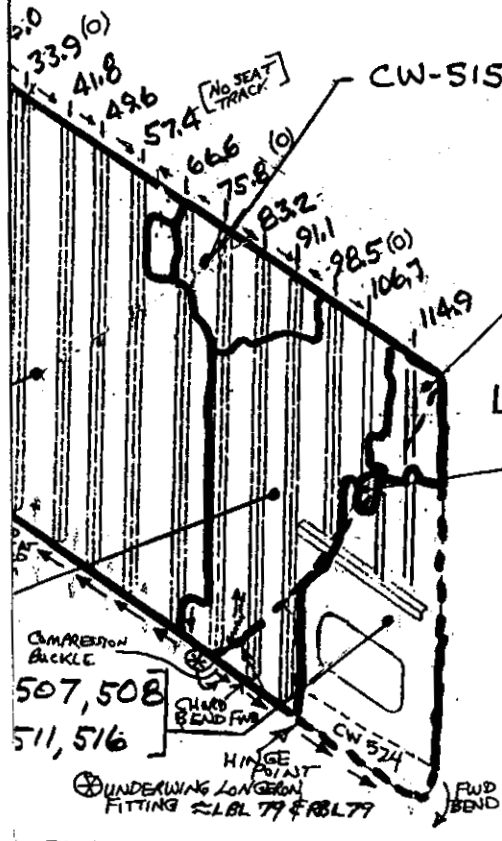
CW-505, 506
CW-509, 510,

FIGURE B-13

TANK - FRONT SPAR



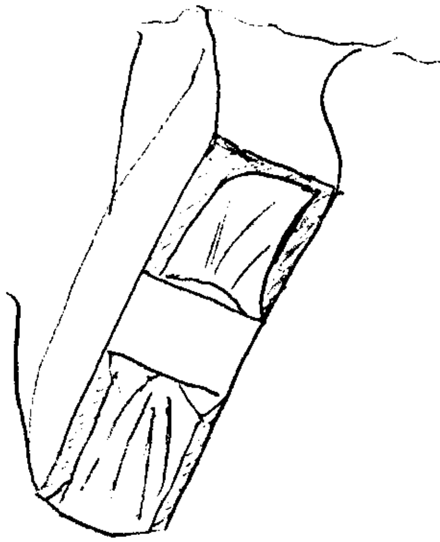
CW-501



SLIGHT BOWING (?) OF VERT. FLANGE OF FRONT SPAR UPPER CHORD FLUID NOTED AT ORIGIN SITES ASSOCIATED WITH FLOOR BEAMS AT RBL 98, RBL 75, RBL 57, LBL 11, LBL 33, LBL 57, LBL 75 AND LBL 98. INITIATION SITES IN UPPER CHORD CO-LOCATED AT FLOOR BEAM AT RBL 75 RBL 57, LBL 11, LBL 33, LBL 75, AND LBL 98. ONE ADD'L INITIATION SITE BETWEEN RBL 41 AND RBL 49 WAS ASSOCIATED WITH WHERE THE FRACTURE DOVE DOWN INTO THE VERTICAL FLANGE.

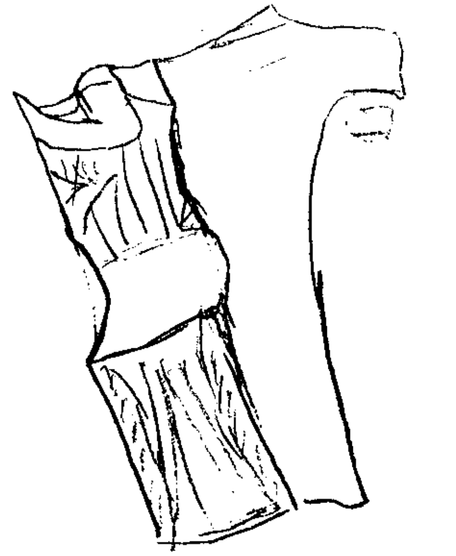
J. W. Wilbur II 1/22/97

[illegible] 1/22/97



RBL 79

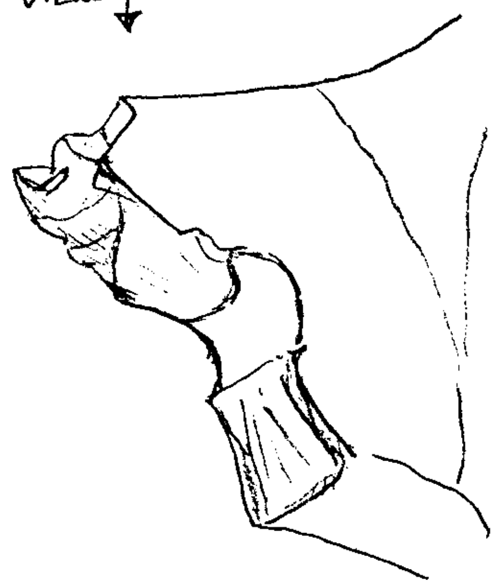
CW 216



LBL 79

CW 221

SAME; BUT DIFFERENT VIEWS



[illegible]
1/24/97

[illegible]
1/24/97

DRAG SPLICE FITTING FRACTURE FACES

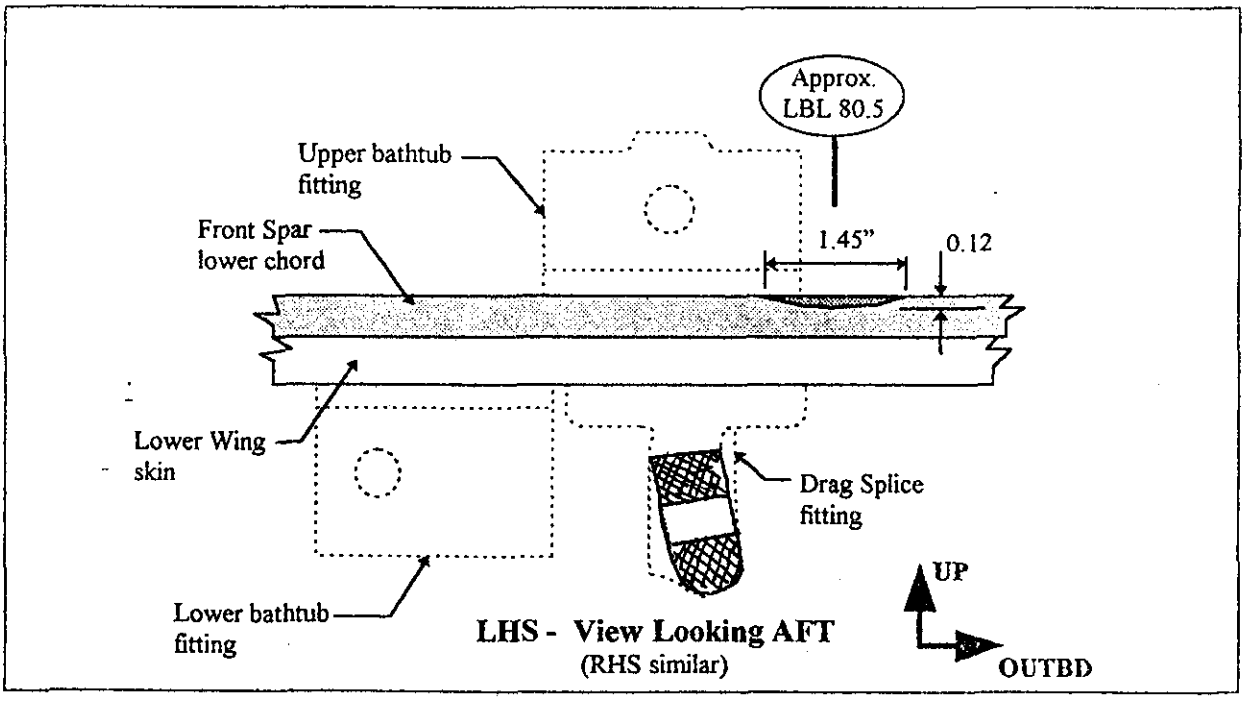
(SEE ALSO RF95 AND LF51)

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 ⇐ 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 Trigil 1/24/97

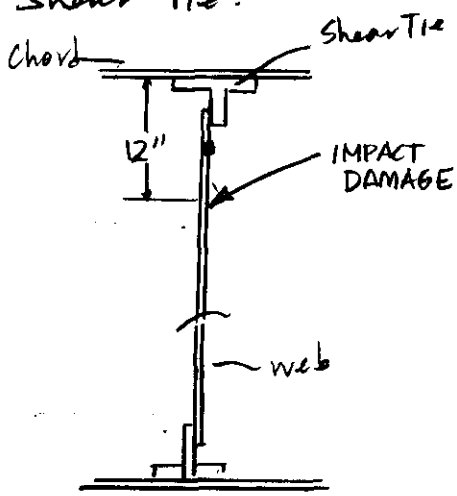


FS & SWB #3 Impact Damage Study

- I made observations of impact damage noted on AFT surface of Front Spar stiffeners and on the Front Surface of SWB #3, (See table attached). Noted dimension of impact damage, and missing structure on SWB #3. on FS; SWB #3

- Graphically depicted what the FWD movement of the SWB #3 would do to the FS stiffeners (impact damage). Assumed the top was free to move and bottom was fixed and rotated about the lower shear tie.

- Top shear tie would impact FS at 12" from top of upper base of upper shear tie.



- Then calculated where the predicted damage range would occur based on the missing portion of the SWB #3. Based on a few examples it was determined that the upper fractured ends of SWB #3 may have easily caused the impact damage noted on the aft FS stiffeners. If the lower end of SWB #3 shifts AFT then the damage to the FS stiffeners will be lower (see enclosed example).

JR Strauss 10/5/96

LH 12/12/96

	Front Spar	Spanwise Beam #3		
Stiffener Location	Impact Damage on Stiffeners (back-Side) [1]		Remaining Structure [1]	Impact Marks on front surface of Beam [1]
		Predicted Damage		
LBL 106.72	No Damage		—	
LBL 98.48	From 16"-24"		LBL 98.48 Below 22"	Nothing
LBL 91.14	" 12"-19"		LBL 91.14 " 18"	Nothing
LBL 83.24	* " 13"-36"	12"-40"	LBL 83.24 " 17"	Nothing
LBL 75.82	" 13-26"		LBL 75.90 " 4"	Fastener heads 41"-12"
LBL 66.65	" 10-21"		LBL 66.65 " 20"	Nothing
LBL 57.40	* " 10-20"	12"-17"	LBL 57.48 " 4"	Fastener heads 20", 11", 8"
LBL 49.66	* " 12-16"	12-20"	49.32 " 6"	Nothing
LBL 41.77	* " 10-31"	12-35"	41.77 " 15"	Fastener head 34"
LBL 33.89	* " 12-34"	12-24"	33.97 " 9"	Nothing
LBL 26.03	* " 12.5-37"	12-31"	25.26 " 16"	Fastener heads 30", 24"
LBL 18.13	" 11-39"		17.27 " 17"	Nothing
LBL 11.07	" 12-15"		11.31 " 30"	Fastener head 31"
BL 0	" 11-17.5"		BL 0 " 23"	Fastener heads 32", 31.5"
RBL 11.07	" 11-30"		RBL 11.31 " 23"	Skin 26"
RBL 18.13	" 11-18		RBL 17.27 " 20"	Fastener heads 38", 35.5"
RBL 26.03	" 11-15.5"		RBL 25.26 " 15"	Fastener heads 42"-34"
RBL 33.89	" 11-19"		RBL 33.97 " 10"	Fastener heads 44"-36", 11"
RBL 41.77	" 10.5-17"		RBL 41.77 " 8"	Fastener heads 41", 9.5"
RBL 49.66	" 13-26"		RBL 49.60 " 19"	Nothing
RBL 57.40	" 12-16"		—	
RBL 66.65	" 11-19"		—	
RBL 75.82	" 7-19"		—	
RBL 83.24	" 4-15"		—	
RBL 91.14	" 12.5-27"		—	
RBL 98.48	" 12.5-31"		—	
RBL 106.72	" 14-22"		—	

[1] All Distances are Measured from the top of the UPPER Shear Tie