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**CASE FAULT ANALYSIS FOR THE
MIRROR FUSION TEST FACILITY
(MFTF) MAGNET SYSTEM**

MASTER

GENERAL DYNAMICS
Convair Division

REPORT NO. GDC-LLL-79-002

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(MFTF) MAGNET SYSTEM**

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TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1 INTRODUCTION	1
2 STRUCTURAL REQUIREMENTS	2
2.1 MATERIAL PROPERTIES	2
2.2 FACTORS OF SAFETY	2
3 ANALYSIS	
3.1 INTRODUCTION	5
3.2 BASELINE	5
3.3 FAULT NO. 1: MINOR RADIUS INTERMEDIATE 3 TO 5 INCH PLATE INTERSECTION IN THE CHAMFER REGION AT THE CENTERLINE OF SYMMETRY	6
3.3.1 Selection Rationale	6
3.3.2 Analysis Methodology	6
3.3.3 Analysis Results	12
3.4 FAULT NO. 2: CONDUCTOR PACK JACKET CLOSE-OUT WELD IN THE MAJOR TO MINOR RADIUS TRANSITION	12
3.4.1 Selection Rationale	12
3.4.2 Analysis Methodology	16
3.4.3 Analysis Results	16
3.5 FAULT NO. 3: INTERCOIL MEMBER SHEAR TRANSFER WELD, BOTTOM CLOSURE PLATE TO SIDE PLATE CORNER WELD	19
3.5.1 Selection Rationale	19
3.5.2 Analysis Methodology	19
3.5.3 Analysis Results	19
3.6 FAULT NO. 4: 3-INCH PLATE CLOSE-OUT WELD AT THE CENTER LINE OF SYMMETRY IN THE MINOR RADIUS AT THE BOTTOM OF THE 9 SECTION	23
3.6.1 Selection Rationale	23
3.6.2 Analysis Methodology	23
3.6.3 Analysis Results	23

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
3.7 FAULT NO. 5: MAJOR TO MINOR RADIUS TRANSITION, 3 TO 5 INCH BUTT WELD JOINT ON THE CONDUCTOR CASE TOP PLATE	25
3.7.1 Selection Rationale	25
3.7.2 Analysis Methodology	25
3.7.3 Analysis Results	25
4 CONCLUSIONS	33
5 RECOMMENDATIONS	35
6 REFERENCES	36
APPENDIX A: MFTF CASE FAULT ANALYSIS: BASELINE MODEL GDSAP COMPUTER ANALYSIS RESULTS	A-1
APPENDIX B: MFTF CASE FAULT ANALYSIS: FAULT NO. 1, MINOR RADIUS INTERMEDIATE 3 TO 5 INCH PLATE INTERSECTION IN THE CHAMFER REGION AT THE CENTER LINE OF SYMMETRY, GDSAP MODEL COM- PUTER ANALYSIS RESULTS	B-1
APPENDIX C: MFTF CASE FAULT ANALYSIS: FAULT NO. 2, CONDUCTOR PACK JACKET CLOSE-OUT WELD IN THE MAJOR TO MINOR RADIUS TRANSITION, GDSAP MODEL COMPUTER ANALYSIS RESULTS	C-1
APPENDIX D: MFTF CASE FAULT ANALYSIS: FAULT NO. 3, INTERCOIL MEMBER SHEAR TRANSFER WELD (BOTTOM CLOSURE PLATE TO SIDE PLATE CORNER WELD), GDSAP MODEL COMPUTER ANALYSIS RESULTS	D-1
APPENDIX E: MFTF CASE FAULT ANALYSIS: FAULT NO. 4, 3-INCH PLATE CLOSE-OUT WELD AT THE CEN- TER LINE OF SYMMETRY IN THE MINOR RADIUS AT THE BOTTOM OF THE 9 SECTION, GDSAP MODEL COMPUTER ANALYSIS RESULTS	E-1
APPENDIX F: MFTF CASE FAULT ANALYSIS: FAULT NO. 5, MAJOR TO MINOR RADIUS TRANSITION 3 TO 5 INCH BUTT WELD JOINT ON THE CONDUCTOR CASE TOP PLATE, GDSAP MODEL COMPUTER ANALYSIS RESULTS	F-1

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1. 1	MFTF GDSAP Finite Element Model	
3. 1	Baseline Model Peak Principal Stresses	7
3. 2	Baseline Model Case Crossover Plate Principal Stresses	8
3. 3	Baseline Model Case Side Plate Principal Stresses	9
3. 4	Baseline Model Corner Longitudinal Stresses	10
3. 5	Fault Condition Number 1	11
3. 6	Fault Condition No. 1 – Baseline Plating Principal Stress Comparison (Case Side Locations)	13
3. 7	Fault Condition No. 1 – Baseline Plating Principal Stress Comparison (Case Crossover Locations)	14
3. 8	Fault Condition Number 2	15
3. 9	Fault No. 2 – Longitudinal Stresses at Top of L Section 0. 5 in. Jacket Close-Out Plate	17
3. 10	Fault No. 2 – Longitudinal Stresses at Bottom of L Section 0. 5 in. Jacket Close-Out Plate	18
3. 11	Fault Condition Number 3	20
3. 12	Intercoil Structure Loads for Baseline No. 6 (Magnetic Loads Only)	21
3. 13	Intercoil Structure Loads for Fault No. 3 (Magnetic Loads Only)	22
3. 14	Fault Condition Number 4	24
3. 15	Fault Condition Number 5	26
3. 16	Fault No. 5 – Baseline Model Plate Membrane Stress Comparison	27
3. 17	Fault No. 5 – Baseline Model Plate Bending Stress Comparison	28
3. 18	Fault No. 5 – Baseline Model Selected Plate Principal Stress Comparison	29

LIST OF FIGURES (Continued)

<u>Figure</u>		<u>Page</u>
3.19	Fault No. 5: Longitudinal Stresses Along Case Top Outside Corner	30
3.20	Fault No. 5: Longitudinal Stresses Along Case Top Inside Corner	31

LIST OF TABLES

<u>Table</u>		<u>Page</u>
2.1	Structural Material Mechanical Properties	3
2.2	MFTF Case Material Fracture Analysis Properties	4
4.1	Results Summary	34

SUMMARY

This report describes the stress analysis performed to determine the criticality of selected failures in the magnet case, jacket, and intercoil member.

Since this task was a follow-on to the program that confirmed the structural integrity of the MFTF magnet case, jacket, and shield system (Ref. 1), every effort was made to utilize analysis methods and tools developed during that program. Figure 1.1 illustrated the large, 5000 degree of freedom GDSAP model developed during that program which was used extensively throughout this analysis task. This model accurately represents the case and jacket structure and simulates the conductor pack stiffness with an array of interconnected rod elements. All results contained in the report are based on linear-elastic, small deflection theory.

The selected faults were idealized by adding additional nodes coincidental to existing nodes in the baseline finite element model and changing fault boundary plate connectivities. No attempt was made to alter the analysis mesh size adjacent to any fault as this degree of effort was beyond the intent and scope of this task.

Subsequent to the finite element computer analysis of each assumed fault condition, deflection data was extracted from the computer output data to determine the tensile stress normal to the approaching fault front. Using this stress data, a Mode I linear-elastic fracture mechanics analysis was performed to quantify the criticality of each fault.

Results of this analysis indicated that two of the five faults analyzed would be catastrophic in nature. Faults of this category are:

Fault No. 1 — A weld joint failure in the minor radius 3 to 5 inch plate intersection in the chamfer region at the centerline of symmetry. (Ref. Figure 3.5)

Fault No. 5 — Failure of the 3 to 5 inch transition butt weld joint at the major to minor radius transition on the magnet case top plate. (Ref. Figure 3.15)

In addition, another one of the faults analyzed was determined to be potentially catastrophic, i. e., it would continue to propagate under cyclic loading until catastrophic failure occurs unless arrested. This fault was fault No. 4, which simulated the failure of the close-out weld in the 3.0-inch plate at the centerline of symmetry in the minor radius at the bottom of the 9 section. (Ref. Figure 3.14)

Figure 1.1. MFTF GDSAP Finite Element Model

Analysis of fault No. 2, the failure of the close-out weld in the 0.5-inch jacket plate at the major to minor radius transition, indicated that the jacket would fail under cyclic loading. However, comparison of the resulting stresses in the case plates before and after jacket failure indicate that the system, as a whole, will not experience a significant increase in local stresses.

In addition, an intercoil member fault condition was analyzed. Implications of this analysis are inconclusive as review of the finite element results of this simulated fault condition indicate no significant redistribution of stresses. This is probably a consequence of the model mesh size adjacent to the fault boundary. Decreasing the mesh size would have indicated local peaking effects and allowed a more accurate appraisal as to the impact of this assumed fault condition. However, additional study of this fault condition does not appear to be warranted.

As a result of this study the following recommendations were made:

1. A periodic magnet inspection plan be developed and implemented for critical areas.
2. In order to more accurately represent the structural behavior in the presence of a crack tip, future fault analyses should utilize a non-linear finite element code (such as MARC) that has that capability.
3. If a linear code such as GDSAP is used for future fault analysis purposes, the mesh size adjacent to fault boundaries should be reduced to more accurately predict local peaking effects.

INTRODUCTION

This report documents the stress analyses for the MFTF magnet system fault analysis task. The analysis is based on LLL requirements to determine the criticality of selected failures in the magnet case, jacket, and intercoil structure.

As a logical follow-on to the program that confirmed the structural integrity of the MFTF magnet case, jacket, and shield system (Ref. 1), every effort was made to utilize analysis methods and tools developed during that program. Figure 1.1 illustrated the large, 5000 degree of freedom GDSAP model developed during that program which was used extensively throughout this analysis task. This model accurately represents the case and jacket structure and simulates the conductor pack stiffness with an array of interconnected rod elements. All results contained in the report are based on linear-elastic, small deflection theory.

The results of the finite element analysis that form the basis of the work contained herein are summarized in Section 3. Details of the finite element model may be found in Ref. 1, Appendix A, Vol. I.

Detailed computer output, including plate margin of safety summaries and plate margin of safety comparisons to the baseline model, are contained in Appendices A through F.

STRUCTURAL REQUIREMENTS

2.1 MATERIAL PROPERTIES

The mechanical properties and fracture analysis materials data for the MFTF structural materials are listed in Tables 2.1 and 2.2, respectively. In the case of E316L welds, flaw growth rate data was unavailable. For analysis purposes, data was estimated from 310S with E310-16 filler data. The yield strengths in Table 2.1 for the E316L welds and the 304LN plate are less than the 120 ksi design values defined by LLL. It is expected that 120 ksi yield strengths will be obtained through increase in nitrogen content in 304LN and control of delta ferrite content in the 316L welds. For design purposes, the mechanical properties of the 304LN and 316L were used as shown in Table 2.1 except for the use of an assumed 120 ksi yield strength.

2.2 FACTORS OF SAFETY

As this study concerns structural analysis of fault conditions, conventional factor of safety requirements are not presented. However, margin of safety fault/baseline model comparisons are presented in the Appendices. These comparisons are based on a factor of safety of 1.5 on yield strength.

Table 2.1. Structural Material Mechanical Properties

Material	Usage	Temp °K	F _{TU} (ksi)	F _{TY} (ksi)	E _{10⁶} (psi)	Source
304L	Support Struts	RT 4.5	100 245	40 70	28.5 29.6	LLL
304LN	Magnet Case and Intercoil	4.5	244.6	111.8*	29.7	NBS
E316L ΔFe = 4.5 ΔFe = 9.2	Case Weld Metal	4.5 4.5	193 187	116* 128*	31.9 31.9	NBS
316L	Jacket	RT 4.5	80 200	40 80	29.5 31.9	
EPON 828/Versamid 125 with Chopped Glass Fiber	Conductor Shimming	20°	-14700	—	—	GDC EMS 0-0096-51
CPR Upjohn Polycast 1009-78	Jacket to Case	RT	-13250	—	.387	Mfgr Data
A286	Support Bolts	RT	140	95	29.1	AMS 5737H

Table 2.2. MFTF Case Material Fracture Analysis Properties

Material	Temp (°K)	F _{TY} (ksi)	K _{IC} (ksi in.)	da/dN Flaw Growth Rate μ in./Cycle	Source
304LN (0.12% N)	4.5	111.8	203	$1.054 \times 10^{-4} (\Delta K)^{3.59}$	1
E316L Weld Filler					
ΔFe = 4.5	4.5	116	110	Not available	1
ΔFe = 9.2	4.5	128	95	Not available	1
E310-16 Weld Filler (AISI 310S, SMAW)	4.2	120	106 3	$4.98 \times 10^{-8} (\Delta K)^{5.15}$	1

ANALYSIS

3.1 INTRODUCTION

The objective of this fault analysis was to determine the criticality of selected failures in the magnet case, jacket, and intercoil member. These fault analyses were accomplished using the GDSAP finite element model developed during the initial structural analysis of the magnet system. All analyses accomplished herein are linear elastic and based on small deflection theory.

A total of five fault conditions were analyzed during this study. Isometric sketches, selection rationale, and analysis results are presented in subsequent sections for each of the following faults:

1. Minor radius intermediate 3 to 5 inch plate intersection in the chamfer region at center line of symmetry.
2. Conductor pack jacket close-out weld in the major to minor radius transition.
3. Intercoil member shear transfer weld, bottom closure plate to side plate corner weld.
4. The 3-inch close-out weld at the center line of symmetry in the minor radius at the bottom of the 9 section.
5. The 3 to 5 inch transition butt weld joint at the major to minor radius transition on the conductor case top plate.

Appendix A contains a plate margin of safety summary and the complete computer print-out for the baseline (no-fault) configuration model. This baseline model is slightly different from the analysis model used in the MFTF design analysis. The triangular plate elements used in the minor radius chamfered region of the design analysis model were replaced by quadrilateral elements in the fault analysis baseline model in an attempt to increase the accuracy of the analysis. Also, some electromagnetic load discrepancies found in the design analysis model were corrected. Appendices B through F contain the above material and comparisons between the plate margins of safety for the baseline model and each fault condition.

3.2 BASELINE

The baseline analysis contained herein is based on conductor pack connectivity scheme No. 6 arrived at during the conductor pack analysis task (Ref. 2).

Figure 3.1 presents peak principal stresses in the case plates for the combined magnetic plus thermal (normal operating) load combination. Figures 3.2 and 3.3 present principal stresses at selected locations for the magnetic loads case only.

Figure 3.4 is of particular importance as it displays the longitudinal stresses close to each corner of the conductor pack and vacuum guard cases. These stresses were developed by simple $\Delta L/L$ calculations using the GDSAP analysis output nodal deflection data. For several analysis conditions it is these stresses that will determine the criticality of an assumed fault.

Appendix A contains a plate margin of safety summary and the complete computer printout for the baseline configuration model.

3.3 FAULT NO. 1: MINOR RADIUS INTERMEDIATE 3 TO 5 INCH PLATE INTERSECTION IN THE CHAMFER REGION AT THE CENTERLINE OF SYMMETRY

3.3.1 SELECTION RATIONALE

Fault No. 1 is displayed graphically in Figure 3.5. The selection rationale for this fault follows:

- Weld Joint
 - Complex unbalanced weld-on-weld joint
 - Heat sink gradient
- Joint Geometry
 - Chamfer region increases welding difficulty but has no significant effect on gross stress distribution
- Stress
 - Plate membrane stresses parallel to this weld joint approach 80 ksi (Ref. 1)
 - Principal stresses in the 5" plate approach 80 ksi (Ref. 1)
- Concern
 - Loss of the 5 to 3 inch joint (basically a shear transfer member) may result in excessive case deflection and subsequent conductor pack crushing

3.3.2 ANALYSIS METHODOLOGY

Concident grids points were installed at the intersection of the 5-inch cross-over and 3-inch case side plate at the chamfer region. Continuous connectivity was provided for in the 3-inch plate while connectivity in the 5-inch was interrupted throughout a 20° arc (approximately 6.82 inches).

Figure 3. 1. Baseline Model Peak Principal Stresses

Figure 3.2. Baseline Model Case Crossover Plate Principal Stresses

Figure 3.3. Baseline Model Case Side Plate Principal Stresses

Figure 3.4. Baseline Model Corner Longitudinal Stresses

JOINT GEOMETRY

Figure 3.5. Fault Condition Number 1

3.3.3 ANALYSIS RESULTS

Figures 3.6 and 3.7 compare principal stresses for this fault condition with baseline principal stresses for selected locations. To determine the tensile stress normal to the approaching fault front, deflection data was extracted from the SAP solution computer output. This normal stress is required to determine the criticality of a flaw using linear elastic fracture mechanics analysis techniques (Mode I analysis).

Analysis of the 5-inch plate deflection data indicates that the stress field normal to the approaching fault front is approximately 25,880 psi, neglecting bending. Assuming an infinite plate with a finite crack,

$$\begin{aligned} K_I &= \sigma \sqrt{\pi a} && (\text{Ref. 3}) \\ &= 25880 \sqrt{6.82\pi} \\ &= 120 \text{ ksi } \sqrt{\text{in.}} \end{aligned}$$

Previous fracture mechanics analyses (Ref. 1) have reported a K_{IC} value for E316 weld filler ($\Delta Fe = 9.2$) at 4.5°K of 95 ksi $\sqrt{\text{in.}}$ Comparison of calculated and critical stress intensity values indicates that this fault would continue to propagate under static loading until a lower stress field is encountered or a crack arrest mechanism is encountered.

3.4 FAULT NO. 2: CONDUCTOR PACK JACKET CLOSE-OUT WELD IN THE MAJOR TO MINOR RADIUS TRANSITION

3.4.1 SELECTION RATIONALE

Fault No. 2 is displayed graphically in Figure 3.8. The selection rationale for this fault follows:

- Weld Joint
 - Close-out weld increases weld inspection difficulty
- Joint Geometry
 - Joint oriented normal to significant plate membrane stresses
- Stresses
 - Principal stresses in the area of the joint approach 50 ksi (Ref. 1)

Figure 3.6. Fault Condition No. 1 — Baseline Plating Principal Stress Comparison
(Case Side Locations)

Figure 3.7. Fault Condition No. 1 — Baseline Plating Principal Stress Comparison (Case Crossover Locations)

- Concern

- Decreased weld inspectability increases probability of potentially critical flaw existing
- Previous stress analysis assumed that the jacket plating contributed to the case stiffness. Jacket failure will increase the primary case plate stresses

3.4.2 ANALYSIS METHODOLOGY

At the fault location, coincident grid points were installed along the entire 0.5" plate "L" section as it was assumed the transition from 0.5" to 1.0" jacket plating would act as a crack arrest mechanism. Continuity was provided for an all case plating while continuity of the 0.5" jacket plate was interrupted at the plane in question.

3.4.3 ANALYSIS RESULTS

Figures 3.9 and 3.10 display the longitudinal stresses that are normal to the assumed fault. These stresses were derived by extracting corner node displacement data from the SAP analysis computer output and performing simple $\Delta l/l$ calculations. At the fault location, plane No. 8, it can be seen that the local stress at the top of the "L" section is compressive in nature and therefore will not encourage fault propagation (Mode I). The local stress at the bottom of the "L" section (Figure 3.10) is approximately 40,271 psi tension and will promote fault propagation. It is interesting to note that for the baseline analysis, this same area had a local tension stress of 40,015 psi (see Figure 3.4).

Assuming an 0.5" edge crack in a infinite plate (the remaining 1.0" "L" section) a Mode I stress intensity may be calculated from the following expression

$$\begin{aligned} K_I &= 1.1215 \sigma \sqrt{\pi a} \quad (\text{Ref. 3}) \\ &= 40015 \sqrt{0.5\pi} \\ &= 50 \text{ ksi } \sqrt{\text{in.}} \end{aligned}$$

Comparison of the calculated and critical stress intensity values indicates that this fault would continue to propagate under cyclic loading, but comparison of the fault plate results and baseline plate results indicates that loss of this jacket stiffness would not have a significant effect on the local stress distribution of the case.

DEGREE OF FIT IS 12 NUMBER OF DATA POINTS = 13

COEFFICIENTS (0, 1, 2, ... DEGREE) ARE

-1.801943985728866E+06	.245723711693452E+07	-2.29440346138824E+07
2.282902980793306E+07	-3.48823304133546E+06	2.78888815004455E+06
-4.1753568286673E+05	5.0134862543E943E+04	-3.88547224917126E+03
1.79499193764404E+02	-3.84778323505451E+00	-1.3592913360184E-02
1.53841242707758E-03		

MEAN OF RESIDUALS = -2.68650743E-10

ONE SIGMA RESIDUAL = 2.62540281E-08

VARIANCE OF RESIDUALS = 5.89273993E-16

Figure 3.9. Fault No. 2 — Longitudinal Stresses at Top of L Section
0.5 in. Jacket Close-Out Plate

DEGREE OF FIT IS 8 NUMBER OF DATA POINTS = 13

COEFFICIENTS(0, 1, 2, ... DEGREE) ARE

- .354684618384308E+05	.840437241040254E+05	-.809179626750052E+05
.383085842857400E+05	-.102951543431890E+05	.161258932318443E+04
-.143430005006308E+03	.687951281380375E+01	-.125308311791313E+00

MEAN OF RESIDUALS = -7.38789542E-10

ONE SIGMA RESIDUAL = 1.06389769E+03

VARIANCE OF RESIDUALS = 1.13187830E+06

Figure 3.10. Fault No. 2 - Longitudinal Stresses at Bottom of L Section
0.5 in. Jacket Close-Out Plate

3.5 FAULT NO. 3: INTERCOIL MEMBER SHEAR TRANSFER WELD, BOTTOM CLOSURE PLATE TO SIDE PLATE CORNER WELD

3.5.1 SELECTION RATIONALE

The intercoil fault condition is shown graphically in Figure 3.11. The selection rationale for this fault follows:

- Weld Joint
 - Joint Geometry — No Significant Effect
- Stress
 - Compressive Only
- Concern
 - Loss of Joint May Cause Intercoil Member Instability and System Catastrophic Failure

3.5.2 ANALYSIS METHODOLOGY

Coincident grid points were installed along the intercoil member fault corner. The plate connectivity was altered so there could be no load transfer between the bottom and side plate locally along the fault perimeter.

3.5.3 ANALYSIS RESULTS

Figures 3.12 and 3.13 present the plate membrane stresses in the intercoil structure for the normal operating magnetic condition for the baseline model (connectivity scheme No. 6) and the intercoil fault condition, respectively.

Principal stress and factor of safety calculations were performed at locations 1 and 2 for both models; results are presented below.

Location/ CQUAD No.	Principal Stress (psi)		Margin of Safety*	
	Baseline	Fault	Baseline	Fault
1/1720	-63700	-55300	0.88	1.17
2/1724	-36800	-35300	2.26	2.40

*Based on a compressive yield allowable of 120 ksi.

Implications of this analysis are inconclusive as review of the finite element results of this simulated fault condition indicate no significant redistribution of stresses.

Figure 3.11. Fault Condition Number 3

Figure 3.12. Intercoil Structure Loads for Baseline No. 6
(Magnetic Loads Only)

Figure 3.13. Intercoil Structure Loads for Fault No. 3
(Magnetic Loads Only)

3.6 FAULT NO. 4: 3-INCH PLATE CLOSE-OUT WELD AT THE CENTER LINE OF SYMMETRY IN THE MINOR RADIUS AT THE BOTTOM OF THE 9 SECTION

3.6.1 SELECTION RATIONALE

An isometric sketch of the fault condition is shown in Figure 3.14. The selection rationale for this fault condition follows:

- Weld Joint
 - Close-out Weld; Increases Weld Inspection Difficulty
- Joint Geometry
 - Not Significant
- Stress
 - Moderate Plate Longitudinal Membrane Stress (Ref. 1)
- Concern
 - Decreased weld inspectability increases probability of potentially critical flaw existing. Joint failure and subsequent redistribution of stresses may result in excessive deflections and conductor pack crushing

3.6.2 ANALYSIS METHODOLOGY

The fault was assumed to extend from the minor radius center line of symmetry through a 20-degree arc (half length = 6.82 in.). Coincident grid points were installed in the baseline model along existing fault line grid points. Continuity of the 3- to 5-inch plate joint was interrupted by redefining existing CQUAD element grid point connectivities.

3.6.3 ANALYSIS RESULTS

Deflection data near the approaching fault front was extracted from the computer output for use in a Mode I fracture analysis. From this deflection data the local plate membrane stress was determined to be approximately 5,667 psi. From linear elastic mechanics theory, for an infinite plate with a finite center crack,

$$K_I = \sigma \sqrt{\pi a}$$

substituting in $\sigma = 5,667$ psi and $a = 6.82$ " yields

$$K_I = 5667 \sqrt{6.82\pi} = 26.23 \text{ ksi } \sqrt{\text{in.}}$$

Figure 3.14. Fault Condition Number 4

As previously noted, K_{IC} for E316 weld filler metal at 4.5°K is 95 ksi $\sqrt{\text{in.}}$. Comparison of the calculated stress intensity factor and the critical stress intensity indicates that this fault will continue to propagate under cyclic loading until failure or a crack arrest mechanism is encountered.

3.7 FAULT NO. 5: MAJOR TO MINOR RADIUS TRANSITION, 3 TO 5 INCH BUTT WELD JOINT ON THE CONDUCTOR CASE TOP PLATE

3.7.1 SELECTION RATIONALE

The selection rationale for this fault (see Figure 3.15 for an isometric illustration) was as follows:

- Weld Joint
 - One Sided Butt Joint (Unbalanced)
 - Weld Bead Reinforcement on (K_T)
 - Heat Sink Gradient
- Joint Geometry
 - 3 to 5 Inch Plate Transition Produces Local Stress Raiser
- Stress
 - Plate Membrane Stresses Normal to This Joint Approach 60 ksi (Ref. 1)
 - Transverse Secondary Bending Moments Approach 95 in-kips/in. (Ref. 1)
- Concern
 - Joint failure causes a significant reduction in magnet section modulus resulting in redistribution of stresses and possible system catastrophic failure

3.7.2 ANALYSIS METHODOLOGY

The existing baseline model was modified to reflect coincident grid point along the fault line. Plate connectivities were modified such that load could not be transferred across the fault line.

3.7.3 ANALYSIS RESULTS

Figures 3.16, 3.17 and 3.18 present plate membrane, bending and principal stresses for selected case elements for the fault and baseline finite element models. Review of these figures indicates significant changes in the local stress fields around the fault. Figures 3.19 and 3.20 present longitudinal plane membrane stresses which

Figure 3. 15. Fault Condition Number 5

Figure 3.16. Fault No. 5 — Baseline Model Plate Membrane Stress Comparison

Figure 3.17. Fault No. 5 — Baseline Model Plate Bending Stress Comparison

Figure 3.18. Fault No. 5 — Baseline Model Selected Plate Principal Stress Comparison

DEGREE OF FIT IS 12 NUMBER OF DATA POINTS = 13

COEFFICIENTS(0, 1, 2, ... DEGREE) ARE

.69368560087010E+07	-.20761880286020E+08	.264193500010855E+08
-.188314105253100E+08	.810010822006720E+07	-.248321200100140E+07
-.615283122580017E+06	-.751418051874963E+05	.787825177854025E+04
-.537825840450467E+03	.84588705088971E+02	-.669818377246443E+00
.791173975227465E-02		

Figure 3.19. Fault No. 5: Longitudinal Stresses Along
Case Top Outside Corner

DEGREE OF FIT IS 12 NUMBER OF DATA POINTS = 12

COEFFICIENTS(0, 1, 2, ... DEGREE) ARE

8	-.224769139982547E+00	.689592300088670E+00	-.870914542542082E+00
7	.629775906403510E+00	-.284976016484290E+00	.866231284527034E+00
6	-.182540900134917E+07	.2700834876399644E+06	-.270639941691853E+00
5	.196300756435245E+04	-.917027957750055E+02	.248082533654035E+00
4	-.300825675519400E-01		

Figure 3.20. Fault No. 5: Longitudinal Stresses Along
Case Top Inside Corner

are perpendicular to the approaching fault front. At plane 8 (Figure 3.20) in the vicinity of the fault, these stresses approach 99,311 psi. For the baseline analysis, these stresses were calculated to be 87,887 psi.

Again, if we assume an edge crack in an infinite plate, then

$$K_I = 1.1215\sigma\sqrt{\pi a}$$

Setting $\sigma = 99311$ psi and $a = 5.0''$ in the above expression yields

$$\begin{aligned} K_I &= 1.1215 \times 99311 \sqrt{5\pi} \\ &= 441 \text{ ksi} \sqrt{\text{in.}} \end{aligned}$$

As compared to the critical stress intensity factors for E316 weld filler and 304LN (95 and 203 ksi $\sqrt{\text{in.}}$ respectively), this calculated K_I reflects a catastrophic failure.

CONCLUSIONS

Results of this study are summarized in Table 4.1. Of the five fault conditions analyzed, two are considered to have structurally catastrophic effects; catastrophic meaning these faults would be reflected by sudden and violent changes in the geometry of the structure. The two faults considered structurally catastrophic (Mode I analysis) were:

Fault No. 1 — Minor radius intermediate 3 to 5 inch plate intersection in the chamfer region at the centerline of symmetry.

Fault No. 5 — The 3 to 5 inch transition butt weld joint at the major to minor radius transition on the conductor case top plate.

Fault No. 4, the 3-inch plate close-out weld at the center line of symmetry in the minor radius at the bottom of the 9 section, is considered to be potentially catastrophic; i. e., the calculated stress intensity factors are lower than the critical stress intensity factor but under cyclic loading this fault will continue to propagate until repaired or a suitable crack arrest mechanism is encountered.

Review of the analysis for Fault No. 2, the failure of the close-out weld in the 0.5-inch jacket plate at the major to minor radius transition indicates that the jacket will fail under cyclic loading. However, this local failure should not significantly affect the structural integrity of the magnet system.

Conclusions about the intercoil member fault condition are somewhat different as this member is basically in compression and faults cannot propagate. Review of the analysis results do not indicate any significant redistribution of stresses in the fault area. This is probably a consequence of the modeling technique which employed a relatively large mesh size. Additional study in this area does not appear to be warranted.

Table 4.1. Results Summary

Fault No.	Fault Description	Calculated K_I or MS	Discussion
1	Minor radius intermediate 3 to 5 inch plate intersection in the chamfer region at the center line of symmetry	120 ksi $\sqrt{\text{in.}}$	K_I higher than K_{IC} Fault will be self propagating Catastrophic failure assumed
2	Conductor pack jacket close-out weld in the major to minor radius transition	50 ksi $\sqrt{\text{in.}}$	K_I lower than K_{IC} Fault will propagate under cyclic loading Overall system integrity not significantly affected
3	Intercoil member shear transfer weld, bottom closure plate to side plate corner weld	M.S. = 1.17	m.s. calculated assuming compression yield allowable of 120 ksi Additional analysis required
4	3-inch plate close-out weld at the center line of symmetry in the minor radius at the bottom of the 9 section	26 ksi $\sqrt{\text{in.}}$	K_I lower than K_{IC} Fault will propagate under cyclic loading
5	3 to 5 inch transition butt weld joint at the major to minor radius transition on the conductor case top plate	441 ksi $\sqrt{\text{in.}}$	K_I higher than K_{IC} Fault will be self propagating Catastrophic failure assumed

RECOMMENDATIONS

As a result of this study the following recommendations are made:

1. A periodic magnet inspection plan should be developed and implemented.
2. In order to more accurately represent the structural behavior in the presence of a crack tip, future fault analyses of this type should utilize a non-linear finite element code (such as MARC) that has that capability.
3. If a linear code such as GDSAP is used for future fault analysis purposes, the mesh size adjacent to fault boundaries should be reduced to more accurately predict local peaking effects.

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