AEROJET NUCLEAR SYSTEMS COMPANY
SACRAMENTO, CALIFORNIA**MASTER**

TO: Distribution

FROM: E. K. Bair

SUBJECT: Turbopump Part Reliability Allocation

28 September 1971
EKB:nla N8300:M0744

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Reference: (a) NERVA Engine Reliability Allocations, N8200:M3041 dated
4 August 1971, J. H. Ramsthaller to A. D. Cornell
(b) Turbopump Reliability Allocation to the Part Level,
N8300R:70-042, dated 19 July 1971

Enclosure: (1) Turbopump Part Identification List
(2) Updated; Turbopump Reliability Allocations to the Part
Level

The reliability allocations for the turbopump parts were reevaluated in accordance with the allocations for the six basic failure modes as defined in Reference (a). The identified modes were:

1. Failure to Start
2. Premature Stop
3. Low Performance
4. Total Loss of Containment
5. Excessive Vibration
6. External Leakage

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The same basic technique as presented in Reference (b) was applied. Enclosure (1) lists the turbopump parts considered and Enclosure (2) contains the attendant reliability allocations.

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E. K. Bair
E. K. Bair, Supervisor
Technical Support Section
Turbopump Department
Engineering Operations

CLASSIFICATION CATEGORY

UNCLASSIFIED

E. K. Bair 9-28-71
CLASSIFYING OFFICER DATE

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TURBOPUMP PART IDENTIFICATION LIST

<u>IDENT. NO.</u>	<u>PART</u>
1	INDUCER
2	1ST IMPELLER
3	2ND IMPELLER
4	THRUST BALANCER
5	TIE BOLT
6	PUMP HOUSING
7	1ST TURBINE ROTOR
8	2ND TURBINE ROTOR
9	1ST TURBINE STATOR
10	2ND TURBINE STATOR
11	TURBINE INLET MANIFOLD
12	TURBINE EXHAUST MANIFOLD
13	PUMP END BEARING CARTRIDGE
14	TURBINE END BEARING CARTRIDGE
15	1ST STAGE IMPELLER SHROUD LABYRINTH
16	FORWARD 1ST STAGE IMPELLER HUB LABYRINTH
17	AFT 1ST STAGE IMPELLER HUB LABYRINTH
18	2ND STAGE IMPELLER SHROUD LABYRINTH
19	TURBINE END BEARING FORWARD LABYRINTH
20	TURBINE END BEARING AFT LABYRINTH
21	INDUCER HOUSING
22	TRUNNION
23	BOLT (21 to 22)
24	INDUCER SHROUD INSERT
25	SHIM
26	BOLT (FOR 24)
27	FILTER
28	FILTER FLANGE BOLT
29	BALANCER RETURN MANIFOLD BOLTS
30	FILTER FLANGE SEAL
31	BALANCER RETURN MANIFOLD SEALS

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TURBOPUMP PART IDENTIFICATION LIST (Cont'd)

Enclosure (1)
N8300:M0744
Page 2

<u>IDENT. NO.</u>	<u>PART</u>
32	BALANCER RETURN MANIFOLD
33	INDUCER SPINNER
34	SPINNER DRIVE PINS
35	SPINNER BOLT
36	SPINNER LOCK
37	SPEED PICKUP
38	SPEED PICKUP RETAINER
39	DISTANCE DETECTOR RETAINER
40	SPEED PICKUP CONNECTOR
41	DISTANCE DETECTOR CONNECTOR
42	THERMOCOUPLE CONNECTOR
43	SPEED PICKUP LEADS
44	DISTANCE DETECTOR LEADS
45	SPEED PICKUP SHIMS
46	DISTANCE DETECTOR SHIMS
47	DISTANCE DETECTOR
48	THRUST BALANCER HOUSING (PUMP BACK PLATE/ AFT BEARING HOUSING)
49	THRUST BALANCER LANDS
50	THRUST BALANCER LANDS SHIMS
51	THRUST BALANCER HOUSING TO PUMP HOUSING SEAL
52	THRUST BALANCER HOUSING TO TURBINE INLET MAN.SEAL
53	THERMOCOUPLE
54	THERMOCOUPLE CONNECTOR SEALS
55	SHEET METAL SHIELD FOR TURBINE END
56	SHEET METAL SHIELD BOLTS
57	AFT BEARING CARTRIDGE RETAINER
58	AFT BEARING CARTRIDGE RETAINER SHIMS
59	1ST STAGE ROTOR SHROUD LABYRINTH OUTER LAND
60	2ND STAGE ROTOR SHROUD LABYRINTH OUTER LAND

TURBOPUMP PART IDENTIFICATION LIST (Cont'd)

<u>IDENT. NO.</u>	<u>PART</u>
61	STATOR STACKING SHIM
62	TURBINE END DISTANCE DETECTOR MOUNTING PL.
63	TURBINE END DISTANCE DETECTOR MOUNTING PL. BOLTS
64	TORQUE CHECK-ASSESS ASSEMBLY
65	BEARING COOLANT FEED LINE
66	THERMOCOUPLE LEADS

UPDATED; TURBOPUMP RELIABILITY ALLOCATIONS TO THE PART LEVEL

TURBOPUMP(TPA) RELIABILITY= .99983000

QUALITY FACTOR= .25000

TPA R FAIL TO START= .99993000000

TPA R PREMATURE ST OP= .99999100000

TPA R LOW PERFORM= .99990000000

TPA R TOT.LOSS CONT= .9999999997

TPA R EXCESSIVE VIB = .99998000000

TPA R EXTERN LEAK= .99999600000

PART IDENT	PART FAIL START	PART PREM.STOP	PART LOW PERFORM
1	.999999606250000	.99999866071429	.999996601562500
2	.999999475000000	.99999872767857	.999998125000000
3	.999999737500000	.999998593750000	.999998476562500
4	.999999901250000	.999999792410714	.999996718750000
5	.999999212500000	.99999892867143	1.000000000000000
6	.999998816750000	.99999876803571	.999997656250000
7	.999999093750000	.999999310196429	.999998242187500
8	.999998818750000	.999998819196429	.999998476562500
9	.999998293750000	.99999832589286	.999998710937500
10	.999998093750000	.99999882589286	.999998710937500
11	.999999343750000	.999999758928571	.999997304687500
12	.999999475000000	.999999758928571	.999997421875000
13	.999997000000000	.999999812500000	1.000000000000000
14	.999997900000000	.999999812500000	1.000000000000000
15	.999995143750000	.999999812500000	.999996132812500
16	.999995143750000	.999999779017857	.999996132812500
17	.999995143750000	.999999779017857	.999996132812500
18	.999995143750000	.999999779017857	.999996132812500
19	.999997000000000	.999999886166714	.999998007812500
20	.999997900000000	.999999886166714	.999998007812500
21	.999999737500000	.999999872767857	.999999765625000
22	1.000000000000000	.999999953125000	.999999882812500

23	1.0000000000000000	.999999953125000	1.0000000000000000
24	.999999868750000	.999999953125000	.999998476562500
25	1.0000000000000000	.999999799107143	1.0000000000000000
26	.999999737500000	.999999959821429	1.0000000000000000
27	.999998950000000	.999999906250000	.999999062500000
28	1.0000000000000000	.999999933035714	1.0000000000000000
29	1.0000000000000000	.999999933035714	1.0000000000000000
30	1.0000000000000000	.999999886160714	.999999765625000
31	1.0000000000000000	.999999886160714	.999999765625000
32	1.0000000000000000	.999999919642857	.999999062500000
33	1.0000000000000000	.999999966517857	1.0000000000000000
34	1.0000000000000000	.999999986607143	1.0000000000000000
35	1.0000000000000000	.999999996607143	1.0000000000000000
36	1.0000000000000000	.999999986607143	1.0000000000000000
37	.999999606250000	.999999959821429	.999998945312500
38	1.0000000000000000	.999999959821429	1.0000000000000000
39	1.0000000000000000	.999999959821429	1.0000000000000000
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41	1.0000000000000000	.999999939732143	.999998476562500
42	1.0000000000000000	.999999939732143	.999998476562500
43	1.0000000000000000	.999999946428571	.999998828125000
44	1.0000000000000000	.999999946428571	.999998828125000
45	1.0000000000000000	.999999966517857	.999999414062500
46	1.0000000000000000	.999999966517857	.999999414062500
47	1.0000000000000000	.999999939732143	.999998945312500
48	.999999212500000	.999999892857143	.999998593750000
49	.999999657000000	.999999812500000	.999996718750000
50	.999999475000000	.999999973214286	1.0000000000000000
51	1.0000000000000000	.999999899553571	.999999765625000
52	1.0000000000000000	.999999899553571	.999999765625000

53	1.0000000000000000	.999999926339286	.999998710937500
54	1.0000000000000000	.999999953125000	.999999179687500
55	1.0000000000000000	.999999979910714	1.000000000000000
56	1.0000000000000000	.999999973214286	1.000000000000000
57	.999999737500000	.999999973214286	1.000000000000000
58	1.0000000000000000	.999999973214286	1.000000000000000
59	.999998162500000	.999999839285714	.999997324687500
60	.999998162500000	.999999839285714	.999997324687500
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62	.999999475000000	.999999933035714	.999998828125000
63	1.0000000000000000	.999999959821429	1.000000000000000
64	1.0000000000000000	.999999946428571	1.000000000000000
65	1.0000000000000000	.999999765625000	.999997421875000
66	1.0000000000000000	.999999946428571	.999998828125000
PART IDENT	PART LOSS CONTN	PART EX,VIBRATION	PART EXTERN LEAK
1	.999999999997325	.999999134020619	1.000000000000000
2	.999999999997640	.999999164948454	1.000000000000000
3	.999999999997010	.999999226804124	1.000000000000000
4	1.0000000000000000	.999999474226804	1.000000000000000
5	.999999999998741	.999999567010309	1.000000000000000
6	.999999999998741	.999999567072165	.999999736111111
7	.999999999996427	.999999474226804	1.000000000000000
8	.999999999997325	.999999474226804	1.000000000000000
9	.999999999999371	.999999331443299	1.000000000000000
10	.999999999999371	.999999381443299	1.000000000000000
11	.999999999996269	.999999721649485	.999999708333333
12	.999999999993741	1.000000000000000	.999999694444444
13	1.0000000000000000	.999999134020619	1.000000000000000
14	1.0000000000000000	.999999134020619	1.000000000000000

15	1.030000000000000000	.999999319587629	1.000000000000000000
16	1.000000000000000000	.999999134020619	1.000000000000000000
17	1.000000000000000000	.999999134020619	1.000000000000000000
18	1.000000000000000000	.999999134020619	1.000000000000000000
19	1.000000000000000000	.999999597938144	1.000000000000000000
20	1.000000000000000000	.999999597938144	1.000000000000000000
21	.999999999999999999	.999999783505155	.9999997777777778
22	.999999999999999999	.999999783505155	1.000000000000000000
23	1.000000000000000000	.999999783505155	1.000000000000000000
24	1.000000000000000000	.999999969072165	1.000000000000000000
25	1.000000000000000000	.999999938144334	1.000000000000000000
26	.999999999999999999	.999999814432990	1.000000000000000000
27	1.000000000000000000	1.000000000000000000	1.000000000000000000
28	1.000000000000000000	1.000000000000000000	.999999951111111
29	1.000000000000000000	1.000000000000000000	.999999951111111
30	1.000000000000000000	1.000000000000000000	.999999763888889
31	1.000000000000000000	1.000000000000000000	.999999763888889
32	1.000000000000000000	1.000000000000000000	.999999944444444
33	1.000000000000000000	.999999907216495	1.000000000000000000
34	1.000000000000000000	.999999969072165	1.000000000000000000
35	1.000000000000000000	.999999969072165	1.000000000000000000
36	1.000000000000000000	1.000000000000000000	1.000000000000000000
37	1.000000000000000000	.999999907216495	1.000000000000000000
38	1.000000000000000000	1.000000000000000000	1.000000000000000000
39	1.000000000000000000	.999999876286660	1.000000000000000000
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44	1.000000000000000000	1.000000000000000000	1.000000000000000000

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47	1.0000000000000000	.999999907216495	.999999958333333
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66	1.0000000000000000	1.0000000000000000	1.0000000000000000

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33	1.0000000000000000	.999999907216495	1.0000000000000000
34	1.0000000000000000	.99999969072165	1.0000000000000000
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41	1.0000000000000000	1.0000000000000000	1.0000000000000000
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43	1.0000000000000000	1.0000000000000000	1.0000000000000000
44	1.0000000000000000	1.0000000000000000	1.0000000000000000

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55	1.0000000000000000	.999999979910714	1.0000000000000000
56	1.0000000000000000	.999999973214286	1.0000000000000000
57	.999999737500000	.999999973214286	1.0000000000000000
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61	1.0000000000000000	.999999959821429	1.0000000000000000
62	.999999475000000	.999999933035714	.999998828125000
63	1.0000000000000000	.999999959821429	1.0000000000000000
64	1.0000000000000000	.999999946428571	1.0000000000000000
65	1.0000000000000000	.999999765625000	.999997421875000
66	1.0000000000000000	.999999946428571	.999998828125000

PART IDENT	PART LOSS CONTN	PART EX,VIBRATION	PART EXTERN LEAK
1	.999999999997325	.999999134020619	1.0000000000000000
2	.999999999997640	.999999164948454	1.0000000000000000
3	.999999999997010	.999999226804124	1.0000000000000000
4	1.0000000000000000	.999999474226804	1.0000000000000000
5	.999999999998741	.999999567010309	1.0000000000000000
6	.999999999998741	.99999969072165	.999999736111111
7	.999999999998427	.999999474226804	1.0000000000000000
8	.999999999997325	.999999474226804	1.0000000000000000
9	.999999999999371	.999999381443299	1.0000000000000000
10	.999999999999371	.999999381443299	1.0000000000000000
11	.999999999998269	.999999721649485	.999999708333333
12	.999999999998741	1.0000000000000000	.999999694444444
13	1.0000000000000000	.999999134020619	1.0000000000000000
14	1.0000000000000000	.999999134020619	1.0000000000000000

23	1.0000000000000000	.999999953125000	1.0000000000000000
24	.999999868750000	.999999953125000	.999998476562500
25	1.0000000000000000	.999999799107143	1.0000000000000000
26	.999999737500000	.999999959821429	1.0000000000000000
27	.999998950000000	.999999906250000	.999999062500000
28	1.0000000000000000	.999999933035714	1.0000000000000000
29	1.0000000000000000	.999999933035714	1.0000000000000000
30	1.0000000000000000	.999999886160714	.999999765625000
31	1.0000000000000000	.999999886160714	.999999765625000
32	1.0000000000000000	.999999919642857	.999999062500000
33	1.0000000000000000	.999999966517857	1.0000000000000000
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37	.999999606250000	.999999959821429	.999998945312500
38	1.0000000000000000	.999999959821429	1.0000000000000000
39	1.0000000000000000	.999999959821429	1.0000000000000000
40	1.0000000000000000	.999999939732143	.999998476562500
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43	1.0000000000000000	.999999946428571	.999998828125000
44	1.0000000000000000	.999999946428571	.999998828125000
45	1.0000000000000000	.999999966517857	.999999414062500
46	1.0000000000000000	.999999966517857	.999999414062500
47	1.0000000000000000	.999999939732143	.999998945312500
48	.999999212500000	.999999892857143	.999998593750000
49	.999999685000000	.999999812500000	.999996718750000
50	.999999475000000	.999999973214286	1.0000000000000000
51	1.0000000000000000	.999999899553571	.999999765625000
52	1.0000000000000000	.999999899553571	.999999765625000

TURBOPUMP(TPA) RELIABILITY= .99983000

QUALITY FACTOR= .25000

TPA R FAIL TO START= .99993000000

TPA R PREMATURE ST OP= .99999100000

TPA R LOW PERFORM= .99990000000

TPA R TOT.LOSS CONT= .9999999997

TPA R EXCESSIVE VIB = .99998000000

TPA R EXTERN LEAK= .99999600000

PART IDENT

PART FAIL START

PART PREM.STOP

PART LOW PERFORM

1

.999999606250000

.999999866071429

.999996601562500

2

.999999475000000

.999999872767857

.999998125000000

3

.999999737500000

.999999859375000

.999998476562500

4

.999996981250000

.999999792410714

.999996718750000

5

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.999999892857143

1.000000000000000

6

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.999997656250000

7

.999998293750000

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8

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9

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12

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.999997421875000

13

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1.000000000000000

14

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1.000000000000000

15

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.999996132812500

16

.999995143750000

.999999779017857

.999996132812500

17

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19

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20

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22

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• XQT MAIN

22 SEP 71 08:08:05.159

Moore Business Forms, Inc.


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00264 77*      61 PREL(J)=1.0D 0=XQEL*FEL(J)/1.0D 06
00266 78*      1 FORMAT(2F15.14)
00267 79*      2 FORMAT(F15.4)
00270 80*      3 FORMAT(I5/(6F10.2))
00271 81*      4 FORMAT(////,10X,'TURBOPUMP(TPA) RELIABILITY=',F10.8,6X,'QUALITY F
00271 82*      1ACTOR=',F7.5)
00272 83*      5 FORMAT(//10X,'TPA R FAIL TO START=',F13.11,4X,'TPA R PREMATURE ST
00272 84*      1OP=',F13.11,4X,'TPA R LOW PERFORM=',F13.11)
00273 85*      6 FORMAT(//,10X,'TPA R TOT.LOSS CONT=',F13.11,4X,'TPA R EXCESSIVE VI
00273 86*      1B =',F13.11,4X,'TPA R EXTERN LEAK=',F13.11)
00274 87*      7 FORMAT(///,10X,'PART IDENT',5X,'PART FAIL START',16X,'PART PREM.ST
00274 88*      1OP',16X,'PART LOW PERFORM')
00275 89*      8 FORMAT(///,10X,'PART IDENT',5X,'PART LOSS CONTN',16X,'PART EX.VIBR
00275 90*      1ATION',14X,'PART EXTERN LEAK')
00276 91*      9 FORMAT(/,I15,9X,F17.15,14X,F17.15,14X,F17.15)
00277 92*      WRITE(6,4)RTPA,QF
00303 93*      WRITE(6,5)RFS,RPS,RLP
00310 94*      WRITE(6,6)RTLCL,REV,REL
00315 95*      WRITE(6,7)
00317 96*      DO 70 J=1,N
00322 97*      70 WRITE(6,9)J,PRFS(J),PRPS(J),PRLP(J)
00331 98*      WRITE(6,8)
00333 99*      DO 80 J=1,N
00336 100*     80 WRITE(6,9)J,PRTLCL(J),PREV(J),PREL(J)
00345 101*     GO TO 500
00346 102*     END

```

END OF UNIVAC 1108 FORTRAN V COMPILATION.

0 *DIAGNOSTIC* MESSAGE(S)


```

00101 17* C PREL=PART RELIABILITY EXTERNAL LEAKAGE
00101 18* C N=PART IDENTIFICATION NUMBER
00101 19* C FFS=PART FAIL TO START MODE VALUE
00101 20* C FPS=PART PREMATURE STOP MODE VALUE
00101 21* C FLP=PART LOW PERFORMANCE MODE VALUE
00101 22* C FTLC=PART TOTAL LOSS OF CONTAINMENT MODE VALUE
00101 23* C FEV=PART EXCESSIVE VIBRATION MODE VALUE
00101 24* C FEL=PART EXTERNAL LEAKAGE MODE VALUE
00103 25* DIMENSION PREV(100),PREL(100),FFS(100),FPS(100),FLP(100),FTLC(100)
00104 26* DIMENSION FEV(100),FEL(100)
00105 27* DIMENSION PRFS(100),PRPS(100),PRLP(100),PRTL(100)
00106 28* 500 READ(5,1)RTPA,QF
00112 29* READ(5,2)RFS
00115 30* READ(5,2)RPS
00120 31* READ(5,2)RLP
00123 32* READ(5,2)RTL
00126 33* READ(5,2)REV
00131 34* READ(5,2)REL
00134 35* READ(5,3)N,(FFS(J),FPS(J),FLP(J),FTLC(J),FEV(J),FEL(J),J=1,N)
00150 36* AQFS=1.0D 06*(1.0D0-RFS)*(1.0D0-QF)
00151 37* AQPS=1.0D 06*(1.0D0-RPS)*(1.0D0-QF)
00152 38* AQLP=1.0D 06*(1.0D0-RLP)*(1.0D0-QF)
00153 39* AQTLC=1.0D 06*(1.0D0-RTL)*(1.0D0-QF)
00154 40* AQEV=1.0D 06*(1.0D0-REV)*(1.0D0-QF)
00155 41* AQEL=1.0D 06*(1.0D0-REL)*(1.0D0-QF)
00156 42* QFS=0.0D0
00157 43* DO 10 J=1,N
00162 44* 10 QFS=QFS+FFS(J)
00164 45* XQFS=AQFS/QFS
00165 46* DO 11 J=1,N
00170 47* 11 PRFS(J)=1.0D0-XQFS*FFS(J)/1.0D 06
00172 48* QPS=0.0D0
00173 49* DO 20 J=1,N
00176 50* 20 QPS=QPS+FPS(J)
00200 51* XQPS=AQPS/QPS
00201 52* DO 21 J=1,N
00204 53* 21 PRPS(J)=1.0D0-XQPS*FPS(J)/1.0D 06
00206 54* QLP=0.0D0
00207 55* DO 30 J=1,N
00212 56* 30 QLP=QLP+FLP(J)
00214 57* XQLP=AQLP/QLP
00215 58* DO 31 J=1,N
00220 59* 31 PRLP(J)=1.0D0-XQLP*FLP(J)/1.0D 06
00222 60* QTLC=0.0D0
00223 61* DO 40 J=1,N
00226 62* 40 QTLC=QTLC+FTLC(J)
00230 63* XQTLC=AQTLC/QTLC
00231 64* DO 41 J=1,N
00234 65* 41 PRTL(J)=1.0D0-XQTLC*FTLC(J)/1.0D 06
00236 66* QEV=0.0D 0
00237 67* DO 50 J=1,N
00242 68* 50 QEV=QEV+FEV(J)
00244 69* XQEV=AQEV/QEV
00245 70* DO 51 J=1,N
00250 71* 51 PREV(J)=1.0D 0-XQEV*FEV(J)/1.0D 06
00252 72* QEL=0.0D0
00253 73* DO 60 J=1,N
00256 74* 60 QEL=QEL+FEL(J)
00260 75* XQEL=AQEL/QEL
00261 76* DO 61 J=1,N

```


*I FOR MAIN,MAIN
 UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F5018S
 THIS COMPILATION WAS DONE ON 22 SEP 71 AT 08:08:03

22 SEP 71 08:08:03.373

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000442
0000	*DATA	005005
0002	*BLANK	000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	NRDUS
0004	NI02\$
0005	NI01\$
0006	NWDUS
0007	NSTOP\$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	004626	1F	0001	000065	137G	0001	000154	160G	0001	000165	166G	0001	000200	174G	
0000	004630	2F	0001	000211	202G	0001	000224	210G	0001	000235	216G	0001	000250	224G	
0001	000261	232G	0001	000274	240G	0001	000305	246G	0001	000320	254G	0001	000331	262G	
0000	004632	3F	0001	000377	320G	0001	000423	334G	0000	004635	4F	0000	004653	5F	
0001	000000	500L	0000	004676	6F	0000	004721	7F	0000	004742	8F	0000	004763	9F	
0000	D	004574	AQEL	0000	D	004572	AQEV	0000	D	004562	AQFS	0000	D	004564	AQPS
0000	D	004570	AQTLC	0000	D	002570	FEL	0000	D	002260	FEV	0000	D	001440	FLP
0000	D	001130	FPS	0000	D	001750	FTLC	0000	I	004561	J	0000	D	000310	PREL
0000	D	000000	PREV	0000	D	003100	PRFS	0000	D	003720	PRLP	0000	D	004230	PRTLCL
0000	D	004622	QEL	0000	D	004616	QEV	0000	D	004542	QF	0000	D	004606	QLP
0000	D	004602	QPS	0000	D	004612	QTLC	0000	D	004556	REL	0000	D	004544	RFS
0000	D	004550	RLP	0000	D	004546	RPS	0000	D	004552	RTLCL	0000	D	004624	XQEL
0000	D	004620	XQEV	0000	D	004600	XQFS	0000	D	004610	XQLP	0000	D	004614	XQTLC

00101	1*		IMPLICIT REAL*8 (A-H,O-Z)
00101	2*	C	PROGRAM COMPUTES RELIABILITY FOR NERVA TURBOPUMP PARTS
00101	3*	C	NOMENCLATURE
00101	4*	C	RTPA=TURBOPUMP RELIABILITY ALLOCATION
00101	5*	C	RFS=FAILURE TO START RELIABILITY OF TPA
00101	6*	C	RPS=PREMATURE STOP RELIABILITY OF TPA
00101	7*	C	RLP=LOW PERFORMANCE RELIABILITY OF TPA
00101	8*	C	RTLCL=TOTAL LOSS OF CONTAINMENT RELIABILITY OF TPA
00101	9*	C	REV=EXCESSIVE VIBRATION RELIABILITY OF TPA
00101	10*	C	REL=EXTERNAL LEAKAGE RELIABILITY OF TPA
00101	11*	C	QF=QUALITY FACTOR
00101	12*	C	PRFS=PART RELIABILITY FAIL TO START
00101	13*	C	PRPS=PART RELIABILITY PREMATURE STOP
00101	14*	C	PRLP=PART RELIABILITY LOW PERFORMANCE
00101	15*	C	PRTLCL=PART RELIABILITY LOSS OF CONTAINMENT
00101	16*	C	PREV=PART RELIABILITY EXCESSIVE VIBRATION

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22 SEP 71 08:08:03.289

Moore Business Forms, Inc. 34

AEROJET NUCLEAR SYSTEMS COMPANY
SACRAMENTO, CALIFORNIA

TO: E. B. Cleveland

11 August 1971
EKB:nla N8300:M0721

FROM: E. K. Bair

SUBJECT: Turbopump Reliability Allocation to the Part Level

DISTRIBUTION: N. A. Edlebeck*, S. A. Lorenc, K. G. Kirk, F. E. McMullen,
G. P. Milligan, J. H. Ramsthaller*

Enclosure: (1) Turbopump Reliability Allocation to the Part Level,
Report N8300R:70-042 dated 19 July 1971

*Without Enclosure

Enclosure (1) contains the turbopump part reliability allocations.
The allocations will be updated, as necessary, to reflect the influence
of probabilistic analysis and test data.

E. K. Bair, Supervisor
Technical Support Section
Turbopump Department
Engineering Operations

CLASSIFICATION CATEGORY	
UNCLASSIFIED
8-11-71
CLASSIFYING OFFICER	DATE

ENGINEERING OPERATIONS REPORT

TURBOPUMP RELIABILITY ALLOCATION
TO THE PART LEVEL

PROJECT 121

19 July 1971

E. K. Bair

APPROVED:

N. A. Edlebeck, Manager
Turbopump Department

CLASSIFICATION CATEGORY	
UNCLASSIFIED	
CLASSIFYING OFFICER	DATE
11-71

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I. INTRODUCTION

A preliminary failure modes analysis for the turbopump, Reference (1), and a reliability allocation to the part, Reference (2), were made in the fourth quarter of CY 70. These data were judged to be somewhat difficult to use in that they were not, necessarily, related to the basic component FMECA failure modes of: Failure to Start, Premature Stop, Low Performance, Total Loss of Containment, Excessive Vibration and External Leakage.

Based upon the three basic failure modes of Failure to Start, Premature Stop and Low Performance, a reallocation of reliability to the part level, for the turbopump was made. The failure modes of Total Loss of Containment, Excessive Vibration and External Leakage were included under the Premature Stop failure mode.

Reference (3) contains the failure mode analysis for the three basic failure modes.

The following report discusses the method used in making the part allocations and the resulting values.

As the turbopump design matures through additional analysis and testing, the allocations will be adjusted, at the part level, to reflect the most realistic apportionment.

II. SUMMARY

The basic failure modes for the turbopump was established as: Fail to Start, Low Performance and Premature Stop. The three basic failure modes were then broken down into fourteen failure functions.

II. (Continued)

Using the failure functions, the part level failure mechanisms were determined. The failure mechanisms were then broken down into causes, the causes being assigned alpha numeric ratings. A given cause was applied to a part only once. The alpha numeric ratings were then converted to numerical equivalents and summed for each part.

The overall turbopump reliability allocation was converted to a quantity "Q" which represents the total allowable failure per million. This number was further reduced by a quality factor which accounts for unknowns and possible oversights in the analysis ($Q_{TPA} = Q_{All} \times (1 - \text{quality factor})$).

Using the summation of the part cause ratings as the counterpart to the Q_{TPA} value, the actual part Q allocations are found by direct ratio. These values are then converted into part reliability allocations.

The reliabilities as related to the three discrete failure modes (part and overall) were determined based on a function/failure mechanism relationship. The relationship is then assessed based upon the quantity of failure modes which were related to the particular failure mechanism. The part values (Q values as related to the failure modes) were then determined by summation and direct ratio and the part failure mode reliability determined. The TPA failure mode reliability apportionments were found by summing the part level function values and then taking the ratio of this value to the overall TPA Q value.

The resulting reliability allocations are included in Appendices A through D. The reliability numbers shown do not agree precisely with the current (7-21-71) allocations as given in the FMECA. A second allocation iteration will be withheld until the results of the initial probabilistic analysis can be incorporated. At that time the analyzed and allocated values will be brought into line.

III. TECHNICAL DISCUSSION

The failure mode requirements (first level) were defined for the turbopump in three basic categories.

1. Start up in the specified sequence, as determined by the engine transient requirements.
2. Provide performance as specified in order to maintain the engine operating conditions within the required limits.
3. Assure that the endurance capability is such that a premature shutdown may be precluded.

Using these basic failure modes, the turbopump reliability allocations were generated in the following manner.

- a. Define failure functions (based on failure modes)
(see Appendix A).
- b. Define for each part the applicable failure functions.
- c. Determine failure function to failure mechanism relationship for each part.
- d. Examine and evaluate failure mechanisms against possible contributing effects or causes.
- e. Assign alpha-numeric values to applicable effects or causes.
- f. Determine criticality index for part, by summing alpha-numeric values (Q value).
- g. Determine part reliability by ratioing part Q value to total Q value of all parts.

III. (Continued)

At this point, the overall part allocations are complete. The turbopump and part reliabilities, based upon the three basic failure modes, were then determined in the following manner.

- a. The failure function/failure mode relationships for each part are determined, based upon the part failure mechanisms, i.e., the failure mechanisms were examined to determine if they could or could not have an effect on one or more of the failure modes.
- b. The part reliability as related to a given failure mode is determined by taking the ratio of the sum of the applicable failure function for a failure mode to the sum of all applicable failure functions for all failure modes.

A detailed description of each activity is as follows, for the overall TPA:

- a. The basic failure modes of Fail to Start, Low Performance and Premature Stop were broken down to failure functions; these are defined as follows:
 - (1) Provide specified flow rate: This is design related and is a judgement of the correctness of the specified through flow areas.
 - (2) Provide specified pressure: This relationship is based upon speed, area, and flow rates demand relationship. It is a measure of the design to satisfy the engine systems requirements.

III. (Continued)

- (3) Provide specified flow path for pump and turbine flows: This is related to the maintenance of the proper flow paths through the TPA.
- (4) Contain pump and turbine flow within specified limitations: Housing rupture and external seal leakage are the main factors in this function.
- (5) Accelerate to rated conditions within specified time: Considerations for rotating static parts are made along with the ability of the unit to meet the transient hydraulic and aerodynamic requirements.
- (6) Shutdown in the specified sequence: Similar to (5) except for the shutdown case.
- (7) Provide pump performance of a specified characteristic and stall margin: The relationship of stability to operating condition and basic design are considered.
- (8) Operate at 0 NPSP at specified conditions (2 NPSP in the single TPA operating mode): The ability to meet the specification requirement is assessed against the design's capability.
- (9) Perform within the specified requirements for 10 hours accumulated duration and 60 cycles: The endurance requirements are used to judge the parts failure mechanisms.
- (10) Provide performance at both start and end of life as specified. The tolerance requirements are considered.

III. (Continued)

- (11) Shall be capable of chilldown within the specified limits: The effect of part mass is considered.
- (12) Shall be operable while sustaining specified line loads: Deflections and their effects are assessed.
- (13) Provide incipient failure detection and trend data: The ability of the TPA instrumentation to meet the requirements and duty cycle is judged.
- (14) Provide turbine limits within the specified limits.

The failure functions are listed in Appendix A.

The list of turbopump component parts may be found in Appendix B along with their attendant failure functions.

Using the associated failure functions for a particular part, failure mechanisms are identified. Appendix C includes the part Failure Function/Failure Mechanisms relationships for each part.

Using the failure function/failure mechanism relationship data, an assessment of the failure mechanism to causes is made. The "causes" listed in Appendix C were derived from those identified in the original FMA, Reference (1). The causes are assigned alpha-numeric rating. A single cause is accounted for only once. As an example, the material properties effects or causes are assumed to have a single influence and are weighted equally to all failure modes to which they can be related. This effect was one of the major deficiencies in the first TPA FMA.

III. (Continued)

The alpha-numeric ratings are then given numeric values based upon the following value matrix:

DESIGN SUCCESS POTENTIAL-ALPHA	RATING		DEGREE OF CONTROL-NUMERIC
A	High		1
B	Medium High		2
C	Medium Low		3
D	Low		4

SCORE				
	1	2	3	4
A	$1/10^6$	$10/10^6$	$100/10^6$	$1000/10^6$
B	$10/10^6$	$100/10^6$	$1000/10^6$	--
C	$100/10^6$	$1000/10^6$	--	--
D	$1000/10^6$	--	--	--

The sum of the numeric cause values are now found for each part (Q_{part}).

At this point, a computer program was generated to compute the actual part reliability allocations based upon the given TPA reliability allocation.

1. The sum of the part numeric cause values (Q_{part}) is found (all parts considered).
2. The TPA allocated reliability is subtracted from 1.0 and the result multiplied by 10^6 . This number is then reduced by a quality factor which accounts for unknowns and possible oversights. This is Q_{TPA} .

III. (Continued)

3. The summation of the causes from 1. is now divided into the Q_{TPA} value found in 2. This factor is now multiplied by each of the Q_{part} values. A $Q_{part\ real}$ relative to the allocated Q_{TPA} value is now known. This is the allocated part Q.

4. The part reliability is simply the value of

$$\frac{10^6 - Q_{part\ real}}{10^6}$$

In order to establish TPA and part reliability allocations for the three failure modes the following technique was applied.

1. At the part "Failure Function/Failure Mechanism" level, Appendix "C", the failure mechanisms are assessed relative to the three possible failure modes of low performance, premature stop, and fail to start. A given failure mechanisms was allowed to be influenced by more than one failure mode if it were judged possible. If a failure mode was identified with a failure mechanisms, the failure mechanisms was assigned a failure mode numerical value equal to the total number of failure functions assigned to that failure mechanisms, see Appendix C. The failure mode part Q values, for the failure mechanisms, are now summed. The resulting values are then summed giving a total failure mode (relative) value for a part. The failure mode influence factors are then determined by dividing the values for a particular mode by the total of all of the failure mode values for a part, i.e., they are evaluated as percentages of the total.

III. (Continued)

The failure mode percentage values, for a part, are now multiplied by the $Q_{\text{part}_{\text{real}}}$ values established during the overall part reliability assessment. The result is a value which can now be converted to a reliability number for the part and for a particular failure mode.

The failure mode reliability for the overall turbopump is determined by summing the part values for a mode (those values which are a percentage of the total $Q_{\text{part}_{\text{real}}}$). The resulting $Q_{\text{failure mode}_{\text{TPA}}}$ numbers are then converted to reliability numbers in the usual manner.

Appendix D lists the failure mode TPA and part reliability allocations as well as the overall part level reliability allocations; the computer program listing is also shown. Part identification numbers are established in Appendix B.

Subsequent to this initial allocation, the Reliability Section made FMECA allocations for the identified failure modes. These allocations differ from those determined. Resolution of these differences will be withheld until the influence of the initial probabilistic analysis can be assessed and incorporated. At that time, the computed allocations and the FMECA allocations will be made identical.

REFERENCES

1. Memorandum 7740:M0535, Preliminary Failure Mode Analysis for Turbopump, W. E. Campbell to J. H. Ramsthaller, dated 21 July 1970.
2. Memorandum 7740:M0568, Preliminary Reliability Allocation for The NERVA Turbopump to the Part Level, N. A. Edlebeck to J. H. Ramsthaller, dated 15 September 1970.
3. Memorandum 8300:M0706, Failure Mode Analysis, N. A. Edlebeck to Distribution, dated 14 July 1971

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E. K. Bair
19 July 1971
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APPENDIX A

TURBOPUMP FAILURE FUNCTIONS

TURBOPUMP FAILURE FUNCTIONS

1. Fails to provide specified flow rate.
2. Fails to provide specified pressure rise or ratio.
3. Does not provide specified flow path.
4. Does not contain flow (pressure) within specified limitations.
5. Does not accelerate to rated conditions within specified time.
6. Does not shutdown in specified sequence.
7. Does not provide pump performance of a specified shape and stall margin.
8. Will not operate at 0 NPSP at specified conditions (2 NPSP in single TPA mode).
9. Does not perform within specified limits for 10 hours accumulated duration and 60 cycles.
10. Fails to meet "start and end" of life performance requirements.
11. Will not meet chilldown requirements.
12. Is not operable while sustaining specified line loads.
13. Does not provide incipient failure detection or trend data.
14. Does not provide turbine performance within specified limits.
15. Does not provide mechanical function.

APPENDIX B

TURBOPUMP COMPONENT PARTS IDENTIFICATION AND APPLICABLE FAILURE FUNCTIONS

TURBOPUMP COMPONENT PARTS IDENTIFICATION AND
APPLICABLE FAILURE FUNCTIONS

A. CRITICAL COMPONENTS

<u>IDENT.NO.</u>	<u>PART</u>	<u>APPLICABLE FAILURE FUNCTIONS</u> (See Appendix A)
1.	INDUCER	1, 2, 3, 5, 7, 8, 9, 10, 15, 12
2.	1ST IMPELLER	1, 2, 3, 5, 7, 8, 9, 10, 11, 15, 12
3.	2ND IMPELLER	1, 2, 3, 5, 7, 9, 10, 11, 15, 12
4.	2ND IMPELLER INLET SECTION	1, 2, 3, 5, 7, 9, 10, 11 12, 15
5.	THRUST BALANCER	3, 5, 6, 9, 10, 11, 12
6.	PUMP TIE BOLT	9, 11, 15
7.	PUMP HOUSING	1, 3, 4, 7, 9, 11, 12, 15, 5
8.	1ST TURBINE ROTOR	3, 4, 5, 9, 10, 11, 12, 15, 14
9.	2ND TURBINE ROTOR	3, 4, 5, 9, 10, 11, 12, 15, 14
10.	1ST TURBINE STATOR	3, 4, 9, 10, 11, 15, 14
11.	2ND TURBINE STATOR	3, 4, 9, 10, 11, 15, 14
12.	TURBINE TIE BOLT	9, 11, 15
13.	TURBINE INLET MANIFOLD	1, 2, 3, 4, 9, 11, 12, 14, 15
14.	TURBINE EXHAUST MANIFOLD	1, 2, 3, 4, 9, 11, 12, 14, 15
15.	PUMP END BEARING CARTRIDGE	5, 6, 9, 10, 11, 12, 15
16.	TURBINE END BEARING CARTRIDGE	5, 6, 9, 10, 11, 12, 15
17.	1ST STAGE IMPELLER SHROUD LABYRINTH	1, 2, 3, 5, 6, 9, 10, 11, 12, 15

TURBOPUMP COMPONENT PARTS IDENTIFICATION AND
APPLICABLE FAILURE FUNCTIONS

A. CRITICAL COMPONENTS (Continued)

<u>IDENT NO.</u>	<u>PART</u>	<u>APPLICABLE FAILURE FUNCTIONS</u>
16-18. <i>Forward</i>	1ST STAGE IMPELLER HUB LABYRINTH	1, 2, 3, 5, 6, 9, 10, 11, 12, 15
17 <i>aft</i>		
19.	2ND STAGE IMPELLER SHROUD LABYRINTH	1, 2, 3, 5, 6, 9, 10, 11, 12, 15
20.	TURBINE END BEARING FORWARD LABYRINTH	1, 2, 3, 5, 6, 9, 10, 11, 12, 15
21.	TURBINE END BEARING AFT LABYRINTH	1, 2, 3, 5, 6, 9, 10, 11, 12, 15

B. NON-CRITICAL COMPONENTS

22.	INDUCER HOUSING	3, 4, 9, 11, 12, 15
23.	TRUNNION	9, 11, 12, 15
24.	BOLT (1 TO 2)	9, 11, 12, 15
25.	INDUCER SHROUD INSERT	3, 7, 8, 10, 11, 15
26.	SHIM	9, 11, 15
27.	BOLT (4 TO 5)	9, 11, 15
28.	FILTER	1, 2, 4, 9
29.	FILTER FLANGE BOLT	9, 11, 15
30.	BALANCER RETURN MANIFOLD BOLTS	9, 11, 15
31.	FILTER FLANGE SEAL	4, 9, 12, 15
32.	BALANCER RETURN MANIFOLD SEALS	4, 9, 11, 12, 15
33.	BALANCER RETURN MANIFOLD	1, 2, 3, 9, 11
34.	INDUCER SPINNER	5, 7, 9
35.	SPINNER DRIVE PINS	15
36.	SPINNER BOLT	15
37.	SPINNER LOCK	15
38.	2ND IMPELLER SEC. RETAINER	3, 5, 9, 11, 15

TURBOPUMP COMPONENT PARTS IDENTIFICATION AND
APPLICABLE FAILURE FUNCTIONS

B. NON-CRITICAL COMPONENTS (Continued)

<u>IDENT NO.</u>	<u>PART</u>	<u>APPLICABLE FAILURE FUNCTIONS</u>
39.	2ND IMPELLER INLET SEC. RETAINER LOCK	15
40.	SPEED PICK UP	4, 9, 11, 13
41.	SPEED PICK UP RETAINER	9, 15
42.	DISTANCE DETECTOR RETAINER	9, 11, 15
43.	SPEED PICK UP CONNECTOR	9, 11, 13
44.	DISTANCE DETECTOR CONNECTOR	9, 11, 13, 15
45.	THERMOCOUPLE CONNECTOR	9, 11, 4, 13, 15
46.	SPEED PICKUP LEADS	9, 11, 13
47.	DISTANCE DETECTOR LEADS	9, 11, 13, 15
48.	SPEED PICKUP SHIMS	9, 11, 15
49.	DISTANCE DETECTOR SHIMS	4, 9, 11, 15
50.	DISTANCE DETECTOR	4, 9, 11, 13
51.	THRUST BALANCER HOUSING (PUMP BACK PLATE/AFT BEARING HOUSING)	3, 4, 9, 11, 12, 15
52.	THRUST BALANCER LANDS	1, 2, 3, 4, 9, 11, 12, 15
53.	THRUST BALANCER LANDS SHIMS	9, 12, 15
54.	THRUST BALANCER HOUSING TO PUMP HOUSING SEAL	4, 9, 11, 12, 15
55.	THRUST BALANCER HOUSING TO TURBINE INLET MAN. SEAL	4, 9, 11, 12, 15
56.	THERMOCOUPLE	4, 9, 11, 13
57.	THERMOCOUPLE CONNECTOR SEALS	4, 9, 11
58.	SHEET METAL SHIELD FOR TURBINE END	9, 11
59.	SHEET METAL SHIELD BOLTS	9, 11, 15
60.	AFT BEARING CARTRIDGE RETAINER	9, 11, 15
61.	AFT BEARING CARTRIDGE RETAINER SHIMS	9, 11, 15

TURBOPUMP COMPONENT PARTS IDENTIFICATION AND
APPLICABLE FAILURE FUNCTIONS

B. NON-CRITICAL COMPONENTS (Continued)

<u>IDENT NO.</u>	<u>PART</u>	<u>APPLICABLE FAILURE FUNCTIONS</u>
62.	1ST STAGE ROTOR SHROUD LABY. OUTER LAND	1, 2, 4, 9, 10, 11, 14, 15
63.	2ND STAGE ROTOR SHROUD LABY. OUTER LAND	1, 2, 4, 9, 10, 11, 14, 15
64.	STATOR STACKING SHIM	9, 11, 12, 15
65.	TURBINE END DIST.DETECT. MTG. PL.	9, 11, 15
66.	TURBINE END DIST. DETECT. MTG. PL. BOLTS	9, 11, 15
67.	TORQUE CHECK-ASSESS ASSY	9, 15
68.	BEARING COOLANT FEED LINE	1, 2, 3, 4, 9, 10, 11, 12, 15
69.	THERMOCOUPLE LEADS	9, 11, 13, 15

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000442
0000	*DATA	005005
0002	*BLANK	000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003	NRDUS
0004	NI026
0005	NI016
0006	NWDUS
0007	NSTOP3

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	004626	1F	0001	000065	137G	0001	000154	160G	0001	000165	166G	0001	000200	174G	
0000	004630	2F	0001	000211	202G	0001	000224	210G	0001	000235	216G	0001	000250	224G	
0001	000261	232G	0001	000274	240G	0001	000305	246G	0001	000320	254G	0001	000331	262G	
0000	004632	3F	0001	000377	320G	0001	000423	334G	0000	004635	4F	0000	004653	5F	
0001	000000	500L	0000	004676	6F	0000	004721	7F	0000	004742	8F	0000	004763	9F	
0000	D	004574	AQEL	0000	D	004572	AGEV	0000	D	004562	AQFS	0000	D	004564	AQPS
0000	D	004570	AQTL	0000	D	002570	FEL	0000	D	002260	FEV	0000	D	001440	FLP
0000	D	001130	FPS	0000	D	001750	FTLC	0000	I	004561	J	0000	I	004560	N
0000	D	000000	PREY	0000	D	003100	PRFS	0000	D	003720	PRLP	0000	D	003410	PRPS
0000	D	004622	QEL	0000	D	004616	QEV	0000	D	004542	QF	0000	D	004576	QFS
0000	D	004602	QPS	0000	D	004612	QTLC	0000	D	004556	REL	0000	D	004554	REV
0000	D	004550	RLP	0000	D	004546	RPS	0000	D	004552	RTLC	0000	D	004540	RTPA
0000	D	004620	XQEV	0000	D	004600	XQFS	0000	D	004610	XQLP	0000	D	004604	XQPS
												0000	D	004614	XQTL

00101	1*		IMPLICIT REAL*8 (A-H,O-Z)
00101	2*	C	PROGRAM COMPUTES RELIABILITY FOR NERVA TURBOPUMP PARTS
00101	3*	C	NOMENCLATURE
00101	4*	C	RTPA=TURBOPUMP RELIABILITY ALLOCATION
00101	5*	C	RFS=FAILURE TO START RELIABILITY OF TPA
00101	6*	C	RPS=PREMATURE STOP RELIABILITY OF TPA
00101	7*	C	RLP=LOW PERFORMANCE RELIABILITY OF TPA
00101	8*	C	RTLC=TOTAL LOSS OF CONTAINMENT RELIABILITY OF TPA
00101	9*	C	REV=EXCESSIVE VIBRATION RELIABILITY OF TPA
00101	10*	C	REL=EXTERNAL LEAKAGE RELIABILITY OF TPA
00101	11*	C	QF=QUALITY FACTOR
00101	12*	C	PRFS=PART RELIABILITY FAIL TO START
00101	13*	C	PRPS=PART RELIABILITY PREMATURE STOP
00101	14*	C	PRLP=PART RELIABILITY LOW PERFORMANCE
00101	15*	C	PRTLC=PART RELIABILITY LOSS OF CONTAINMENT
00101	16*	C	PREV=PART RELIABILITY EXCESSIVE VIBRATION

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00101 17* C PREL=PART RELIABILITY EXTERNAL LEAKAGE
00101 18* C N=PART IDENTIFICATION NUMBER
00101 19* C FFS=PART FAIL TO START MODE VALUE
00101 20* C FPS=PART PREMATURE STOP MODE VALUE
00101 21* C FLP=PART LOW PERFORMANCE MODE VALUE
00101 22* C FTLC=PART TOTAL LOSS OF CONTAINMENT MODE VALUE
00101 23* C FEV=PART EXCESSIVE VIBRATION MODE VALUE
00101 24* C FEL=PART EXTERNAL LEAKAGE MODE VALUE
00103 25* DIMENSION PREV(100),PREL(100),FFS(100),FPS(100),FLP(100),FTLC(100)
00104 26* DIMENSION FEV(100),FEL(100)
00105 27* DIMENSION PRFS(100),PRPS(100),PRLP(100),PRTL(100)
00106 28* 500 READ(5,1)RTPA,QF
00112 29* READ(5,2)RFS
00115 30* READ(5,2)RPS
00120 31* READ(5,2)RLP
00123 32* READ(5,2)RTLC
00126 33* READ(5,2)REV
00131 34* READ(5,2)REL
00134 35* READ(5,3)N,(FFS(J),FPS(J),FLP(J),FTLC(J),FEV(J),FEL(J),J=1,N)
00150 36* AQFS=1.0D 06*(1.0D0-RFS)*(1.0D0-QF)
00151 37* AQPS=1.0D 06*(1.0D0-RPS)*(1.0D0-QF)
00152 38* AQLP=1.0D 06*(1.0D0-RLP)*(1.0D0-QF)
00153 39* AQTLC=1.0D 06*(1.0D0-RTLC)*(1.0D0-QF)
00154 40* AQEV=1.0D 06*(1.0D0-REV)*(1.0D0-QF)
00155 41* AQEL=1.0D 06*(1.0D0-REL)*(1.0D0-QF)
00156 42* QFS=0.0D0
00157 43* DO 10 J=1,N
00162 44* 10 QFS=QFS+FFS(J)
00164 45* XQFS=AQFS/QFS
00165 46* DO 11 J=1,N
00170 47* 11 PRFS(J)=1.0D0-XQFS*FFS(J)/1.0D 06
00172 48* QPS=0.0D0
00173 49* DO 20 J=1,N
00176 50* 20 QPS=QPS+FPS(J)
00200 51* XQPS=AQPS/QPS
00201 52* DO 21 J=1,N
00204 53* 21 PRPS(J)=1.0D0-XQPS*FPS(J)/1.0D 06
00206 54* QLP=0.0D0
00207 55* DO 30 J=1,N
00212 56* 30 QLP=QLP+FLP(J)
00214 57* XQLP=AQLP/QLP
00215 58* DO 31 J=1,N
00220 59* 31 PRLP(J)=1.0D0-XQLP*FLP(J)/1.0D 06
00222 60* QTLC=0.0D0
00223 61* DO 40 J=1,N
00226 62* 40 QTLC=QTLC+FTLC(J)
00230 63* XQTLC=AQTLC/QTLC
00231 64* DO 41 J=1,N
00234 65* 41 PRTL(J)=1.0D0-XQTLC*FTLC(J)/1.0D 06
00236 66* QEV=0.0D0
00237 67* DO 50 J=1,N
00242 68* 50 QEV=QEV+FEV(J)
00244 69* XQEV=AQEV/QEV
00245 70* DO 51 J=1,N
00250 71* 51 PREV(J)=1.0D 0-XQEV*FEV(J)/1.0D 06
00252 72* QEL=0.0D0
00253 73* DO 60 J=1,N
00256 74* 60 QEL=QEL+FEL(J)
00260 75* XQEL=AQEL/QEL
00261 76* DO 61 J=1,N

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00264 77* 61 PREL(J)=1.0D 0-XQEL*FEL(J)/1.0D 06
00266 78* 1 FORMAT(2F15,14)
00267 79* 2 FORMAT(F15,4)
00270 80* 3 FORMAT(I5/(6F10,2))
00271 81* 4 FORMAT(////,10X,'TURBOPUMP(TPA) RELIABILITY=I,F10,8,6X,'QUALITY F
00271 82* 1ACTOR=I,F7,5)
00272 83* 5 FORMAT(//10X,'ITPA R FAIL TO START=I,F13,11,4X,'ITPA R PREMATURE ST
00272 84* 1OP=I,F13,11,4X,'ITPA R LOW PERFORM=I,F13,11)
00273 85* 6 FORMAT(//,10X,'ITPA R TOT,LOSS CONT=I,F13,11,4X,'ITPA R EXCESSIVE VI
00273 86* 1B =I,F13,11,4X,'ITPA R EXTERN LEAK=I,F13,11)
00274 87* 7 FORMAT(///,10X,'PART IDENTI',5X,'PART FAIL START',16X,'PART PREM,ST
00274 88* 1OP',16X,'PART LOW PERFORM')
00275 89* 8 FORMAT(///,10X,'PART IDENTI',5X,'PART LOSS CONTNI',16X,'PART EX,VIBR
00275 90* 1ATION',14X,'PART EXTERN LEAK')
00276 91* 9 FORMAT(/,I15,9X,F17,15,14X,F17,15,14X,F17,15)
00277 92* WRITE(6,4)RTPA,QF
00303 93* WRITE(6,5)RFS,RPS,RLP
00310 94* WRITE(6,6)RTLCL,REV,REL
00315 95* WRITE(6,7)
00317 96* DO 70 J=1,N
00322 97* 70 WRITE(6,9)J,PRFS(J),PRPS(J),PRLP(J)
00331 98* WRITE(6,8)
00333 99* DO 80 J=1,N
00336 100* 80 WRITE(6,9)J,PRTLCL(J),PREV(J),PREL(J)
00345 101* GO TO 500
00346 102* END

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 *DIAGNOSTIC* MESSAGE(S)

TURBOPUMP(TPA) RELIABILITY= .99983000

QUALITY FACTOR= .25000

TPA R FAIL TO START= .99993000000

TPA R PREMATURE ST OP= .99999100000

TPA R LOW PERFORM= .99990000000

TPA R TOT.LOSS CONT= .99999999997

TPA R EXCESSIVE VIB = .99998000000

TPA R EXTERN LEAK= .99999600000

PART IDENT	PART FAIL START	PART PREM.STOP	PART LOW PERFORM
1	.999999606250000	.999999866071429	.999996601562500
2	.999999475000000	.999999872767857	.999998125000000
3	.999999737500000	.999999859375000	.999998476562500
4	.999996981250000	.999999792410714	.999996718750000
5	.999999212500000	.999999892857143	1.000000000000000
6	.999998818750000	.999999805803571	.999997656250000
7	.999998293750000	.999999819196429	.999998242187500
8	.999998818750000	.999999819196429	.999998476562500
9	.999998293750000	.999999832589286	.999998710937500
10	.999998293750000	.999999832589286	.999998710937500
11	.999999343750000	.999999758928571	.999997304687500
12	.999999475000000	.999999758928571	.999997421875000
13	.999997900000000	.999999812500000	1.000000000000000
14	.999997900000000	.999999812500000	1.000000000000000
15	.999995143750000	.999999812500000	.999996132812500
16	.999995143750000	.999999779017857	.999996132812500
17	.999995143750000	.999999779017857	.999996132812500
18	.999995143750000	.999999779017857	.999996132812500
19	.999997900000000	.999999886160714	.999998007812500
20	.999997900000000	.999999886160714	.999998007812500
21	.999999737500000	.999999872767857	.999999765625000
22	1.000000000000000	.999999953125000	.999999882812500

23	1.0000000000000000	.999999953125000	1.0000000000000000
24	.999999868750000	.999999953125000	.999998476562500
25	1.0000000000000000	.999999799107143	1.0000000000000000
26	.999999737500000	.99999959821429	1.0000000000000000
27	.999998950000000	.999999062500000	.999999062500000
28	1.0000000000000000	.99999933035714	1.0000000000000000
29	1.0000000000000000	.99999933035714	1.0000000000000000
30	1.0000000000000000	.99999886160714	.999999765625000
31	1.0000000000000000	.99999886160714	.999999765625000
32	1.0000000000000000	.99999919642857	.999999062500000
33	1.0000000000000000	.99999966517857	1.0000000000000000
34	1.0000000000000000	.99999986607143	1.0000000000000000
35	1.0000000000000000	.99999986607143	1.0000000000000000
36	1.0000000000000000	.99999986607143	1.0000000000000000
37	.999999606250000	.99999959821429	.999998945312500
38	1.0000000000000000	.99999959821429	1.0000000000000000
39	1.0000000000000000	.99999959821429	1.0000000000000000
40	1.0000000000000000	.99999939732143	.999998476562500
41	1.0000000000000000	.99999939732143	.999998476562500
42	1.0000000000000000	.99999939732143	.999998476562500
43	1.0000000000000000	.99999946428571	.999998828125000
44	1.0000000000000000	.99999946428571	.999998828125000
45	1.0000000000000000	.99999966517857	.999999414062500
46	1.0000000000000000	.99999966517857	.999999414062500
47	1.0000000000000000	.99999939732143	.999998945312500
48	.999999212500000	.999999892857143	.999998593750000
49	.999996850000000	.999999812500000	.999996718750000
50	.999999475000000	.999999973214286	1.0000000000000000
51	1.0000000000000000	.999999899553571	.999999765625000
52	1.0000000000000000	.999999899553571	.999999765625000

53	1.0000000000000000	.999999926339286	.999998710937500
54	1.0000000000000000	.999999953125000	.999999179687500
55	1.0000000000000000	.999999979910714	1.0000000000000000
56	1.0000000000000000	.999999973214286	1.0000000000000000
57	.999999737500000	.999999973214286	1.0000000000000000
58	1.0000000000000000	.999999973214286	1.0000000000000000
59	.999998162500000	.999999839285714	.999997304687500
60	.999998162500000	.999999839285714	.999997304687500
61	1.0000000000000000	.999999959821429	1.0000000000000000
62	.999999475000000	.999999933035714	.999998828125000
63	1.0000000000000000	.999999959821429	1.0000000000000000
64	1.0000000000000000	.999999946428571	1.0000000000000000
65	1.0000000000000000	.999999765625000	.999997421875000
66	1.0000000000000000	.999999946428571	.999998828125000

PART IDENT	PART LOSS CONTN	PART EX.VIBRATION	PART EXTERN LEAK
1	.99999999997325	.999999134020619	1.0000000000000000
2	.99999999997640	.999999164948454	1.0000000000000000
3	.99999999997010	.999999226804124	1.0000000000000000
4	1.0000000000000000	.999999474226804	1.0000000000000000
5	.99999999998741	.999999567010309	1.0000000000000000
6	.99999999998741	.999999969072165	.999999736111111
7	.99999999998427	.999999474226804	1.0000000000000000
8	.99999999997325	.999999474226804	1.0000000000000000
9	.99999999999371	.999999381443299	1.0000000000000000
10	.99999999999371	.999999381443299	1.0000000000000000
11	.99999999998269	.999999721649485	.999999708333333
12	.99999999998741	1.0000000000000000	.999999694444444
13	1.0000000000000000	.999999134020619	1.0000000000000000
14	1.0000000000000000	.999999134020619	1.0000000000000000

15	1.0000000000000000	.999999319587629	1.0000000000000000
16	1.0000000000000000	.999999134020619	1.0000000000000000
17	1.0000000000000000	.999999134020619	1.0000000000000000
18	1.0000000000000000	.999999134020619	1.0000000000000000
19	1.0000000000000000	.999999597938144	1.0000000000000000
20	1.0000000000000000	.999999597938144	1.0000000000000000
21	.999999999999213	.999999783505155	.999999777777778
22	.9999999999998899	.999999783505155	1.0000000000000000
23	1.0000000000000000	.999999783505155	1.0000000000000000
24	1.0000000000000000	.99999969072165	1.0000000000000000
25	1.0000000000000000	.99999938144330	1.0000000000000000
26	.999999999999371	.999999814432990	1.0000000000000000
27	1.0000000000000000	1.0000000000000000	1.0000000000000000
28	1.0000000000000000	1.0000000000000000	.999999861111111
29	1.0000000000000000	1.0000000000000000	.999999861111111
30	1.0000000000000000	1.0000000000000000	.999999763888889
31	1.0000000000000000	1.0000000000000000	.999999763888889
32	1.0000000000000000	1.0000000000000000	.999999944444444
33	1.0000000000000000	.999999907216495	1.0000000000000000
34	1.0000000000000000	.99999969072165	1.0000000000000000
35	1.0000000000000000	.99999969072165	1.0000000000000000
36	1.0000000000000000	1.0000000000000000	1.0000000000000000
37	1.0000000000000000	.999999907216495	1.0000000000000000
38	1.0000000000000000	1.0000000000000000	1.0000000000000000
39	1.0000000000000000	.999999876288660	1.0000000000000000
40	1.0000000000000000	1.0000000000000000	1.0000000000000000
41	1.0000000000000000	1.0000000000000000	1.0000000000000000
42	1.0000000000000000	1.0000000000000000	1.0000000000000000
43	1.0000000000000000	1.0000000000000000	1.0000000000000000
44	1.0000000000000000	1.0000000000000000	1.0000000000000000

45	1.0000000000000000	.999999938144330	1.0000000000000000
46	1.0000000000000000	.999999938144330	1.0000000000000000
47	1.0000000000000000	.999999907216495	.999999958333333
48	.9999999999999371	.999999876288660	.999999819444444
49	1.0000000000000000	.999999690721649	1.0000000000000000
50	1.0000000000000000	.999999938144330	1.0000000000000000
51	1.0000000000000000	1.0000000000000000	.999999791666667
52	1.0000000000000000	1.0000000000000000	.999999791666667
53	1.0000000000000000	1.0000000000000000	1.0000000000000000
54	1.0000000000000000	1.0000000000000000	.999999902777778
55	1.0000000000000000	.999999907216495	1.0000000000000000
56	1.0000000000000000	1.0000000000000000	1.0000000000000000
57	1.0000000000000000	.999999876288660	1.0000000000000000
58	1.0000000000000000	1.0000000000000000	1.0000000000000000
59	1.0000000000000000	.999999876288660	1.0000000000000000
60	1.0000000000000000	.999999876288660	1.0000000000000000
61	1.0000000000000000	.999999814432990	1.0000000000000000
62	1.0000000000000000	.999999690721649	1.0000000000000000
63	1.0000000000000000	.999999814432990	1.0000000000000000
64	.9999999999999685	1.0000000000000000	.999999944444444
65	1.0000000000000000	1.0000000000000000	.999999680555556
66	1.0000000000000000	1.0000000000000000	1.0000000000000000

APPENDIX C

FAILURE FUNCTION/FAILURE MECHANISMS AND CRITICALITY RATINGS

PART LEVEL FAILURE MECHANISMS

1. INDUCER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 7, 8, 10	6			INCORRECT FLOW AREA (DESIGN)
1, 2, 5, 7, 8, 10, 12	7			INCORRECT SPEED
1, 2, 5, 7, 8, 10	6			CAVITATION (EXCESSIVE)
1, 2, 3, 5, 7, 8, 9, 10		8		BLADE RUPTURE
1, 2, 3, 5, 7, 8, 9, 10, 15		9		HUB RUPTURE
2, 3, 7, 8, 10	5			INCORRECT BLADE DESIGN
2, 3, 7, 8, 10	5			EXCESSIVE CLEARANCE (TIP)
5, 9, 12		3	3	BLADE RUB
	<u>29</u>	<u>20</u>	<u>3</u>	

1. INDUCER

PART RELATED FAILURE CAUSES

[illegible]

PART LEVEL FAILURE MECHANISMS

2. 1ST IMPELLER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 7	4			INCORRECT FLOW AREA (DESIGN)
1, 2, 5, 7	4			INCORRECT SPEED
1, 2, 3, 9, 15		5		SHROUD RUPTURE
1, 2, 3, 9, 15		5		BLADE RUPTURE
1, 2, 3, 9, 15		5		HUB RUPTURE
2, 3, 7, 10	4			INCORRECT BLADE DESIGN
5, 9, 15, 12		4	4	SHROUD RUB
11	<u>4</u>	<u> </u>	<u> </u>	EXCESSIVE MASS
	16	19	4	

2. 1ST IMPELLER

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>			<u>MECHANICAL</u>			<u>MATERIALS</u>			<u>INSPECTION</u>		
Boost Loads	A1	1	Geometry	A2	10	Mat'l Strength	B2	100	NDT	B2	100
Flu. Pro. Var.	A1	1	Fillet Radii	A1	1	Ductility	B2	100	Handling	B1	10
Speed	A2	10	Dimensions	A1	1	Thermal α 's	A1	1	Scratches	A2	10
Radiation	A1	1	Pilot Fits	A1	1	Fatigue	B2	100	Dim. Insp.	B1	10
Sys. Stabil.	A2	10	Brg. Clear.	A1	1	Corrosion			Clean.		
Solar Heat	A1	1	Eccent.	A1	1	Grain Orient.	B2	100	Contam.	A1	1
Chilldown	A2	10	Tolerances	A1	1				Assy Error		
Coolant Flow			Preload	A1	1						
Pressure	A1	1	Brg/Hsg Stiff.								
Flow Rate	A1	1	Heat Trans.	A2	10						
LP's	B2	100	Clearances	A2	10						
Temperature	A1	1	Torque	A1	1						
Pump Unloads	A2	10	Finish	A2	10						
Laby. Flow			Location	A2	10						
Crit.Speed	A3	100	Press. Fit	A1	1						
Fluid Wakes	A2	10	Thermal Ex.	B1	10						
Inlet Conditions	A2	10	Rotor Iner.								
			Dyn. Disp.	A1	1						
			Cent.Load.	C2	1000						
			Stress Con.								

TOTAL 1869

PART LEVEL FAILURE MECHANISMS

3. 2ND IMPELLER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 9, 11	5			INCORRECT FLOW AREA (DESIGN)
1, 2, 3, 7	4			INCORRECT SPEED
1, 2, 3, 5, 7, 10		6		BLADE RUPTURE
1, 2, 3, 5, 7, 10		6		SHROUD RUPTURE
1, 2, 3, 5, 7, 10, 15		7		HUB RUPTURE
2, 3, 7	3			INCORRECT BLADE DESIGN
5, 10		2	2	SHROUD RUB
11	<u>1</u>	<u>—</u>	<u>—</u>	EXCESSIVE MASS
	13	21	2	

3. 2ND IMPELLER

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>			<u>MECHANICAL</u>			<u>MATERIALS</u>			<u>INSPECTION</u>		
Boost Loads			Geometry	A2	10	Mat'l Strength	B2	100	NDT	B2	100
Flu. Pro. Var.	A1	1	Fillet Radii	A1	1	Ductility	B2	10	Handling	A2	10
Speed	A1	1	Dimensions	A2	10	Thermal α 's	A1	1	Scratches		
Radiation	A1	1	Pilot Fits	A2	10	Fatigue	B2	100	Dim. Insp.	A2	10
Sys. Stabil.	A2	10	Brg. Clear.	A1	1	Corrosion			Clean.		
Solar Heat	A1	1	Eccent.	A2	10	Grain Orient.	B2	100	Contam.	A1	1
Chilldown	B2	100	Tolerances	A1	1				Assy Error		
Coolant Flow			Preload	A2	10						
Pressure	A1	1	Brg/Hsg Stiff.								
Flow Rate	A1	1	Heat Trans.	A2	10						
ΔP 's	A2	10	Clearances	A1	1						
Temperature	A1	1	Torque	A2	10						
Pump Unloads	A2	10	Finish	A2	10						
Laby. Flow			Location	A1	1						
Crit.Speed	A3	100	Press. Fit	A2	10						
Fluid Wakes	A3	100	Thermal Ex.	A2	10						
Inlet Conditions	A1	10	Rotor Iner.								
			Dyn. Disp.	A2	10						
			Cent.Load.	B3	1000						
			Stress Con.	A2	10						
						TOTAL 1914					

PART LEVEL FAILURE MECHANISMS

4. 2ND IMPELLER INLET SECTION

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 7, 10	5			INCORRECT FLOW AREA (DESIGN)
1, 2, 7	3			INCORRECT SPEED
1, 2, 3, 5, 7, 9, 10, 11, 12		9		SHROUD RUPTURE
1, 2, 3, 7, 9, 10, 11		7		BLADE RUPTURE
1, 2, 3, 5, 7, 9, 10, 11, 15		9		HUB RUPTURE
2, 3, 7, 10	4			INCORRECT BLADE DESIGN
11	1			EXCESSIVE MASS
12		<u>1</u>	<u>1</u>	SHROUD RUB
	<u>13</u>	<u>26</u>	<u>1</u>	

4. 2ND IMPELLER INLET SECTION

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES				INSPECTION	
		MECHANICAL		MATERIALS			
Boost Loads	A1	Geometry	A3	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii	A2	Ductility	B2	Handling	A2
Speed	A2	Dimensions	A2	Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	
Solar Heat		Eccent.	A2	Grain Orient.	A2	Contam.	
Chilldown	A2	Tolerances	A2			Assy Error	
Coolant Flow	A1	Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate	A2	Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature	A2	Torque	A2				
Pump Unloads	A2	Finish	A2				
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes	A3	Thermal Ex.	A2				
Inlet Conditions	A3	Rotor Iner.	A1				
ΔT 's	A2	Dyn. Disp.	A2				
		Cent.Load.	B2				
		Stress Con.	A2				
				TOTAL 1065			

PART LEVEL FAILURE MECHANISMS

5. THRUST BALANCER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3, 6, 9, 10, 11, 12	6	6	6	LAND CLEARANCE WIRING ^{USING}
3, 5, 6, 9, 10, 11, 12	7	7	7	HOUSING DISTORTED
3, 5, 6, 9, 10, 11, 12	7	7	7	IMPELLER DISTORTED
3, 6, 7, 10	4	4		FEED PASSAGE RESTRICTED
3, 6, 9, 10	4	4		EXHAUST PACKAGE ^{S.A.C.} RESTRICTED
5, 6, 10	<u> </u>	<u>3</u>	<u>3</u>	LAND RUB
	28	31	23	

5. THRUST BALANCER

		PART RELATED FAILURE CAUSES					
PERFORMANCE RELATED		MECHANICAL		MATERIALS		INSPECTION	
Boost Loads	A1	Geometry	A2	Mat'l Strength		NDT	
Flu. Pro. Var.	A3	Fillet Radii	A2	Ductility	B2	Handling	A2
Speed	A2	Dimensions	A1	Thermal α 's	A2	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue		Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	
Solar Heat		Eccent.	A2	Grain Orient.	B2	Contam.	A2
Chilldown	B3	Tolerances	A1			Assy Error	A2
Coolant Flow		Preload	A2				
Pressure	A2	Brg/Hsg Stiff.					
Flow Rate	A2	Heat Trans.	A3				
ΔP 's	A2	Clearances	B2				
Temperature	A2	Torque					
Pump Unloads	A2	Finish	A1				
Laby. Flow		Location	A1				
Crit.Speed	A2	Press. Fit	A2				
Fluid Wakes	A2	Thermal Ex.	A2				
Inlet Conditions	A2	Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.	A2				
		Stress Con.					
						TOTAL	1765

PART LEVEL FAILURE MECHANISMS

6. PUMP TIE BOLT

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		MATERIAL CREEP
9, 11		2	2	LOSSES PRELOAD
9, 11, 15		2	2	THERMAL GROWTH
9, 11, 15		2		L/C THERMAL FATIGUE
9, 15		2		FAILURE (RUPTURE)
9, 11, 15		2		EXCESSIVE LOADING
9, 11, 15		2	2	PILOT FAILURES
9, 11, 15	<u> </u>	<u>2</u>	<u> </u>	FAILURE OF LOCKING RETAINER
	0	16	6	

6. PUMP TIE BOLT

		PART RELATED FAILURE CAUSES					
PERFORMANCE RELATED		MECHANICAL		MATERIALS		INSPECTION	
Boost Loads	A1	Geometry	A1	Mat'l Strength	B2	NDT	B1
Flu. Pro. Var.		Fillet Radii	A1	Ductility	B2	Handling	
Speed	A2	Dimensions	A1	Thermal α 's	A1	Scratches	B2
Radiation	A1	Pilot Fits	A2	Fatigue	B2	Dim. Insp.	B1
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	
Solar Heat	A1	Eccent.	A2	Grain Orient.	B1	Contam.	
Chilldown	B2	Tolerances	A1	Creep	A2	Assy Error	A2
Coolant Flow	A1	Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.	A2				
ΔP 's	B2	Clearances	A2				
Temperature	A1	Torque	B2				
Pump Unloads	A2	Finish					
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.	A2				
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					
						TOTAL 950	

PART LEVEL FAILURE MECHANISMS

7. PUMP HOUSING

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 3, 5, 11	4			INCORRECT FLOW AREA (DESIGN)
1, 3, 4, 5, 9, 11, 12, 15		8		CASING FAILURE
1, 3, 9, 11, 12, 15	4	5	5	DIFFUSER ^{or} AS GUIDE VANE FAILURE
1, 5, 4, 11	4	4		EXCESSIVE LOSSES (PERFORMANCE)
3, 5, 9, 11	4	4		SECONDARY PASSAGES BLOCKED
5, 9, 11, 15		4	4	EXCESSIVE DEFLECTION (RUB)
4, 9, 11		3		SEAL GLAND FAILURE
4, 11	2			BLADE ANGLES & AREA DIS. WRONG
11	2			EXCESSIVE MASS
15	—	<u>1</u>	—	HOUSING STIFFNESS WRONG
	20	29	9	

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A2	Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii	A2	Ductility	B2	Handling	A2
Speed	A2	Dimensions	A1	Thermal α 's	A1	Scratches	
Radiation	A2	Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A2
Solar Heat	A2	Eccent.	A2	Grain Orient.	A2	Contam.	A2
Chilldown	A2	Tolerances	A2	"E"	A2	Assy Error	
Coolant Flow	A2	Preload LOADING	A2				
Pressure	A1	Brg/Hsg Stiff.	A3				
Flow Rate	A2	Heat Trans.	A2				
ΔP 's	A2	Clearances	A1				
Temperature	A2	Torque					
Pump Unloads	A2	Finish	A2				
Laby. Flow		Location					
Crit.Speed	A3	Press. Fit	A2				
Fluid Wakes	B2	Thermal Ex.	A2				
Inlet Conditions	A2	Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.	B3				
				TOTAL		1915	

PART LEVEL FAILURE MECHANISMS

8. 1ST TURBINE

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3, 4	2			INCORRECT FLOW AREA (DESIGN)
3, 4, 9, 10, 12, 14	6	6	6	EXCESSIVE SHROUD LAB WEAR
3, 9, 10, 14		4		BLADE FAILURE
3, 9, 10, 14		4		BLADE DEFLECTION
5, 9, 14	3	3	3	LABYRINTH RUB
5, 9, 10, 14		4	4	SHROUD FAILURE
5, 9, 14		3		EXCESSIVE DISC GROWTH
5, 10, 14	3			INCORRECT AERODYNAMIC DESIGN
11	1			EXCESSIVE MASS.
15		1		SPLINE FAILURE
14, 15		2		SECOND STATE CLUTCH FAILURE
	<u>15</u>	<u>27</u>	<u>13</u>	

8. 1ST TURBINE

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A3	Fillet Radii	A1	Ductility	B2	Handling	A2
Speed	A2	Dimensions	A1	Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A1	Brg. Clear.	A2	Corrosion		Clean.	
Solar Heat		Eccent.	A2	Grain Orient.	B2	Contam.	A2
Chilldown	A2	Tolerances	A2	"E"	A2	Assy Error	
Coolant Flow		Preload	A2				
Pressure	A2	Brg/Hsg Stiff.					
Flow Rate	A2	Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature	A3	Torque	A2				
Pump Unloads	A2	Finish	A2				
Laby. Flow	A2	Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes	A3	Thermal Ex.	A2				
Inlet Conditions	A2	Rotor Iner.					
		Dyn. Disp.	B2				
		Cent.Load.	A3				
		Stress Con.	A2				

TOTAL 1154

PART LEVEL FAILURE MECHANISMS

9. 2ND TURBINE ROTOR

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3, 14	2			INCORRECT FLOW AREA (DESIGN)
3, 4, 9, 10, 12 14	6	6	6	EXCESSIVE SHROUD LAB. WEAR
3, 9, 10, 14		4		BLADE FAILURE
3, 9, 10, 14		4		BLADE DEFLECTION
5, 9, 14	3	3	3	LABYRINTH RUB
5, 9, 10, 14		4		SHROUD FAILURE
5, 9, 14		4		EXCESSIVE DISC GROWTH
5, 10, 14	3			INCORRECT AERODYNAMIC DESIGN
11	1			EXCESSIVE MASS
15, 14	<u> </u>	<u>2</u>	<u> </u>	SECOND STAGE CLUTCH FAILURE
	13	27	9	

9. 2ND TURBINE ROTOR

PART RELATED FAILURE CAUSES							
PERFORMANCE RELATED		MECHANICAL		MATERIALS		INSPECTION	
Boost Loads		Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A3	Fillet Radii	A1	Ductility	B2	Handling	A2
Speed	A2	Dimensions	A1	Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A1	Brg. Clear.	A2	Corrosion		Clean.	
Solar Heat		Eccent.	A2	Grain Orient.	B2	Contam.	A2
Chilldown	A2	Tolerances	A2	"E"	A2	Assy Error	
Coolant Flow		Preload	A2				
Pressure	A2	Brg/Hsg Stiff.					
Flow Rate	A2	Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature	A3	Torque	A2				
Pump Unloads	A2	Finish	A2				
Alaby. Flow	A2	Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes	A3	Thermal Ex.	A2				
Inlet Conditions	A2	Rotor Iner.	B2				
DT's	A3	Dyn. Disp.	A3				
		Cent.Load.	A3				
		Stress Con.	A2				
				TOTAL 1364			

PART LEVEL FAILURE MECHANISMS

10. 1ST TURBINE STATOR

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3, 4	2			Incorrect Flow Area (design)
3, 4, 9, 10	4	4	4	Labyrinth Failure
3, 4, 9, 10	4	4	4	Excessive Lab Rub
3, 4, 9, 10		4		Blade Rupture
3, 4, 9, 10		4		Outer Shroud Rupture
2, 3, 9, 10		4		Inner Shroud Rupture
4, 9, 10, 15		4		Loss of Axial Stack
11	1			Excessive Mass
15		1	1	Excessive Outer Shroud Preload
	<hr/>	<hr/>	<hr/>	
	11	25	13	

10. 1ST TURBINE STATOR

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A3	Fillet Radii	A1	Ductility	B2	Handling	A2
Speed	A2	Dimensions	A1	Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A1
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2			Assy Error	
Coolant Flow		Preload	A2				
Pressure	A2	Brg/Hsg Stiff.	B2				
Flow Rate	A2	Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature	A2	Torque					
Pump Unloads	A2	Finish	A2				
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit	A2				
Fluid Wakes	A2	Thermal Ex.	A1				
Inlet Conditions	A2	Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.	A2				

PART LEVEL FAILURE MECHANISMS

11. 2ND TURBINE STATOR

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3, 4,	2			Incorrect Flow Area (Design)
3, 4, 9, 10	4	4	4	Labyrinth Failure
3, 4, 9, 10	4	4	4	Excessive Labs Rub
3, 4, 9, 10		4		Blade Rupture
3, 4, 9, 10		4		Outer Shroud Rupture
3, 4, 9, 10		4		Inner Shroud Rupture
4, 9, 10, 15		4	4	Loss of Axial Stack
11				Excessive Mass
15		1	1	Excessive Outer Shroud Preload
	<u>11</u>	<u>25</u>	<u>13</u>	

11. 2nd TURBINE STATOR

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A3	Fillet Radii	A1	Ductility	B2	Handling	A1
Speed	A2	Dimensions	A1	Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A1
Sys. Stabil.	A2	Brg. Clear.	A3	Corrosion		Clean.	A1
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2			Assy Error	
Coolant Flow		Preload	A2				
Pressure	A2	Brg/Hsg Stiff.	B2				
Flow Rate	A2	Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature	A2	Torque					
Pump Unloads	A2	Finish	A2				
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit	A2				
Fluid Wakes	B2	Thermal Ex.	A1				
Inlet Conditions	A1	Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.	A2				
						TOTAL 1037	

PART LEVEL FAILURE MECHANISMS

12. TURBINE TIE BOLT

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Threads fail
9, 15		2		Shank Fatigue
9, 15		2		Shank Unloads due to Plastic Deformation
9, 15		2	2	Loss of Retainer Torque
11		1		Lack of Coolant Flow
11		1		Excessive Mass
11,15		1	2	Thermal Deflections cause Loss of Preload
15			1	Shank Fails Due to Excessive Torque
	<u>0</u>	<u>11</u>	<u>15</u>	

12. TURBINE TIE BOLT

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A1	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.		Fillet Radii	A1	Ductility	B2	Handling	A1
Speed	A2	Dimensions	A1	Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A1
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	A1
Solar Heat		Eccent.	A1	Grain Orient.		Contam.	
Chilldown	B2	Tolerances	A2	Creep	A2	Assy Error	A2
Coolant Flow	A2	Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's		Clearances	A2				
Temperature	A2	Torque	A2				
Pump Unloads	A2	Finish	A2				
Laby. Flow		Location					
Crit.Speed	B1	Press. Fit	A2				
Fluid Wakes		Thermal Ex.	A2				
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.	A2				
						TOTAL 599	

PART LEVEL FAILURE MECHANISMS

13. TURBINE INLET MANIFOLD

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 14	4			Incorrect Flow Area (design)
1, 2, 9, 14	4			Excessive Losses (perform)
1, 2, 3, 4, 9, 11, 12		9		Housing Rupture
1, 2, 3, 9, 11, 12	7	7		Inlet Guide Vane Failure
2, 3, 4, 9, 11, 12, 14	8	8		Loss of Stator O.D. Fit (Leakage)
4, 9, 11, 12, 14		5		External Seal Leakage
9, 12, 15		3	3	Distortion/Deflection (Mech)
11, 15		2	2	Distortion/Deflection (Thermal)
12, 15		2		Line Dynamics Effect
	23	36	5	

13. TURBINE INLET MANIFOLD

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A2	Fillet Radii	A1	Ductility	B2	Handling	A2
Speed		Dimensions	A1	Thermal α 's	A1	Scratches	A2
Radiation	B2	Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A1
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.	A2	Grain Orient.	A1	Contam.	A2
Chilldown	A2	Tolerances	A1			Assy Error	
Coolant Flow		Preload					
Pressure	A2	Brg/Hsg Stiff.	B1				
Flow Rate	A1	Heat Trans.	B1				
ΔP 's	A2	Clearances					
Temperature	A2	Torque					
Pump Unloads	A2	Finish	A2				
Laby. Flow		Location	A1				
Crit.Speed	A3	Press. Fit	A2				
Fluid Wakes	A2	Thermal Ex.	A2				
Inlet Conditions	A2	Rotor Iner.					
		Dyn. Disp.	B2				
		Cent.Load.					
		Stress Con.	A2				

TOTAL 839

PART LEVEL FAILURE MECHANISMS

14. TURBINE EXHAUST MANIFOLD

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 14	4			Incorrect Flow Area
1, 2, 11, 14	4			Excessive Losses
1, 2, 3, 4, 9, 11, 14, 15	8			Housing Rupture
1, 2, 3, 7, 11, 12, 14	7	7		Guide Vane Failure
1, 2, 3, 9, 11, 12, 14	7	7		Exhaust Stator Failure
3, 4, 9, 11, 14		5		Leakage at Access Port
3, 4, 9, 1, 12		5		In Man Interface Seal Leakage
12, 15		2	2	Excessive Distort/Deflect (Mech)
12,15		2	2	Excessive Distort/Deflect (Thermal)
	<u>22</u>	<u>36</u>	<u>4</u>	

14. TURBINE EXHAUST MANIFOLD

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES					
		MECHANICAL		MATERIALS		INSPECTION	
Boost Loads	A2	Geometry	A1	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A2	Fillet Radii	A2	Ductility	B2	Handling	B2
Speed		Dimensions	A1	Thermal α 's	A1	Scratches	
Radiation	B2	Pilot Fits		Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.	A1	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A1			Assy Error	
Coolant Flow		Preload	A2				
Pressure	A2	Brg/Hsg Stiff.					
Flow Rate	A2	Heat Trans.					
ΔP 's	A2	Clearances					
Temperature	A2	Torque					
Pump Unloads		Finish	A2				
Laby. Flow		Location					
Crit.Speed	B1	Press. Fit					
Fluid Wakes	A2	Thermal Ex.	A2				
Inlet Conditions	A2	Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.	A2				
				TOTAL 715			

PART LEVEL FAILURE MECHANISMS

15. PUMP END BEARING CARTRIDGE

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
5, 6, 9, 10, 15		5	5	Cage Failure
5, 6, 9, 10, 15		5		Rolling Element Failure (Fatigue)
5, 6, 9, 10, 11		5	5	Contaminated (Foreign Object)
9, 11		2		Lack of Coolant
9, 11		2		Load too High
9		1		Speed too high
9, 5, 6, 10, 15		5	5	Wearout
10		1		Excessive Clearance
15		1	1	Loss of Clearance
15		1		Loss of Axial Preload
		<hr/>	<hr/>	
		28	16	

15. PUMP END BEARING CARTRIDGE

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii		Ductility	B2	Handling	A2
Speed	C2	Dimensions	B2	Thermal α 's	A1	Scratches	A2
Radiation	A2	Pilot Fits	A2	Fatigue	B2	Dim. Insp.	B2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A2
Solar Heat		Eccent.	A2	Grain Orient.	A2	Contam.	B2
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow	B2	Preload	B2				
Pressure	A2	Brg/Hsg Stiff.	C1				
Flow Rate	A2	Heat Trans.	A3				
ΔP 's	B2	Clearances	B2				
Temperature	A2	Torque					
Pump Unloads	A2	Finish	B2				
Laby. Flow	A2	Location					
Crit.Speed	C2	Press. Fit	C2				
Fluid Wakes		Thermal Ex.	A2				
Inlet Conditions		Rotor Iner.	B2				
		Dyn. Disp.	B2				
		Cent.Load.	C1				
		Stress Con.					
				Total 4,794			

PART LEVEL FAILURE MECHANISMS

16. TURBINE END BEARING CARTRIDGE

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
5, 6, 9, 10, 15		5	5	Cage Failure
5, 6, 9, 10, 15		5		Rolling Element Failure (Fatigue)
5, 6, 9, 10, 11		5	5	Contaminated (Foreign Object)
9, 11		2		Lack of Coolant
9, 11		2		Load too High
9		1		Speed too high
9, 5, 6, 10, 15		5	5	Wearout
10		1		Excessive Clearance
15		1	1	Loss of Clearance
15		1		Loss of Axial Preload
		<u>28</u>	<u>16</u>	

16. TURBINE END BEARING CARTRIDGE

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii		Ductility	B2	Handling	A2
Speed	C2	Dimensions	B2	Thermal α 's	A1	Scratches	A2
Radiation	A2	Pilot Fits	A2	Fatigue	B2	Dim. Insp.	B2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A2
Solar Heat		Eccent.	A2	Grain Orient.	A2	Contam.	B2
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow	B2	Preload	B2				
Pressure	A2	Brg/Hsg Stiff.	C1				
Flow Rate	A2	Heat Trans.	A3				
ΔP 's	B2	Clearances	B2				
Temperature	A2	Torque					
Pump Unloads	A2	Finish	B2				
Laby. Flow	A2	Location					
Crit.Speed	C2	Press. Fit	C2				
Fluid Wakes		Thermal Ex.	A2				
Inlet Conditions		Rotor Iner.	B2				
		Dyn. Disp.	B2				
		Cent.Load.	C1				
		Stress Con.					
						Total	4,794

PART LEVEL FAILURE MECHANISMS

17. 1ST STAGE IMPELLER SHROUD LABYRINTH

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 9, 10, 12	5	5	5	Excessive Wear
1, 2, 3	3			Incorrect Area (Design)
1, 2, 3, 9, 10, 11, 12	7			Excessive Clearance
1, 2, 3, 7, 10, 11, 12	7			
1, 2, 3, 6, 9, 10, 11	7	7	7	Loss of Pilot
1, 2, 3, 6, 9, 10 11, 12, 15		9	9	Loss of Clamping Fence
5, 6, 9, 10, 11, 12		6	6	Loss Clearance
5, 6, 9, 10			4	Contamination
5, 6, 9, 10, 12, 15		6	6	Rupture or Fracture
9, 10	2			Erosion
11	2			Excessive Wear

2 1

17. 1ST STAGE IMPELLER SHROUD LABYRINTH

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii		Ductility	B2	Handling	A2
Speed	A2	Dimensions	A2	Thermal α 's	A	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A1
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2	Erosion	B1	Assy Error	A2
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
Δ P's	A1	Clearances	A2				
Temperature		Torque					
Pump Unloads		Finish	A2				
Laby. Flow	A2	Location					
Crit.Speed	B2	Press. Fit	A2				
Fluid Wakes		Thermal Ex.	A1				
Inlet Conditions		Rotor Iner.					
TS	A1	Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					
						TOTAL 617	

PART LEVEL FAILURE MECHANISMS

18. 1ST STAGE IMPELLER HUB LABYRINTH

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 9, 10, 12	5	5	5	Excessive Wear
1, 2, 3	3			Incorrect Area (Design)
1, 2, 3, 9, 10, 11, 12	7			Excessive Clearance
1, 2, 3, 7, 10, 11, 12	7			
1, 2, 3, 6, 9, 10, 11	7	7	7	Loss of Pilot
1, 2, 3, 6, 9, 10 11, 12, 15		9	9	Loss of Clamping Fence
5, 6, 9, 10, 11, 12		6	6	Loss Clearance
5, 6, 9, 10			4	Contamination
5, 6, 9, 10, 12, 15		6	6	Rupture or Fracture
9, 10	2			Erosion
11	2			Excessive Wear
	<u>22</u>	<u>23</u>	<u>37</u>	

18. 1ST STAGE IMPELLER HUB LABYRINTH

<u>PART RELATED FAILURE CAUSES</u>							
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii		Ductility	B2	Handling	A2
Speed	A2	Dimensions	A2	Thermal α 's	A	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A1
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2	Erosion	B1	Assy Error	A2
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A1	Clearances	A2				
Temperature		Torque					
Pump Unloads		Finish	A2				
Laby. Flow	A2	Location					
Crit.Speed	B2	Press. Fit	A2				
Fluid Waxes		Thermal Ex.	A1				
Inlet Conditions		Rotor Iner.					
TS	A1	Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					
				TOTAL 617			

PART LEVEL FAILURE MECHANISMS

19. 2nd STAGE IMPELLER SHROUD LABYRINTH

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 9, 10, 12	5	5	5	Excessive Wear
1, 2, 3	3			Incorrect Area (Design)
1, 2, 3, 9, 10, 11, 12	7			Excessive Clearance
1, 2, 3, 7, 10, 11, 12	7			
1, 2, 3, 6, 9, 10, 11	7	7	7	Loss of Pilot
1, 2, 3, 6, 9, 10 11, 12, 15		9	9	Loss of Clamping Fence
5, 6, 9, 10, 11, 12		6	6	Loss Clearance
5, 6, 9, 10			4	Contamination
5, 6, 9, 10, 12, 15		6	6	Rupture or Fracture
9, 10	2			Erosion
11	2			Excessive Wear
	<hr/>	<hr/>	<hr/>	
	33	33	37	

19. 2ND STAGE IMPELLER SHROUD LABYRINTH

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii		Ductility	B2	Handling	A2
Speed	A2	Dimensions	A2	Thermal α 's	A	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A1
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2	Erosion	B1	Assy Error	A2
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A1	Clearances	A2				
Temperature		Torque					
Pump Unloads		Finish	A2				
Laby. Flow	A2	Location					
Crit.Speed	B2	Press. Fit	A2				
Fluid Waxes		Thermal Ex.	A1				
Inlet Conditions		Rotor Iner.					
TS	A1	Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					
				TOTAL 617			

PART LEVEL FAILURE MECHANISMS

20. TURBINE END BEARING FORWARD LABYRINTH

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3	3			Incorrect Area (design)
1, 2, 3, 12	4	4		Excessive Wear
1, 2, 3	3			Excessive Clearance
1, 2, 3	3			Secondary Leak Path
1, 2, 3, 5		4	4	Fracture or Rupture
1, 2, 3	3			Erosion
3, 5, 6			3	Contamination
3, 5, 6, 15, 12		5	5	Loss of Pilot
15, 12		2	2	Loss of Clamping Loads
3, 5, 6, 12		2	2	Loss of Clearance
ii	1			Excessive Mass
	<u>17</u>	<u>17</u>	<u>16</u>	

20. TURBINE END BEARING FORWARD LABYRINTH

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES				INSPECTION	
		MECHANICAL		MATERIALS			
Boost Loads		Geometry	A2	Mat'l Strength	B2	NDT	
Flu. Pro. Var.	A1	Fillet Radii		Ductility	B2	Handling	A2
Speed		Dimensions	A2	Thermal α 's	A1	Scratches	
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A1
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A3
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow		Preload	A1				
Pressure	A2	Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature		Torque					
Pump Unloads		Finish	A2				
Laby. Flow	A2	Location					
Crit.Speed	B2	Press. Fit	A2				
Fluid Wakes		Thermal Ex.	A2				
Inlet Conditions		Rotor Iner.					
T's	A2	Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

21 TURBINE END BEARING AFT LABYRINTH

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3	3			Incorrect Area (design)
1, 2, 3, 12	4	4		Excessive Wear
1, 2, 3	3			Excessive Clearance
1, 2, 3	3			Secondary Leak Path
1, 2, 3, 5		4	4	Fracture or Rupture
1, 2, 3	3			Erosion
3, 5, 6			3	Contamination
3, 5, 6, 15, 12		5	5	Loss of Pilot
15, 12		2	2	Loss of Clamping Loads
3, 5, 6, 12		2	2	Loss of Clearance
11	1			Excessive Mass
	<u>17</u>	<u>17</u>	<u>16</u>	

21. TURBINE END BEARING AFT LABYRINTH

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES				INSPECTION	
		MECHANICAL		MATERIALS			
Boost Loads		Geometry	A2	Mat'l Strength	B2	NDT	
Flu. Pro. Var.	A1	Fillet Radii		Ductility	B2	Handling	A2
Speed		Dimensions	A2	Thermal α 's	A1	Scratches	
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	A1
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A3
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow		Preload	A1				
Pressure	A2	Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature		Torque					
Pump Unloads		Finish	A2				
Laby. Flow	A2	Location					
Crit.Speed	B2	Press. Fit	A2				
Fluid Wakes		Thermal Ex.	A2				
Inlet Conditions		Rotor Iner.					
T's	A2	Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

22. INDUCER HOUSING

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3	1			Incorrect Area (design)
4, 9, 11, 12		4		Flange Failure
4, 9, 11, 12		4		Flange Seal Failure
4, 9, 11, 12		4		Pump Hsg. Interface Seal Failure
4, 9, 11, 12, 15		4		Rupture
11	1			Excessive Mass
12		1	1	Excessive Deflection
15		1	1	Inducer Shroud Ret/Bolt Thd Failure
15	<u> </u>	<u>1</u>	<u> </u>	Trunnion Mtg. Bolt Failure
	2	19	2	

22. INDUCER HOUSING

		<u>PART RELATED FAILURE CAUSES</u>			
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>	<u>MATERIALS</u>		<u>INSPECTION</u>
Boost Loads	A2	Geometry	A2	Mat'l Strength	B1
Flu. Pro. Var.	A2	Fillet Radii		Ductility	B1
Speed		Dimensions	A1	Thermal α 's	
Radiation		Pilot Fits		Fatigue	
Sys. Stabil.	A2	Brg. Clear.		Corrosion	
Solar Heat		Eccent.		Grain Orient.	
Chilldown	A2	Tolerances			
Coolant Flow		Preload	A2		
Pressure		Brg/Hsg Stiff.			
Flow Rate	A1	Heat Trans.			
ΔP 's	A1	Clearances			
Temperature		Torque			
Pump Unloads		Finish	A2		
Laby. Flow		Location			
Crit.Speed	A2	Press. Fit			
Fluid Wakes		Thermal Ex.	A2		
Inlet Conditions		Rotor Iner.			
T's	A2	Dyn. Disp.	A2		
		Cent.Load.			
		Stress Con.			
				TOTAL	174

PART LEVEL FAILURE MECHANISMS

23. TRUNNION

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 12, 15		3		Fatigue Failure
9, 12, 15		3		Shear Failure
11	1			Excessive Mass
15		1		Bolt Failure
	<u>1</u>	<u>7</u>		

23. TRUNNION

PART RELATED FAILURE CAUSES

[illegible]

PART LEVEL FAILURE MECHANISMS

24. TRUNNION TO HOUSING BOLT

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Fatigue Failure
9, 11, 12, 15		4		Tensile Failure
15				Thread Failure
	<u>0</u>	<u>7</u>	<u>0</u>	

24. TRUNNION TO HOUSING BOLT

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A1	Mat'l Strength	B1	NDT	A2
Flu. Pro. Var.		Fillet Radii	A1	Ductility	B1	Handling	A2
Speed		Dimensions	A1	Thermal α 's		Scratches	A2
Radiation		Pilot Fits		Fatigue	B1	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	
Solar Heat		Eccent.		Grain Orient.	A2	Contam.	
Chilldown	A2	Tolerances	A2			Assy Error	B1
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's		Clearances					
Temperature		Torque	A3				
Pump Unloads		Finish					
Laby. Flow		Location					
Crit.Speed	A2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					
				TOTAL		243	

25. INDUCER SHROUD INSERT

PART LEVEL FAILURE MECHANISMS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3, 7, 8	3			Incorrect Area (design)
3, 7, 10	3			Secondary Leakage
7, 8, 10	3	3		
7, 8, 10	3	3	3	Excessive Clearance
11	1			Excessive Mass
15	<u> </u>	<u> 1 </u>	<u> 1 </u>	Flange Failure
	13	7	1	

25. INDUCER SHROUD INSERT

PART RELATED FAILURE CAUSES

PERFORMANCE RELATED		MECHANICAL		MATERIALS		INSPECTION	
Boost Loads		Geometry	A1	Mat'l Strength	B1	NDT	
Flu. Pro. Var.	A1	Fillet Radii		Ductility	A1	Handling	A2
Speed		Dimensions	A1	Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue		Dim. Insp.	A2
Sys. Stabil.	A1	Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.		Grain Orient.		Contam.	A2
Chilldown	A1	Tolerances				Assy Error	
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate	A1	Heat Trans.					
1P's		Clearances					
Temperature		Torque					
Pump Unloads		Finish	A2				
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					
				TOTAL 148			

PART LEVEL FAILURE MECHANISMS

26. \$HIM

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Extruder due to repeated loadings
11		1		Wrong Thermal
	<u>0</u>	<u>30</u>	<u>0</u>	

26. SHIM

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	A2	NDT	A1
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	
Speed		Dimensions		Thermal α 's	A2	Scratches	
Radiation		Pilot Fits		Fatigue		Dim. Insp.	
Sys. Stabil.	A1	Brg. Clear.		Corrosion		Clean.	
Solar Heat		Eccent.		Grain Orient.		Contam.	
Chilldown		Tolerances				Assy Error	A2
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's		Clearances					
Temperature		Torque					
Pump Unloads		Finish					
Laby. Flow		Location					
Crit.Speed		Press. Fit	A2				
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					
				TOTAL 43			

PART LEVEL FAILURE MECHANISMS

27. INDUCER SHROUD RETAINING BOLTS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
6, 15		2	2	Fatigue Failure
9, 11, 15		2		Tensile Failure
11, 15	<u> </u>	<u>2</u>	<u> </u>	Yields
	0	6	2	

27. INDUCER SHROUD RETAINING BOLTS

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	A1	Geometry	Mat'l Strength A2	NDT A1
Flu. Pro. Var.		Fillet Radii	Ductility A2	Handling A2
Speed		Dimensions	Thermal α 's	Scratches A2
Radiation		Pilot Fits	Fatigue B2	Dim. Insp. A1
Sys. Stabil.	A1	Brg. Clear.	Corrosion	Clean.
Solar Heat		Eccent.	Grain Orient.	Contam.
Chilldown		Tolerances		Assy Error
Coolant Flow		Preload A2		
Pressure		Brg/Hsg Stiff.		
Flow Rate		Heat Trans.		
ΔP 's		Clearances		
Temperature		Torque		
Pump Unloads		Finish		
Laby. Flow		Location		
Crit.Speed		Press. Fit		
Fluid Wakes		Thermal Ex.		
Inlet Conditions		Rotor Iner.		
T's	A1	Dyn. Disp.		
		Cent.Load.		
		Stress Con.		
			TOTAL	165

PART LEVEL FAILURE MECHANISMS

28. FILTER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1	1			Incorrect Area (design)
1, 2, 9	3			Contamination
1	1			Low ΔP Available
1, 2, 9		3	3	Screen Failure
2	1	3		Screen ΔP too High
4, 9		2	2	Case Failure
4, 9	2	2	2	Secondary Leak Path
9		1	1	Fatigues
	<u>8</u>	<u>14</u>	<u>8</u>	

28. FILTER

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii		Ductility		Handling	A2
Speed		Dimensions	A1	Thermal α 's		Scratches	
Radiation		Pilot Fits		Fatigue	A2	Dim. Insp.	
Sys. Stabil.		Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.		Grain Orient.		Contam.	A2
Chilldown		Tolerances	A1			Assy Error	
Coolant Flow		Preload	A1				
Pressure	A1	Brg/Hsg Stiff.					
Flow Rate	A1	Heat Trans.					
ΔP 's	A2	Clearances					
Temperature	A1	Torque					
Pump Unloads		Finish				TOTAL	78
Laby. Flow		Location					
Crit.Speed		Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

29. FILTER FLANGE BOLT

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Fatigue Failure
9, 11, 15		3		Tensile Failure
9, 11, 15		3		Thread Failure
11, 15		2		Thread Failure
	<u>0</u>	<u>10</u>	<u>0</u>	

29. FILTER FLANGE BOLT

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry A2	Mat'l Strength A2	NDT A2
Flu. Pro. Var.	Fillet Radii	Ductility A2	Handling A2
Speed	Dimensions	Thermal α 's	Scratches A2
Radiation	Pilot Fits	Fatigue A2	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean.
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown	Tolerances		Assy Error
Coolant Flow	Preload A2		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's A2	Clearances		
Temperature	Torque		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		
		TOTAL 100	

PART LEVEL FAILURE MECHANISMS

30. BALANCER RETURN MANIFOLD BOLT

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Fatigue Failure
9, 11, 15		3		Tensile Failure
9, 11, 15		3		Thread Failure
11, 15		<u>2</u>	<u> </u>	Thread Failure
	<u>0</u>	10	0	

30. BALANCER RETURN MANIFOLD BOLT

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry A2	Mat'l Strength A2	NDT A2
Flu. Pro. Var.	Fillet Radii	Ductility A2	Handling A2
Speed	Dimensions	Thermal α 's	Scratches A2
Radiation	Pilot Fits	Fatigue A2	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean.
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown	Tolerances		Assy Error
Coolant Flow	Preload A2		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's A2	Clearances		
Temperature	Torque		
Pump Unloads	Finish		
Laby. Flow	Location	TOTAL 100	
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		

PART LEVEL FAILURE MECHANISMS

31. FILTER FLANGE SEAL

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 9, 12		3		Seal Fails Structurally
4, 9, 12		3		Losses Preload
4, 9, 12		3		Seal does not Seat
4, 7	2	2		Excessive ΔP
9, 12		2		Seat frets
12		2		Coolant Line Deflect Load Excessive
15		2		Fails in Compression (excessive preload)
	<u>2</u>	<u>17</u>	<u>—</u>	

31. FILTER FLANGE SEAL

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry A1	Mat'l Strength A2	NDT
Flu. Pro. Var.	Fillet Radii	Ductility A2	Handling A2
Speed	Dimensions A2	Thermal α 's A2	Scratches A2
Radiation	Pilot Fits A2	Fatigue	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent. A2	Grain Orient.	Contam. A2
Chilldown	Tolerances A2		Assy Error A3
Coolant Flow	Preload A2		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's A2	Clearances		
Temperature	Torque		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex. A2		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		

TOTAL 240

PART LEVEL FAILURE MECHANISMS

32. BALANCER RETURN MANIFOLD SEAL

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 9, 12		3		Seal Fails Structurally
4, 9, 12		3		Losses Preload
4, 9, 12		3		Seal does not Seat
4, 7	2	2		Excessive Δ P
9, 12		2		Seat frets
12		2		Coolant Line Deflect Load Excessive
15		2		Fails in Compression (excessive preload)
	<u>2</u>	<u>17</u>		

32. BALANCER RETURN MANIFOLD SEAL

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry A1	Mat'l Strength A2	NDT
Flu. Pro. Var.	Fillet Radii	Ductility A2	Handling A2
Speed	Dimensions A2	Thermal α 's A2	Scratches A2
Radiation	Pilot Fits A2	Fatigue	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent. A2	Grain Orient.	Contam. A2
Chilldown	Tolerances A2		Assy Error A3
Coolant Flow	Preload A2		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's A2	Clearances		
Temperature	Torque		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex. A2		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		
		TOTAL 240	

PART LEVEL FAILURE MECHANISMS

33. BALANCER RETURN MANIFOLD

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2	2			Incorrect Area (Design)
1, 2, 3, 4	2	4		Line Becomes Plugged
1, 2	2	2		Losses Excessive
1, 2	2			DP too low
3, 9		2		Rupture'
3, 9		2		Secondary Leakage
9		1		Fails in Fatiuge
11		<u>1</u>	<u> </u>	Thermal Deflections too Large
	<u>8</u>	<u>12</u>	<u>0</u>	

23. BALANCER RETURN MANIFOLD

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.	A1	Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions		Thermal α 's	A2	Scratches	A2
Radiation		Pilot Fits		Fatigue	A2	Dim. Insp.	A2
Sys. Stabil.		Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.		Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow		Preload					
Pressure	A2	Brg/Hsg Stiff.					
Flow Rate	A2	Heat Trans.					
Δp 's	A2	Clearances					
Temperature		Torque					
Pump Unloads		Finish	A1				
Laby. Flow		Location					
Crit.Speed	A2	Press. Fit					
Fluid Wakes		Thermal Ex.	A2				
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					
				TOTAL		192	

PART LEVEL FAILURE MECHANISMS

34. INDUCER SPINNER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
5, 9		2		Drive Clutch Fails
5		1		Retainer Fails
7		1		Wrong Shape (design)
9		1		Wall Failure Due to Δ P's
	<u>0</u>	<u>5</u>	<u>0</u>	

34. INDUCER SPINNER

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry A2	Mat'l Strength A2	NDT A1
Flu. Pro. Var.	Fillet Radii	Ductility A2	Handling A1
Speed	Dimensions A2	Thermal α 's	Scratches A1
Radiation	Pilot Fits A2	Fatigue A2	Dim. Insp. A1
Sys. Stabil.	Brg. Clear.	Corrosion	Clean.
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown	Tolerances A1		Assy Error A2
Coolant Flow	Preload A2		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's	Clearances A2		
Temperature	Torque		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed A3	Press. Fit		
Fluid Wakes A2	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		
		TOTAL 205	

PART LEVEL FAILURE MECHANISMS

35. SPINNER DRIVE PINS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
15		1		Shear Failure
15	<u> </u>	<u>1</u>	<u> </u>	Dimensionally Wrong
	0	2	0	

35. SPINNER DRIVE PINS

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry	Mat'l Strength A2	NDT
Flu. Pro. Var.	Fillet Radii	Ductility	Handling A2
Speed	Dimensions	Thermal α 's	Scratches A2
Radiation	Pilot Fits	Fatigue	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown	Tolerances		Assy Error
Coolant Flow	Preload		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's	Clearances		
Temperature	Torque A1		TOTAL 21
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		

PART LEVEL FAILURE MECHANISMS

36. SPINNER BOLT

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
15		1		Fails due to excessive torque
15	<u>1</u>	<u>1</u>	<u>1</u>	Spinner Load Excessive
	0	2	0	

36. SPINNER BOLT

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry	Mat'l Strength A2	NDT
Flu. Pro. Var.	Fillet Radii	Ductility	Handling A2
Speed	Dimensions	Thermal α 's	Scratches A2
Radiation	Pilot Fits	Fatigue A1	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent.	Grain Orient.	Contam. A2
Chilldown	Tolerances		Assy Error
Coolant Flow	Preload		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's A2	Clearances		
Temperature	Torque A2		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex. A1		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		

PART LEVEL FAILURE MECHANISMS

37. SPINNER LOCK

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
15		1		Fails due to Bolt Torquing
15	<u>0</u>	<u>1</u> 2	<u>0</u>	Excessive Loading

37. SPINNER LOCK

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry A2	Mat'l Strength A2	NDT A2
Flu. Pro. Var.	Fillet Radii	Ductility A2	Handling A2
Speed	Dimensions A2	Thermal α 's A2	Scratches A2
Radiation	Pilot Fits	Fatigue A2	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown	Tolerances		Assy Error
Coolant Flow	Preload		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's	Clearances		
Temperature	Torque A1		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		
		TOTAL 41	

PART LEVEL FAILURE MECHANISMS

38. 2ND IMPELLER INLET SEC RETAINER

1A-5 NO CHANGE
APPROX 12 APR 72

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3,		1	1	Galling on O.D.
5, 11	2			Excessive Mass
5		1	1	Locking Slot Shear Failure
9		1	1	Loss of Pilot
9		1	1	Rupture
15		1	1	Won't retain 2nd imp. inlet section (Threads seize)
15		1	1	Low Preload or excessive thermal contraction
15		1		Second Stage imp. inlet section loading excessive
	<u>2</u>	<u>8</u>	<u>6</u>	

38. 2ND IMPELLER INLET SEC RETAINER

PART RELATED FAILURE CAUSES

[illegible]

PART LEVEL FAILURE MECHANISMS

39. 2ND STAGE INLET SEC. RETAINER LOCK

THIS NO LONGER
APPLICABLE

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
15		1		Fails due to retainer torquing during assy.
15		1		Excessive torque due to retainer rub (shear)
15		1		Excessive thermal contraction.
		<hr/> 3		

39. 2ND STAGE INLET SEC. RETAINER LOCK

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry A2	Mat'l Strength A2	NDT A2
Flu. Pro. Var.	Fillet Radii	Ductility	Handling A2
Speed	Dimensions	Thermal α 's	Scratches A2
Radiation	Pilot Fits	Fatigue	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown A2	Tolerances		Assy Error
Coolant Flow	Preload		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's	Clearances		
Temperature	Torque A2		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		
		TOTAL 50	

PART LEVEL FAILURE MECHANISMS

40. SPEED PICK-UP

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 9, 13	3	3		Case failure due to delta P's.
4, 9, 13	3	3	3	Case fails due to rub.
9, 11, 13	3			Thermal cyclic failure.
	<u>9</u>	<u>6</u>	<u>3</u>	

40. SPEED PICK-UP

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility		Handling	A2
Speed		Dimensions	A2	Thermal α 's	A2	Scratches	A2
Radiation		Pilot Fits	A2	Fatigue		Dim. Insp.	A2
Sys. Stabil.		Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown		Tolerances	A1			Assy Error	A2
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances					
Temperature		Torque					
Pump Unloads		Finish					
Laby. Flow		Location				TOTAL	182
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

41. SPEED PICK-UP RETAINER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Shear failure due to wrench torque.
9, 15		2		Failure due to loading imposed by probe.
15		2		Tab fracture.
		<hr/> 6		

41. SPEED PICK-UP RETAINER

PART RELATED FAILURE CAUSES

PERFORMANCE RELATED	MECHANICAL	MATERIALS	INSPECTION
Boost Loads	Geometry	Mat'l Strength A2	NDT A2
Flu. Pro. Var.	Fillet Radii	Ductility	Handling A2
Speed	Dimensions	Thermal α 's	Scratches A2
Radiation	Pilot Fits	Fatigue A2	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown	Tolerances		Assy Error A2
Coolant Flow	Preload		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's A1	Clearances		
Temperature	Torque A2		
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit	TOTAL 51	
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		

PART LEVEL FAILURE MECHANISMS

42. DISTANCE DETECTOR RETAINER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Shear failure due to wrench torque.
9, 15		2		Failure due to loading imposed by probe.
15		2		Tab fracture
		<u>6</u>		

42. DISTANCE DETECTOR RETAINER

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>	<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads	Geometry	Mat'l Strength A2	NDT A2
Flu. Pro. Var.	Fillet Radii	Ductility	Handling A2
Speed	Dimensions	Thermal α 's	Scratches A2
Radiation	Pilot Fits	Fatigue A2	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent.	Grain Orient.	Contam.
Chilldown	Tolerances		Assy Error A2
Coolant Flow	Preload		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's A1	Clearances		
Temperature	Torque A2	TOTAL	51
Pump Unloads	Finish		
Laby. Flow	Location		
Crit.Speed	Press. Fit		
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		

PART LEVEL FAILURE MECHANISMS

43. SPEED PICKUP CONNECTOR

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 13	2			Terminal Failure
9, 11	2	2		Hermetic Sealing Failure
9, 11, 13	3	3		Terminal Loss of Fits
9, 13	2			Corrosion
9, 13	2	2		Terminal Fatigue Failure
15	1	1		Mtg mech. failure
9	1	1		Fails due to vib.
	<u>13</u>	<u>9</u>	<u>0</u>	

43. SPEED PICKUP CONNECTOR

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions		Thermal α 's	A2	Scratches	
Radiation	A2	Pilot Fits		Fatigue	A2	Dim. Insp.	A1
Sys. Stabil.		Brg. Clear.		Corrosion	A2	Clean.	
Solar Heat		Eccent.		Grain Orient.		Contam.	
Chilldown	A2	Tolerances				Assy Error	A3
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.	A2				
ΔP 's	A3	Clearances					
Temperature	A2	Torque					
Pump Unloads		Finish					
Laby. Flow		Location			TOTAL	332	
Crit.Speed	A2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

44. DISTANCE DETECTOR CONNECTOR

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 13	2			Terminal failure
9, 11	2	2		Hermetic sealing failure
9, 11, 13	3	3		Terminal loss of fits
9, 13	2			corrosion
15	1	1		Mtg mech. failure
9	1	1		Fails due to vib.
	<u>13</u>	<u>9</u>	<u>0</u>	

44. DISTANCE DETECTOR CONNECTOR

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions		Thermal α 's	A2	Scratches	
Radiation	A2	Pilot Fits		Fatigue	A2	Dim. Insp.	A1
Sys. Stabil.		Brg. Clear.		Corrosion	A2	Clean.	
Solar Heat		Eccent.		Grain Orient.		Contam.	
Chilldown	A2	Tolerances				Assy Error	A3
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.	A2				
ΔP 's	A3	Clearances					
Temperature	A2	Torque					
Pump Unloads		Finish					
Laby. Flow		Location					
Crit.Speed	A2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

45. THERMOCOUPLE CONNECTOR

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 13	2			Terminal failure
9, 11	2	2		Hermetic sealing failure
9, 11, 13	3	3		Terminal loss of fits
9, 13	2			Corrosion
15	1	1		Mtg mech. failure
9	1	1		Fails due to vib.
	<u>13</u>	<u>9</u>	<u>0</u>	

45. THERMOCOUPLE CONNECTOR

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A1	Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions		Thermal α 's	A2	Scratches	
Radiation	A2	Pilot Fits		Fatigue	A2	Dim. Insp.	A1
Sys. Stabil.		Brg. Clear.		Corrosion	A2	Clean.	
Solar Heat		Eccent.		Grain Orient.		Contam.	
Chilldown	A2	Tolerances				Assy Error	A3
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.	A2				
ΔP 's	A3	Clearances					
Temperature	A2	Torque					
Pump Unloads		Finish				TOTAL	332
Laby. Flow		Location					
Crit.Speed	A2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

46. SPEED PICK-UP LEADS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 13	2	2		Wire fatiguer
9, 11, 13	3	3		Insulation Fails (short)
9, 11, 13	3	3		Connection fails
11, 13	2			No slack-wire fails by thermal contraction
	<u>10</u>	<u>8</u>	<u>0</u>	

46. SPEED PICK-UP LEADS

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES					
		MECHANICAL		MATERIALS		INSPECTION	
Boost Loads	A2	Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions	A2	Thermal α 's	A2	Scratches	A2
Radiation	A2	Pilot Fits		Fatigue	A2	Dim. Insp.	
Sys. Stabil.	A2	Brg. Clear.		Corrosion	A2	Clean.	
Solar Heat	A2	Eccent.		Grain Orient.		Contam.	A2
Chilldown		Tolerances	A1			Assy Error	A2
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's		Clearances					
Temperature	A2	Torque				TOTAL	271
Pump Unloads		Finish					
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

47. DISTANCE DETECTOR LEADS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 13	2	2		Wire fatiguer
9, 11, 13	3	3		Insulation fails (short)
9, 11, 13	3	3		Connection fails
11, 13	2			No slack - wire fails by thermal contraction.
	<u>10</u>	<u>8</u>	<u>0</u>	

47. DISTANCE DETECTOR LEADS

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES				INSPECTION	
		MECHANICAL		MATERIALS			
Boost Loads	A2	Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions	A2	Thermal α 's	A2	Scratches	A2
Radiation	A2	Pilot Fits		Fatigue	A2	Dim. Insp.	
Sys. Stabil.	A2	Brg. Clear.		Corrosion	A2	Clean.	
Solar Heat	A2	Eccent.		Grain Orient.		Contam.	A2
Chilldown		Tolerances	A1			Assy Error	A2
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
LP's		Clearances					
Temperature	A2	Torque					
Pump Unloads		Finish					
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					
				TOTAL 271			

PART LEVEL FAILURE MECHANISMS

48. SPEED PICKUP SHIMS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15	2	2		Extrudes due to excessive preloading
9, 15	2	2		Ruptures due to speed pickup probe loading
11	1	1		Thermal contraction incorrect.
	<u>5</u>	<u>5</u>	<u>0</u>	

48.

SPEED PICKUP SHIMS

PART RELATED FAILURE CAUSES

PERFORMANCE RELATED		MECHANICAL		MATERIALS		INSPECTION	
Boost Loads		Geometry		Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility		Handling	A2
Speed		Dimensions		Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits		Fatigue		Dim. Insp.	A2
Sys. Stabil.		Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.		Grain Orient.		Contam.	A2
Chilldown	A1	Tolerances	A1			Assy Error	
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's		Clearances					
Temperature		Torque				TOTAL	53
Pump Unloads		Finish					
Laby. Flow		Location					
Crit.Speed	A2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

49. DISTANCE DETECTOR SHIMS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15	2	2		Extrudes due to excessive preloading.
9, 15	2	2		Ruptures due to speed pickup probe Loading
11	1	1		Thermal contraction incorrect.
	<u>5</u>	<u>5</u>	<u>0</u>	

49. DISTANCE DETECTOR SHIMS

<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads		Geometry		Mat'l Strength	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2
Speed		Dimensions		Thermal α 's	A1
Radiation		Pilot Fits		Fatigue	A2
Sys. Stabil.		Brg. Clear.		Corrosion	A2
Solar Heat		Eccent.		Grain Orient.	A2
Chilldown	A1	Tolerances	A1		Assy Error
Coolant Flow		Preload	A2		
Pressure		Brg/Hsg Stiff.			
Flow Rate		Heat Trans.			
ΔP 's		Clearances			
Temperature		Torque			
Pump Unloads		Finish			
Laby. Flow		Location			
Crit.Speed	A2	Press. Fit			
Fluid Wakes		Thermal Ex.			
Inlet Conditions		Rotor Iner.			
		Dyn. Disp.	A2		
		Cent.Load.			
		Stress Con.			
				TOTAL	53

PART LEVEL FAILURE MECHANISMS

50. DISTANCE DETECTOR

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 9, 11	3	3		Casing ruptures.
9, 11	2	2		Fails due to thermal cycling
9, 11, 13	3	3		Changes position thermal deflection/housing deflection
9	1	1		Fails due to vib.
	<u>9</u>	<u>9</u>	<u>0</u>	

50. DISTANCE DETECTOR

PART RELATED FAILURE CAUSES					
PERFORMANCE RELATED		MECHANICAL		MATERIALS	
				INSPECTION	
Boost Loads		Geometry		Mat'l Strength	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2
Speed		Dimensions		Thermal α 's	A1
Radiation		Pilot Fits		Fatigue	
Sys. Stabil.		Brg. Clear.		Corrosion	
Solar Heat		Eccent.		Grain Orient.	
Chilldown		Tolerances	A1		
Coolant Flow		Preload	A2		
Pressure		Brg/Hsg Stiff.	A2		
Flow Rate		Heat Trans.			
ΔP 's	A1	Clearances			
Temperature		Torque			
ΔT 's	A2	Finish			
Pump Unloads		Location		TOTAL	83
Laby. Flow		Press. Fit			
Crit.Speed	A2	Thermal Ex.			
Fluid Wakes		Rotor Iner.			
Inlet Conditions		Dyn. Disp.			
		Cent.Load.			
		Stress Con.			

PART LEVEL FAILURE MECHANISMS

51. THRUST BALANCER HOUSING (PUMP BACKPLATE/AFT BEARING HOUSING)

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
3, 9, 12, 15	4	4	4	Housing deflection excessive
3, 9, 12	3			Passages blocked
4, 7, 12, 15		4		Ruptures
4, 9, 12		3		Seal glands fail
4, 9, 12	3	3		Deflections constrict flow
4, 15	2	2	2	Thermally imposed deflections excessive
	<u>12</u>	<u>16</u>	<u>6</u>	

51. THRUST BALANCER HOUSING (PUMP BACKPLATE/AFT BEARING HOUSING)

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES				INSPECTION	
		MECHANICAL		MATERIALS			
Boost Loads	A2	Geometry	A2	Mat'l Strength	B2	NDT	
Flu. Pro. Var.		Fillet Radii	A2	Ductility	B2	Handling	
Speed		Dimensions	A1	Thermal α 's	A2	Scratches	
Radiation	A2	Pilot Fits	A2	Fatigue		Dim. Insp.	
Sys. Stabil.	A2	Brg. Clear.	A2	Corrosion		Clean.	
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2	"E"	A2	Assy Error	A2
Coolant Flow		Preload	A2				
Pressure	A2	Brg/Hsg Stiff.	B2				
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances					
Temperature	A2	Torque					
ΔT 's		Finish	A2				
Pump Unloads		Location					
Laby. Flow					TOTAL	581	
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

52. THRUST BALANCER LANDS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 4, 9	5	5	5	Clearance changes due to rubs
1, 2, 3, 4, 11	5	5	5	Clearance changes due to thermals
1, 2, 3, 4, 9, 12	5	5	5	Clearance changes due to deflection
1, 2, 3, 4, 9	5			Clearance changes due to erosion
3, 4, 9, 11	4	4	4	Becomes constricted
3, 4, 9, 12, 15		5	5	Retaining flange ruptures
4, 9, 11, 12	4	4		Secondary leak path
	<u>28</u>	<u>28</u>	<u>24</u>	

52. THRUST BALANCER LANDS

PERFORMANCE RELATED		<u>PART RELATED FAILURE CAUSES</u>			
		MECHANICAL		MATERIALS	INSPECTION
Boost Loads		Geometry	A2	Mat'l Strength	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2
Speed		Dimensions	A2	Thermal α 's	A2
Radiation		Pilot Fits	A2	Fatigue	A2
Sys. Stabil.	A3	Brg. Clear.		Corrosion	
Solar Heat		Eccent.		Grain Orient.	A2
Chilldown	A1	Tolerances	A2		Assy Error
Coolant Flow		Preload	A2		
Pressure		Brg/Hsg Stiff.	A3		
Flow Rate		Heat Trans.			
ΔP 's	A3	Clearances	A2		
Temperature		Torque			
Pump Unloads		Finish			
Laby. Flow		Location			
Crit.Speed	B2	Press. Fit			
Fluid Wakes		Thermal Ex.			
Inlet Conditions		Rotor Iner.			
		Dyn. Disp.			
		Cent.Load.			
		Stress Con.			
				TOTAL	532

PART LEVEL FAILURE MECHANISMS

53. THRUST BALANCER LAND SHIMS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2	2	Extrudes due to vib. or excessive preload
9, 15				Frets/wears due to fiv.
12, 15		2	2	Extrudes due to excessive loading
	<u>0</u>	<u>4</u>	<u>4</u>	

53. THRUST BALANCER LAND SHIMS

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	A2	NDT	
Flu. Pro. Var.		Fillet Radii		Ductility		Handling	A2
Speed		Dimensions	A1	Thermal α 's	A1	Scratches	
Radiation		Pilot Fits		Fatigue		Dim. Insp.	A2
Sys. Stabil.		Brg. Clear.		Corrosion		Clean.	
Solar Heat		Eccent.		Grain Orient.		Contam.	
Chilldown		Tolerances				Assy Error	A2
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's		Clearances					
Temperature		Torque					
Pump Unloads		Finish					
Laby. Flow		Location			TOTAL	153	
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

54. THRUST BALANCER HOUSING TO PUMP HOUSING SEAL

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 9, 11		3		Seal mech. failure
4, 9	2	2		Excessive pressure
4, 9, 11, 12		4		Losses preload
9		1		Fails due to vibratory loads
4, 9, 11, 12		4		Flange load distortion
15		1		Fails in compression
	<u>2</u>	<u>15</u>	<u>0</u>	

54. THRUST BALANCER HOUSING TO PUMP HOUSING SEAL

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions	A1	Thermal α 's		Scratches	A2
Radiation		Pilot Fits		Fatigue	A2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.		Grain Orient.		Contam.	A2
Chilldown		Tolerances	A2			Assy Error	
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature		Torque	A2				
ΔT 's	A2	Finish	A2				
Pump Unloads		Location					
Laby. Flow							
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.			TOTAL	262	
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

55. THRUST BALANCER HOUSING TO TURBINE INLET MAN. SEAL

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 9, 11		3		Seal mech. failure
4, 9	2	2		Excessive pressure
4, 9, 11, 12		4		Losses preload
9		1		Fails due to vibratory loads
4, 9, 11, 12		4		Flange load distortion
15		1		Fails in compression
	<u>2</u>	<u>15</u>	<u>0</u>	

55. THRUST BALANCER HOUSING TO TURBINE INLET MAN. SEAL

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A1	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions	A1	Thermal α 's		Scratches	A2
Radiation		Pilot Fits		Fatigue	A2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.		Grain Orient.		Contam.	A2
Chilldown		Tolerances	A2			Assy Error	
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature		Torque	A2				
ΔT 's	A2	Finish	A2				
Pump Unloads		Location				TOTAL	262
Laby. Flow		Press. Fit					
Crit.Speed	B2	Thermal Ex.					
Fluid Wakes		Rotor Iner.					
Inlet Conditions		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

56. THERMOCOUPLE

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 13	2	2		Case rupture
9, 11, 13	3	3		Fails due to thermal cycle
9, 13	2	2		Fails due to vibratory loads
9, 13	2	2		Fails due to preload
13, 9	2	2		Insulation ruptures
	<u>11</u>	<u>11</u>	<u>0</u>	

56. THERMOCOUPLE

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions	A2	Thermal α 's		Scratches	
Radiation		Pilot Fits		Fatigue		Dim. Insp.	A2
Sys. Stabil.		Brg. Clear.		Corrosion		Clean.	
Solar Heat		Eccent.		Grain Orient.		Contam.	
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances					
Temperature		Torque					
ΔT 's	A2	Finish					
Pump Unloads		Location					
Laby. Flow							
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.	A1				
Inlet Conditions		Rotor Iner.				TOTAL	221
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

57. THERMOCOUPLE CONNECTOR SEALS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
4, 9, 11	3	3		Seal Mech. failure
9	1	1		Fails due to vib. loads
9	1	1		Fails due to excessive pressure
9	1	1		Fails due to loss of preload
11	1	1		Fails due to thermal cycling
	<u>7</u>	<u>7</u>	<u>0</u>	

57. THERMOCOUPLE CONNECTOR SEALS

		<u>PART RELATED FAILURE CAUSES</u>			
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads		Geometry	A1	Mat'l Strength	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2
Speed		Dimensions	A1	Thermal α 's	A2
Radiation		Pilot Fits		Fatigue	A2
Sys. Stabil.		Brg. Clear.		Corrosion	A2
Solar Heat		Eccent.		Grain Orient.	A2
Chilldown		Tolerances	A2		Assy Error
Coolant Flow		Preload	A2		
Pressure		Brg/Hsg Stiff.			
Flow Rate		Heat Trans.			
ΔP 's	A2	Clearances			
Temperature		Torque			
ΔT 's	A2	Finish	A2		
Pump Unloads		Location		TOTAL	132
Laby. Flow		Press. Fit			
Crit.Speed	A2	Thermal Ex.			
Fluid Wakes		Rotor Iner.			
Inlet Conditions		Dyn. Disp.			
		Cent.Load.			
		Stress Con.			

PART LEVEL FAILURE MECHANISMS

58. SHEET METAL SHIELD FOR TURBINE END

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9		1		Ruptures by Delta P's and provide direct impingement of tur. gas on hs
11		1		Fails due to thermal cycling
9		1		Fails due to vib.loading
	<u>0</u>	<u>3</u>	<u>0</u>	

58. SHEET METAL SHIELD FOR TURBINE END

PART RELATED FAILURE CAUSES

[illegible]

PART LEVEL FAILURE MECHANISMS

59. SHEET METAL SHIELD BOLTS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9		1		LOSS OF PRELOAD
9		1		FAIL DUE TO VIB. LOADING
11		1		THERMAL CONTRACTION TOO GREAT
15		1		ALL BOLTS FAIL AND ALLOW SHIELD TO MOVE FREELY
	<u>0</u>	<u>4</u>	<u>0</u>	

59. SHEET METAL SHIELD BOLTS

PART RELATED FAILURE CAUSES			
PERFORMANCE RELATED	MECHANICAL	MATERIALS	INSPECTION
Boost Loads	Geometry	Mat'l Strength	NDT
Flu. Pro. Var.	Fillet Radii	Ductility	Handling A2
Speed	Dimensions	Thermal α 's A1	Scratches A2
Radiation	Pilot Fits	Fatigue A1	Dim. Insp. A2
Sys. Stabil.	Brg. Clear.	Corrosion	Clean. A2
Solar Heat	Eccent.	Grain Orient.	Contam. A2
Chilldown	Tolerances		Assy Error
Coolant Flow	Preload A1		
Pressure	Brg/Hsg Stiff.		
Flow Rate	Heat Trans.		
ΔP 's	Clearances		
Temperature	Torque		
Pump Unloads	Finish	TOTAL	14
Laby. Flow	Location		
Crit.Speed A1	Press. Fit		
Fluid Wakes	Thermal Ex.		
Inlet Conditions	Rotor Iner.		
	Dyn. Disp.		
	Cent.Load.		
	Stress Con.		

PART LEVEL FAILURE MECHANISMS

60. AFT BEARING CARTRIDGE RETAINER

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2	2	Flange ruptures due to load
9, 15		2		Loss of preload cause wear due to vib
11, 15		2		Tab rupture due to thermal
11, 15		2		Failure due to brittle (no deflection condition
	<u>0</u>	<u>4</u>	<u>2</u>	

60. AFT BEARING CARTRIDGE RETAINER

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A2	Mat'l Strength	B2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	B2	Handling	
Speed		Dimensions	A2	Thermal α 's	A1	Scratches	
Radiation		Pilot Fits	A2	Fatigue	B2	Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	
Solar Heat		Eccent.		Grain Orient.		Contam.	
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances					
Temperature		Torque					
Pump Unloads		Finish					
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					
				TOTAL		501	

PART LEVEL FAILURE MECHANISMS

61. AFT BEARING CARTRIDGE

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9,15		2		Fails in compression (extrudes)
11, 15		2		Thermal contraction wrong
	<u>0</u>	<u>4</u>	<u>0</u>	

61. AFT BEARING CARTRIDGE RETAINER SHIM

<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads		Geometry	A1	Mat'l Strength	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2
Speed		Dimensions		Thermal α 's	A1
Radiation		Pilot Fits		Fatigue	A2
Sys. Stabil.		Brg. Clear.		Corrosion	A2
Solar Heat		Eccent.		Grain Orient.	A2
Chilldown		Tolerances			Assy Error
Coolant Flow		Preload	A2		
Pressure		Brg/Hsg Stiff.			
Flow Rate		Heat Trans.			
ΔP 's		Clearances			
Temperature	A1	Torque			
ΔT 's		Finish			
Pump Unloads		Location			
Laby. Flow					TOTAL 43
Crit.Speed	A2	Press. Fit			
Fluid Wakes		Thermal Ex.			
Inlet Conditions		Rotor Iner.			
		Dyn. Disp.			
		Cent.Load.			
		Stress Con.			

PART LEVEL FAILURE MECHANISMS

62. FIRST STAGE ROTOR SHROUD LABYRINTH OUTER LAND

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 9, 10, 14	5	5		Excessive wear
1, 2, 9, 14	4	4	4	Thermal distortion
1, 2, 9, 14, 15	5	5	5	Preload (mech) distortion
1, 2, 9, 14	4			Excessive clearance
4, 9, 10, 14, 15	5	5		Distorts due to Delta P's (secondary flow path)
4, 9, 10, 14, 15		5	5	Loss of stacking load
	<u>23</u>	<u>24</u>	<u>14</u>	

62. FIRST STAGE ROTOR SHROUD LABYRINTH OUTER LAND

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry	A2	Mat'l Strength	A2	NDT	
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed	A2	Dimensions	A2	Thermal α 's	A2	Scratches	
Radiation		Pilot Fits	A2	Fatigue		Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature		Torque					
ΔT 's	A2	Finish					
Pump Unloads		Location					
Laby. Flow						TOTAL	165
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

63. SECOND STAGE ROTOR SHORUD LABYRINTH OUTER LAND

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 9, 10, 14	5	5		Excessive wear
1, 2, 9, 14	4	4	4	Thermal distortion
1, 2, 9, 14, 15	5	5	5	Preload (mech) distortion
1, 2, 9, 14	4			Excessive clearance
4, 9, 10, 14, 15	5	5		Distorts due to Delta P's (secondary flow path)
4, 9, 10, 14, 15		5	5	Loss of stacking load.
	<u>23</u>	<u>24</u>	<u>14</u>	

63. SECOND STAGE ROTOR SHROUD LABYRINTH OUTER LAND

PERFORMANCE RELATED		PART RELATED FAILURE CAUSES				INSPECTION	
		MECHANICAL		MATERIALS			
Boost Loads		Geometry	A2	Mat'l Strength	A2	NDT	
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed	A2	Dimensions	A2	Thermal α 's	A2	Scratches	
Radiation		Pilot Fits	A2	Fatigue		Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	A2
Chilldown	A2	Tolerances	A2			Assy Error	A2
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances	A2				
Temperature		Torque					
Delta T's	A2	Finish					
Pump Unloads		Location					
Laby. Flow							
Crit.Speed	B2	Press. Fit				TOTAL	165
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

64. STATOR STACKING SHIM

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Extrudes or fails due to vib loading.
9, 15		2		Excessive preload.
9, 11		2		Thermal contraction.
	<u>0</u>	<u>6</u>	<u>0</u>	

64. STATOR STACKING SHIM

		<u>PART RELATED FAILURE CAUSES</u>				
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>
Boost Loads		Geometry		Mat'l Strength	A2	NDT
Flu. Pro. Var.		Fillet Radii		Ductility		Handling A2
Speed		Dimensions	A2	Thermal α 's	A1	Scratches A2
Radiation		Pilot Fits		Fatigue		Dim. Insp. A2
Sys. Stabil.		Brg. Clear.		Corrosion		Clean. A2
Solar Heat		Eccent.		Grain Orient.		Contam. A2
Chilldown		Tolerances				Assy Error
Coolant Flow		Preload	A2			
Pressure		Brg/Hsg Stiff.				
Flow Rate		Heat Trans.				
ΔP 's	A2	Clearances				
Temperature		Torque			TOTAL	51
Pump Unloads		Finish				
Laby. Flow		Location				
Crit.Speed	A2	Press. Fit				
Fluid Wakes		Thermal Ex.				
Inlet Conditions		Rotor Iner.				
		Dyn. Disp.				
		Cent.Load.				
		Stress Con.				

PART LEVEL FAILURE MECHANISMS

65. TURBINE END DIST. DETECTOR MTG. PL.

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15	2	2	2	Fails due to Delta P's.
9, 15	2	2		Fails due to vib loading
9, 15	2	2	2	Retaining flg failure
9, 11, 15	3	3		Distorts due to thermal cycling.
15	1	3		Does not maintain probe positions.
	<u>10</u>	<u>10</u>	<u>4</u>	

65. TURBINE END DIST. DETECTOR MTG. PL.

		<u>PART RELATED FAILURE CAUSES</u>					
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>	<u>INSPECTION</u>		
Boost Loads		Geometry	A1	Mat'l Strength	A2	NDT	
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions	A1	Thermal α 's		Scratches	A2
Radiation		Pilot Fits	A2	Fatigue		Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.	A2	Grain Orient.		Contam.	
Chilldown		Tolerances	A2			Assy Error	
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A1	Clearances					
Temperature		Torque					
Pump Unloads		Finish					
Laby. Flow		Location				TOTAL	94
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

66. TURBINE END DIST. DETECTOR MTG BOLTS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Fails due to vib. loading.
9, 11, 15		3		Fails due to thermal cycling.
15		1		Loses preload torque.
	<u>0</u>	<u>6</u>	<u>0</u>	

66. TURBINE END DIST. DETECTOR MTG BOLTS

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads		Geometry		Mat'l Strength	A2	NDT	
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions		Thermal α 's	A1	Scratches	A2
Radiation		Pilot Fits		Fatigue		Dim. Insp.	A2
Sys. Stabil.	A2	Brg. Clear.		Corrosion		Clean.	A2
Solar Heat		Eccent.		Grain Orient.		Contam.	A2
Chilldown		Tolerances				Assy Error	
Coolant Flow		Preload	A2				
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's	A2	Clearances					
Temperature		Torque					
Delta T's	A2	Finish					
Pump Unloads		Location					
Laby. Flow							
Crit.Speed	B2	Press. Fit				TOTAL	190
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.	A2				
		Cent.Load.					
		Stress Con.					

PART LEVEL FAILURE MECHANISMS

67. TORQUE CHECK ACCESS ASSEMBLY

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 15		2		Seal Failure.
9, 15		2		Engages while TPA is operating.
9, 15		2		Access cap loses torque.
9, 15		2		Torque rod seizes.
	---	---	---	
	0	8	0	

67. TORQUE CHECK ACCESS ASSEMBLY

		<u>PART RELATED FAILURE CAUSES</u>		
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>	<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads		Geometry A2	Mat'l Strength	NDT
Flu. Pro. Var.		Fillet Radii	Ductility	Handling
Speed		Dimensions A2	Thermal α 's	Scratches
Radiation		Pilot Fits A2	Fatigue	Dim. Insp.
Sys. Stabil.		Brg. Clear.	Corrosion	Clean.
Solar Heat		Eccent.	Grain Orient.	Contam.
Chilldown		Tolerances A2		Assy Error
Coolant Flow		Preload A2		
Pressure		Brg/Hsg Stiff.		
Flow Rate		Heat Trans.		
ΔP 's	A2	Clearances		
Temperature		Torque		
Pump Unloads		Finish		
Laby. Flow		Location		
Crit.Speed	A2	Press. Fit		TOTAL 70
Fluid Wakes		Thermal Ex.		
Inlet Conditions		Rotor Iner.		
		Dyn. Disp.		
		Cent.Load.		
		Stress Con.		

PART LEVEL FAILURE MECHANISMS

68. BRG COOLANT FEED LINE

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
1, 2, 3, 4, 9, 10, 12, 15	8	8		Rupture of Line
1, 2, 3, 9, 10	5	5		Line becomes plugged.
1, 2, 3, 9, 10, 12, 15	7	7		Line constricts
1, 2, 4, 9, 10, 12		6		Flange failure.
1, 2, 4, 9, 10, 12		6		Flange seal failure.
2	1			Excessive loss.
9		1		Fails due to vibration
9, 11		2		Fails due to thermal cycling
1	1			Thermal input causes excessive line losses.
	<u>22</u>	<u>35</u>	<u>0</u>	

C8. BRG COOLANT FEED LINE

		<u>PART RELATED FAILURE CAUSES</u>			
<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>	<u>INSPECTION</u>
Boost Loads		Geometry	A2	Mat'l Strength	A2
Flu. Pro. Var.		Fillet Radii		Ductility	B2
Speed		Dimensions	A1	Thermal α 's	A2
Radiation		Pilot Fits	A1	Fatigue	
Sys. Stabil.	A2	Brg. Clear.		Corrosion	
Solar Heat		Eccent.	A1	Grain Orient.	
Chilldown	A2	Tolerances	A1		
Coolant Flow		Preload	A2		
Pressure		Brg/Hsg Stiff.			
Flow Rate		Heat Trans.	A2		
ΔP 's	A2	Clearances	A2		
Temperature	A2	Torque			
Delta T's	A2	Finish	A2		
Pump Unloads		Location			
Laby. Flow		Press. Fit			
Crit.Speed	B2	Thermal Ex.			
Fluid Wakes		Rotor Iner.			
Inlet Conditions		Dyn. Disp.			
		Cent.Load.			
		Stress Con.			
				TOTAL	394

PART LEVEL FAILURE MECHANISMS

69. THERMOCOUPLE LEADS

<u>FAILURE FUNCTION</u>	<u>LOW PERFORMANCE</u>	<u>PREMATURE STOP</u>	<u>FAILURE TO START</u>	<u>FAILURE MECHANISMS</u>
9, 13	2	2		Wire fatigue
9, 11, 13	3	3		Insulation fails (short)
9, 11, 13	3	3		Connection fails
11, 13	2			No slack - wire fails by thermal contraction
	<u>10</u>	<u>8</u>	<u>0</u>	

69. THERMOCOUPLE LEADS

PART RELATED FAILURE CAUSES

<u>PERFORMANCE RELATED</u>		<u>MECHANICAL</u>		<u>MATERIALS</u>		<u>INSPECTION</u>	
Boost Loads	A2	Geometry	A2	Mat'l Strength	A2	NDT	A2
Flu. Pro. Var.		Fillet Radii		Ductility	A2	Handling	A2
Speed		Dimensions	A2	Thermal α 's	A2	Scratches	A2
Radiation	A2	Pilot Fits		Fatigue	A2	Dim. Insp.	
Sys. Stabil.	A2	Brg. Clear.		Corrosion	A2	Clean.	
Solar Heat	A2	Eccent.		Grain Orient.		Contam.	A2
Chilldown		Tolerances	A1			Assy Error	A2
Coolant Flow		Preload					
Pressure		Brg/Hsg Stiff.					
Flow Rate		Heat Trans.					
ΔP 's		Clearances					
Temperature	A2	Torque					
Pump Unloads		Finish				TOTAL	271
Laby. Flow		Location					
Crit.Speed	B2	Press. Fit					
Fluid Wakes		Thermal Ex.					
Inlet Conditions		Rotor Iner.					
		Dyn. Disp.					
		Cent.Load.					
		Stress Con.					

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19 July 1971
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APPENDIX D

COMPUTER PROGRAM AND RELIABILITY ALLOCATIONS

LABEL ADDR

500 002834
24 0028AC

LABEL ADDR

21 0028FA
25 002C74

LABEL ADDR

22 002974

LABEL ADDR

23 002302

PAGE 003

OPTIONS IN EFFECT NAME= MAIN,OPT=00,LINECNT=72

OPTIONS IN EFFECT SOURCE,PCD,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

STATISTICS SOURCE STATEMENTS = 51 ,PROGRAM SIZE = 11544

STATISTICS NO DIAGNOSTICS GENERATED

***** END OF COMPILATION *****

IFF373I STEP /COMPIL / START 70313.0943
IFF374I STEP /COMPIL / STOP 70313.0943

```
*****  
**CURRENT TIME 09.308 STEP TIME IN MINUTES (CPU-000.021 BILLED-000.095) LOAD ADDR 74AB8 $0000.35**  
*****REGION (EST-256 ACT-240)K NO. OF DISK-TAPES-OTHERS 05-00-00 NO. OF EXCP REQUESTS 0000094*****  
*****  
XXLINK EXFC PGM=LV1128,PARM='LET,LIST,MAP,SIZE=(234K,125K)', C00000019  
XX REGION=250K 00000021  
XXSYSLIB DD DSN=SYS1.FORTLIB,DISP=SHR 00000023  
XX DD DSN=SYS1.ASLIB,DISP=SHR 00000025  
XXSYSPRINT DD SYSOUT=P,DCB=(,BLKSIZE=121), C00000027  
XX UNIT=(SYSDATA,2) 00000029  
XXSYSLMOD DD DSN=SYS1.GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS), *00000031  
XX SPACE=(CYL,(10,,1)) 00000033  
XXSYSLMOD DD UNIT=SYSDA,SPACE=(1024,(500,20)) 00000035  
XXLOADM DD DSN=CHKDLMOD,DISP=SHR 00000037  
XXSYSLIN DD DSN=SYS1.LOADSET,DISP=(OLD,DELETE) 00000039  
XX DD DSN=XLOADM 00000041
```

MODULE MAP

CONTROL SECTION

ENTRY

NAME	ORIGIN	LENGTH	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION	NAME	LOCATION
MAIN	00	2D18								
IHCFCMH*	2D18	F31								
IHCFCMH2*	3C50	581	IBCOM#	2D18	FDIDCS#	2DD4	INTSWCH	3C36		
IHCFCVTH*	41D8	1195	SEQDASD	3EEC						
			ADCON#	41D8	FCVADUTP	4282	FCVLOUTP	4312	FCVZDUTP	4462
IHCFFNTH*	5370	512	FCVIOUTP	4908	FCVFOUTP	4D0A	FCVCOUTP	4F24	INT6SWCH	520B
IHCFFIOS*	5898	129C	ARITH#	5370	ADJSWCH	56DC				
IHCUPPT *	6928	3A0	FIDCS#	5898	FIDCSBEP	588E				
IHCPRM *	6EC8	58C								
IHCUTBL*	7488	638	ERRMON	6EC8	IHCERRE	6EE0				
IHCCTRCH*	7AC0	28E								
			IHCCTRCH	7AC0	ERRTRA	7AC8				

ENTRY ADDRESS 00
 TOTAL LENGTH 7D50

*****MAIN DOES NOT EXIST BUT HAS BEEN ADDED TO DATA SET

ICF373I P /LINK / START 70313.0948
ICF374I P /LINK / STOP 70313.0948

CURRENT TIME 09.315 STEP TIME IN MINUTES (CPU-000.015 BILLED-000.151) LOAD ADDR 763A8 \$0000.60
*****REGION (EST-250 ACT-242)K NO. OF DISK-TAPES-OTHERS 08-00-00 NO. OF EXCP REQUESTS 0000194*****

XXPERF EXFC PGM=*,LINK,SYSLMOD 00000043
XXFT06F001 DD SYSDUT=P,DCB=(,RECFM=FB,LRECL=138,BLKSIZE=1104) 00000045
//PERF.FT05F001 DD *

TPA REL.	TPA PERF.REL.	TPA FAIL.START	TPA PRE.STOP	REL.QUAL.FACTOR
.999736000000	.99962478922	.999966241897	.999910779178	.2500

PART IDENT.NO.	PART REL.	PART PERF.REL.	PART PREM.STOP	PART FAIL START
1	.999992757887	.999995961128	.999997214571	.999999582185
2	.999992331156	.999996853807	.999996263896	.999999213451
3	.999992146513	.999997164018	.999995418798	.999999563694
4	.999995630113	.999998579786	.999997159572	.99999890752
5	.999992757887	.999997527082	.999997262127	.999997968675
6	.999996101979	.999999999999	.999997165074	.999998936902
7	.999992142410	.999997290485	.999996071204	.999998780718
8	.999995264930	.999998708616	.999997675510	.999998880801
9	.999994403262	.999998515150	.999996916082	.999998972027
10	.999996446646	.999999202307	.999998187063	.999999057272
11	.999995745002	.999999044795	.999997829082	.999998871122
12	.999997542195	.999999999999	.999998310258	.999999231935
13	.999996557432	.999998762826	.999998063554	.999999731048
14	.999997066226	.999998958982	.999998296517	.999999810723
15	.9999980329354	.999999999999	.9999987482315	.9999992847037
16	.9999980329354	.999999999999	.9999987482315	.9999992847037
17	.999997468338	.999999314340	.999999129740	.999999024254
18	.999997468338	.999999314340	.999999129740	.999999024254
19	.999997468338	.999999314340	.999999129740	.999999024254
20	.999997111361	.999999017862	.999999017862	.999999075635
21	.999997111361	.999999017862	.999999017862	.999999075635
22	.999999286047	.999999937916	.999999410211	.999999937916
23	.999999733293	.999999966661	.999999766631	.999999999999
24	.999999002927	.999999999999	.999999002926	.999999999999
25	.999999392729	.999999624070	.999999797575	.99999971081
26	.999999323563	.999999999999	.999999823562	.999999999999
27	.999999322975	.999999999999	.999999492230	.999999830743
28	.999999679952	.999999914653	.999999850643	.999999914653
29	.999999589682	.999999999999	.999999589681	.999999999999
30	.999999589682	.999999999999	.999999589681	.999999999999
31	.999999111361	.999999017862	.999999017862	.999999075635

30	.99999589682	.99999999999	.99999589681	.99999999999
31	.999999015237	.99999999999	.999999118895	.99999999999
32	.999999015237	.99999999999	.999999118895	.99999999999
33	.999999212187	.999999684875	.999999527313	.99999999999
34	.999999158848	.99999999999	.999999158847	.99999999999
35	.999999913833	.99999999999	.999999913832	.99999999999
36	.999999327666	.99999999999	.999999827665	.99999999999
37	.999999331770	.99999999999	.999999831769	.99999999999
38	.999999339388	.999999917422	.999999669693	.999999752269
39	.999999794841	.99999999999	.999999794840	.99999999999
40	.999999253221	.999999626610	.999999751073	.999999875536
41	.999999790738	.99999999999	.999999790737	.99999999999
42	.999999790738	.99999999999	.999999790737	.99999999999
43	.999998637744	.999999195030	.999999442713	.99999999999
44	.999998637744	.999999195030	.999999442713	.99999999999
45	.999998637744	.999999195030	.999999442713	.99999999999
46	.999998888038	.999999382242	.999999505794	.99999999999
47	.999998888038	.999999382242	.999999505794	.99999999999
48	.999999782531	.999999891265	.999999891265	.99999999999
49	.999999782531	.999999891265	.999999891265	.99999999999
50	.999999659436	.999999229717	.999999629717	.99999999999
51	.999997616052	.999999158606	.999998878141	.999999579302
52	.999997317108	.999999235987	.999999235987	.999999345131
53	.999999372213	.99999999999	.999999686106	.999999686106
54	.999998924967	.999999873525	.999999051440	.99999999999
55	.999998924967	.999999873525	.999999051440	.99999999999
56	.999999093197	.999999546598	.999999546598	.99999999999
57	.999999458380	.999999729189	.999999729189	.99999999999
58	.999999868698	.99999999999	.999999868697	.99999999999
59	.999999942555	.99999999999	.999999942554	.99999999999
60	.999997944307	.99999999999	.999998629537	.999999314768
61	.999999823563	.99999999999	.999999823562	.99999999999
62	.999999322975	.999999744727	.999999733629	.999999844616
63	.999999322975	.999999744727	.999999733629	.999999844616
64	.999999790738	.99999999999	.999999790737	.99999999999
65	.999999614301	.999999839291	.999999839291	.999999935716
66	.999999220396	.99999999999	.999999220395	.99999999999
67	.999999712777	.99999999999	.999999712776	.99999999999
68	.999998383347	.999999176028	.999999007317	.99999999999
69	.999998888038	.999999382242	.999999505794	.99999999999

IHC900I EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER 217

IHC217I FIDCS - END OF DATA SET ON UNIT 5

TRACEBACK ROUTINE CALLED FROM ISN REG. 14 REG. 15 REG. 0 REG. 1