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THERMAL SHOCK INVESTIGATION

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THERMAL SHOCK INVESTIGATION

OBJECT

The object of this research is to evaluate optimum design of test specimens and to establish criteria which will permit the correlation of thermal-shock data with performance of the material in the form of turbine buckets.

SUMMARY

Work has been completed on the assembly of the control panels for four thermal-shock testing rigs. One complete rig has been put together, and a trial run made. The results of the trial have been satisfactory. Completion of the three remaining rigs will greatly enlarge the testing capacity of the facilities.

INTRODUCTION

The testing rigs used to date were originally developed by the WADC. They were designed to test two specimens simultaneously, and were provided with a set of levers to impose an axial tensile load on the specimen in addition to the thermal shock. These rigs have been in more or less continuous use for the past two years, and in the course of their operation it has become apparent that more rigs would be highly desirable.

The primary reason for building more testing units is to permit the gathering of more data in less time. This will be reflected in a marked reduction in the time required to complete a series of tests.

Because the new units are being constructed without the axial-loading feature, it will be possible to test material either with or without axial loading on a simultaneous basis. This provides a considerable increase in the flexibility of the testing program. It will also be possible to conduct two-stage tests, in which the specimens are first subjected to creep deformation or stress-rupture loading before being tested in thermal shock. It has been possible to run such tests on the present equipment, but only on a very low production basis.

Experience gathered in the operation of the WADC units has provided a basis for certain design improvements which are included in the new apparatus. It has been found troublesome to observe the formation of cracks in the present equipment, therefore the mounting of the specimen has been changed to make inspection easier and to provide for the mounting of a camera to make photographic observations in situ. The camera equipment has been developed by the Technical Photo section of WADC.

Other design improvements have been directed at increasing the accuracy of alignment of the specimen so as to reduce the geometrical irregularity between tests. The calibration process has also been revised and improved by redesign.

From a maintainance point of view, several changes have been made for the betterment of efficiency. The new units have been designed to operate independently of each other, thus reducing the number of complete shut downs caused by interdependency. Many of the circuit components have been relocated to provide easier access in case a defective part must be removed and replaced. This relocation has been done also with an eye to reducing the time required to mount and change specimens, and to speed up routine maintainance procedures.

DESCRIPTION OF APPARATUS

As in the original equipment, the new ones are composed of two basic units, a control unit and an operating unit. The original apparatus is all designed to be used with 120 volts; however, the new apparatus had to be redesigned to use 230-volt-power circuits for heating purposes in order to avoid overloading the feeders. There was enough 120-volt power available, however, to operate the control circuits alone, hence the heating and the control circuits were separated to gain the advantage of independence. Except for the voltage changes required, the circuits of the new and the old equipment are essentially the same.

Because of space requirements, the operating units had to be located away from the control units. This feature made it necessary to include more pilot lights on the new control panels in order to facilitate calibration and inspection of the apparatus by the operator. General arrangement of the control panels is shown in Fig. 1.

The operating units are arranged for bench mounting. The essentials of the design are the same as in the original equipment, with the specimen being held in electrodes for heating. One of the electrodes is fixed and the other is freely movable in the axial direction in order to allow for thermal expansion of the specimen. The temperature of the specimen is sensed by a vacuum thermocouple which operates an electronic pyrometer controller.

OPERATION OF APPARATUS

The apparatus consists of two interconnected units: the operating unit and the control unit. The operating unit comprises three elements: (1) means for supporting and heating the specimen, (2) means for sensing the temperature of the specimen at the test section, and (3) means for suddenly cooling the test portion of the specimen to induce thermal shock. The control unit comprises five elements: (1) means for controlling power input to the specimen, (2) means for controlling the temperature of the specimen, (3) means for timing the various portions of the thermal-shock cycle, (4) means for measuring the total number of thermal-shock cycles and the total elapsed time for a test and, (5) necessary safety devices to permit 24-hours-per-day operation with a minimum of attention.

The thermal-shock cycle may be divided into two portions, the heating time and the cooling time. In ordinary operation the length of the heating time is controlled by adjusting the power input to the specimen. In order to minimize the effects of lag in the temperature-control system, the heating time must be at least one minute. It is undesirable to exceed this minimum time because the total elapsed time for each test rapidly becomes excessive as the heating time is lengthened. The length of the heating cycle is therefore held at 60 seconds, plus or minus 5 seconds. This control is performed by manual adjustment of the input voltage.

Between the hours of 8 a.m. and 10 p.m. it is necessary to check the apparatus at frequent intervals in order to compensate for changes in the line voltage. There are also some relatively smaller changes in the contact resistance between the electrodes and the specimen which also require that the input voltage be adjusted from time to time. During the night-time hours there are only minor line-voltage variations, and the contact resistance changes only a little in that time, hence it is possible to leave the apparatus unattended from 10 p.m. until 8 a.m.

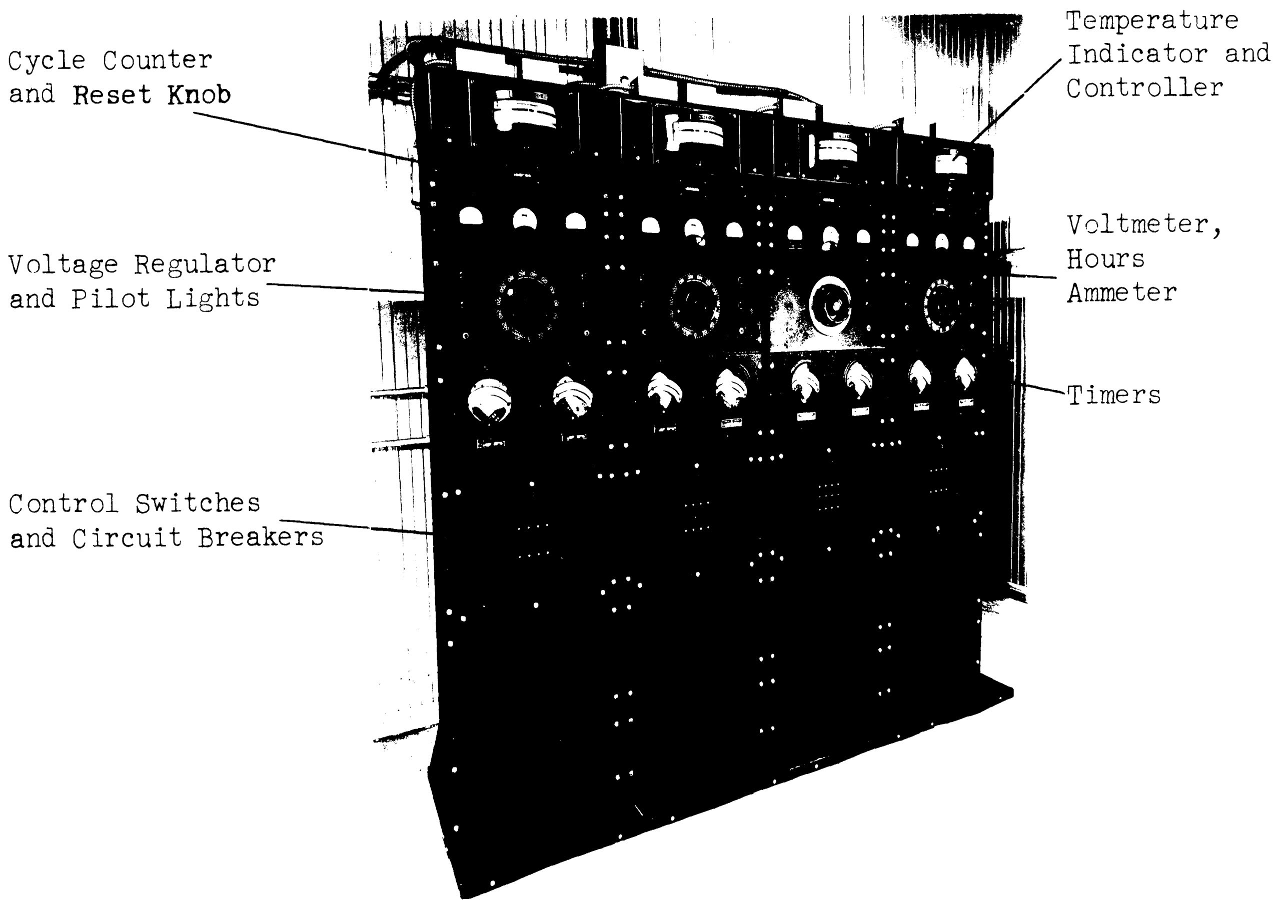


Fig. 1. Control Panel Assemblies

Heating of the specimen is accomplished by passing a current of about 800 amperes through it. The heating effect is localized by making the test portion of a smaller cross section than the rest of the piece. This area reduction increases the electrical resistance at the test portion, and results in that portion being heated to red heat while the rest of the piece remains comparatively cool. The heating current is supplied by a step-down transformer which is fed by a Variac autotransformer. The actual control of the heating rate is accomplished by varying the output of the Variac. When the specimen reaches the desired maximum temperature, a vacuum thermocouple which is aimed at one of the specimen faces, causes the controller to stop the heating cycle and begin the cooling cycle.

Cooling of the specimen is effected by opening the heating circuit and turning on an air jet. The jet of air is directed at one edge of a three-sided test section. This shape of test section provides that the air jet will cool the specimen in an asymmetrical manner and thus induce thermal stresses in a very short time. Alignment of the specimen is controlled by the specimen holder. To preserve the alignment it is necessary that no deflection due to bending action be allowed while the specimen cools asymmetrically. At the same time it is necessary to permit axial expansion and contraction to take place freely in order to avoid interaction of the axial stresses with the thermal-shock stresses. If bending were allowed it would be very difficult to keep the nozzle aimed at the same region of the specimen without actually contacting the heated area with the nozzle. Such contact would necessarily introduce undesirable nonuniformities in the temperature distribution on the test section.

The duration of the cooling portion of the cycle is controlled by a timer, and a standard cooling of 5 seconds is used. At the end of the cooling time, the air is cut off and the heating cycle begun again.

In certain types of tests it is desirable to be able to heat the specimen to a given temperature, hold it there for a certain time, then cool it either suddenly or gradually for a certain time. Both the new and the old units have circuits for accomplishing this type of cycle.

KEY TO LOG

Column (1)

	(1) Relative position on bar stock
	1 Specimen number

Column (2)

	Arrow indicates direction and location of cooling jet; cooling medium is air unless otherwise stated
W	Cooling medium is water
.045	Width of cooled edge, inches
P.F.	Previously subjected to rotating beam fatigue as shown in column (6)
X	Failed during pre-fatigue
1700/5 (1718)	Number in parentheses indicates average of calibrations at beginning and end of test (Mean max test temp)

Column (3)

M	Thermal shock cycle manually controlled
1500/5	Automatic cycle control; maximum temperature, °F, and length of cooling period, seconds
P1800	Dead load, 1800 lbs
+10/100	Starting with stated maximum temperature, maximum temperature was increased 10°F after each 100 cycles
40.5K	Reversed-bending (rotating-beam) fatigue tests; maximum stress, 40,500 psi
to 1800	Maximum temperature held constant after 1800°F was reached

Column (4)

A	Air cooling for stated number of cycles
W	Water cooling for stated number of cycles
no symbol	Air cooling for stated number of cycles

Column (5)

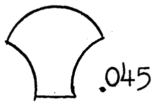
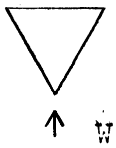
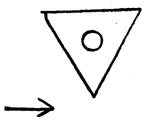
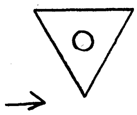
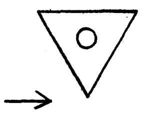
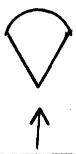
O	No failure visible
F	Fracture
C	Cracks
G	Grooves
FC	Face crack
PC	Possible crack

Column (6)

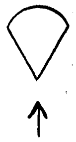
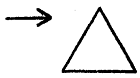
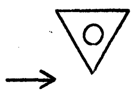
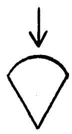
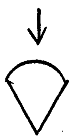
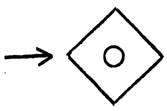
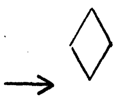
B	Specimen warped due to thermal strains
A 0.14	Area of cross section, square inch
T300/1600	Heat treated before testing 300 hr at 1600°F
G1500	Grooves first appeared at 1500 cycles

OH	Stated maximum temperature was exceeded due to malfunction of control unit
BT	Broke through to thermocouple hole
P {1700/60 / 1200/23} 1000	Previously subjected to cyclic heating and cooling (Max temp) 1700/60 (Heating time, seconds) (Min temp) 1200/23 (Cooling time, seconds) (Number of cycles) 1000
40.5K/ 82000	Previously subjected to 82000 cycles at 40,500 psi
R	Reproducibility test
N	Specimen formed a neck due to tensile strain.
+100/5108	Maximum temperature was increased 100°F at 5108 cycles.
Check II	Second test to determine the effect of alteration of testing procedure.
P	Study of crack propagation
PT1	Previously subjected to tensile strain of 1% at room temperature
LRSI	Long-time test at reduced severity, Test No. I
T{}I	Heat treated as shown in braces { }. Lot No. I
C20/1700	Heat treated for 20 hours by heating to 1700°F and allowing to cool for 5 seconds by natural convection.

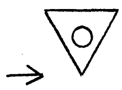
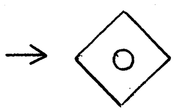
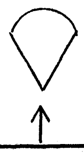
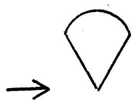
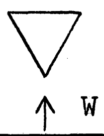
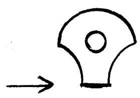
TEST LOG

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 304 Stainless Steel					
1		M	—	O	B
2		1600/10	4400 A 300 W	C	B
3		1600/4	1783	C	
4a 4b	Fatigue Specimens	40.5K 40.5K	3300 2600	F F	
5		1700/4 1800/4	1100 675	O C	
6		1600/4 1900/4	6240 1240	O C	G6500
7		1500/4 P600	4130	F	A 0.16

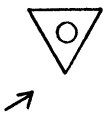
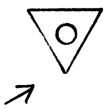
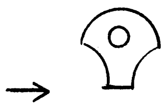
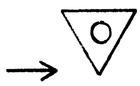
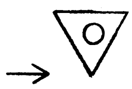
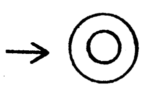
TEST LOG (cont)

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 304 Stainless Steel (cont)					
8		1600/5 1800/4	3082 517	O C	T300/1600
9		1500/3	5753	O	
10		1600/4 1700/4 1800/4	1000 1000 80	O O C	
11		1500/5 P1800	1000	F	A 0.132
12		1500/5 P600 P900 P1800	 5000 1200 203	 O O F	A 0.133
13		1600/4	1284	C	G115
14		1500/4	1000	F	OH

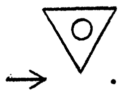
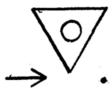
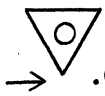
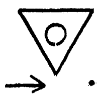
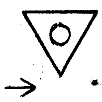
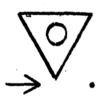
TEST LOG (cont)

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 304 Stainless Steel (cont)					
15		1600/5	1900	C	T300/1600
16		1600/5	409	C	
17		1500/5 P1800	300	F	A 0.140
18		1800/4	1950	C	G 1500
19		1700/3	530W	C	
20		1500/3	1000	O	BT

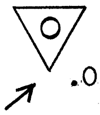
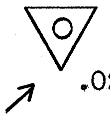
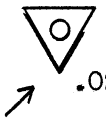
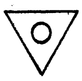
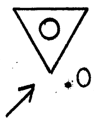
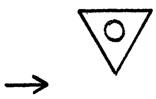
TEST LOG (cont)

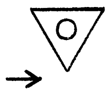
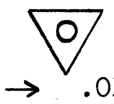
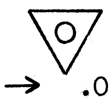
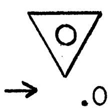
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 347 Stainless Steel					
1	 .045	1600/4 +10/100	866	C	
2	 .020	1600/4 +10/100	1147	C	
3		1500/4 +10/100	575	C	BT
4a 4b	Fatigue Specimens	54K 54K	5200 10400	F F	40.5K 82000
5		1500/4 +10/100	1326	C	
		1500/4 +10/100	1990	C	
7		1600/3.5 +10/100 to 1800	2700	G	

TEST LOG (cont)

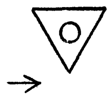
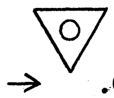
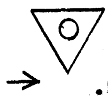
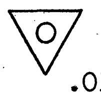
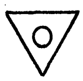
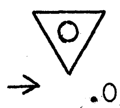
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 347 Stainless Steel (cont)					
8	(Defective)				
9	 .035	1600/4	2863	C	R
10	 .020	1600/4	3787	C	Check II
11	 .050	1600/4	2580	C	
12	 .020	1600/4	3162	C	G 736
13	 .020	1600/4	2204	C	G 2072
14	 .020	1600/4	2707	C	G 2604

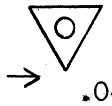
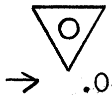
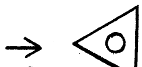
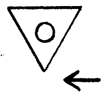
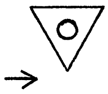
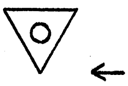
TEST LOG (cont)

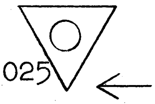
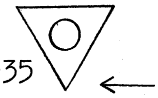
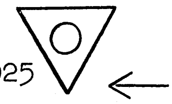
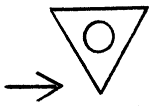
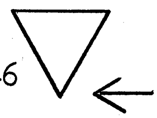
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 347 Stainless Steel (cont)					
15	 .035	1600/4	3003	C	G2820 R
16	 .020	1600/4	2518	C	R
17	 .023	1600/4	4850	O	Check I
18		Fatigue 64K	7200	F	54K 103300
19	 .035	1600/4	1825	C	R
20		Fatigue 64K	4300	F	37K/217100 42K/11000 48K/35600 54K/10000 59K/10400
21		1600/4	4430	C	

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 347 Stainless Steel (cont)					
22	(Defective)				
23		1600/5	2962	C	
24	 .010	Fatigue 59K	52900	F	
25	 .010	1600/5 P.F.	1562	C	54K/50000
26	 .010	1600/5	1960	C	53K/52000 59K/12000 64K/1000 70K/1000 75K/500
27	 .010	X P.F.	——	F	53K/52000 59K/11300
28	 .010	1600/5 P.F.	1594	C	53K/52000 59K/12000 64K/1000 70K/1000 75K/500

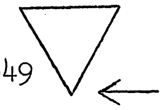
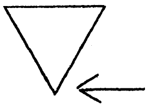
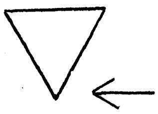
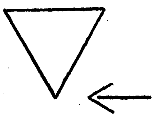
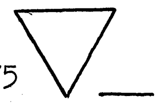
TEST LOG (cont)

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 347 Stainless Steel (cont)					
29		X P.F.	—	C	53K/52000 59K/12000 64K/1000 70K/1000 75K/300
30	 .010	1600/5	1973	C	
31	 .010	1600/5	2764	C	
32	 .010	1600/5	1500	C	
33 (4)	 .040	X P.F.	—	F	59K/32600
34 (3)	 .036	P.F.	1811	C	60K/39000
35 (2)	(Used for calibration of Heat-Eye)				

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 347 Stainless Steel (cont)					
36 (1)	 .040	1600/5 P.F.	1859	C	58K/30000
37 (5)	 .040	1600/5	4635	C	
38	 .025	1600/5	2114	C	T2/2000
39 (7)		1600/5	2440	G	G 2440 Rigid Support Nozzle No. 3
40 (8)		1600/5	3143	G	Nozzle No. 4
41		1600/5	2710	C	G 2000 Rigid Support Nozzle No. 3
42		(used for calibration)			

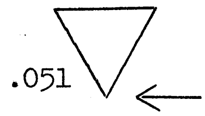
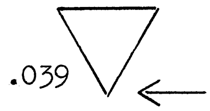
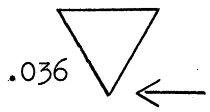
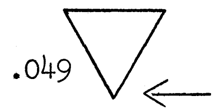
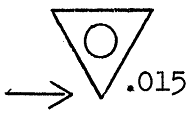
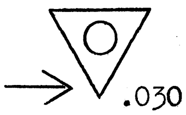
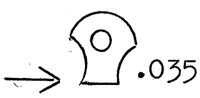
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Type 347 Stainless Steel (cont)					
43 (11)	.025 	1600/5	10708	C	P Rigid Support Nozzle No. 4
44	.035 	1600/5	2046	C	T2/2000
45	.025 	1600/5	1956	C	T2/2000
H. S. 21 (vitallium) Cast					
1		1500/3.5	1000	C	BT
2	.046 	1700/5 (1718)	3552	C	
3					

TEST LOG (cont)

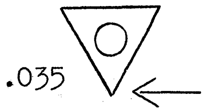
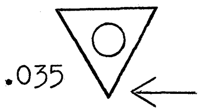
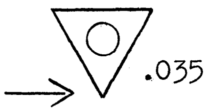
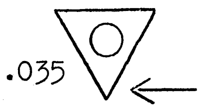
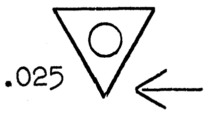
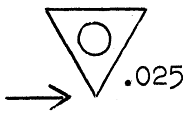
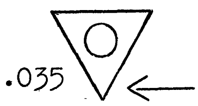
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
H. S. 21 (vitallium)		Cast (cont)			
4	.049 	1700/5 (1719)	6820	C	FC6003 .4C6561
5	.045 	1800/5 √	1252	C	
6					
7	.048 	1700/5 (1720)	1506	C	
8	.047 	1800/5 √	3468	C	
9	.0375 	1600/5 (1603)	5305	C	
10					

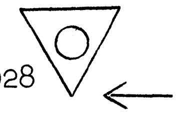
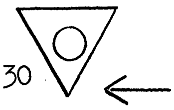
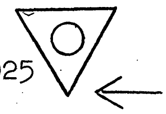
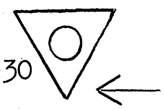
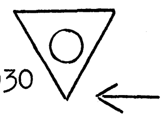
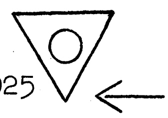
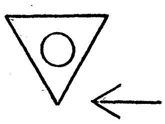
Specimen Number (1)	Cross Section (2)	Cycles (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
H. S. 21 (vitallium) Cast (cont)					
11	.043	1600/5 1605	17615	C	
12	.049	1700/5	7375		T51/1350
13	.044	1800/5 ✓	3902	C	
14					
15	.035	1600/5 (1607)	15334	O	
16	.038	1700/5	14489		T51/1350
17	.040	1700/5 (1708)	3279	C FC.004	

TEST LOG (cont)

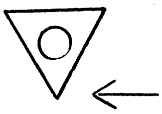
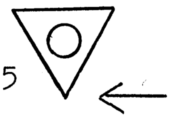
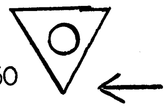
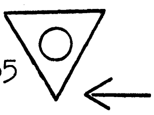
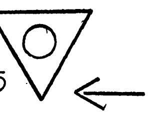
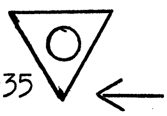
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
H. S. 21 (vitallium) Cast (cont)					
19		1700/5 (1710)	10060		T51/1350
20		1800/5 ✓	4147	C	
21		1600/5 ✓	9938	C	
22		1700/5 ✓	18411	C	T51/1350
Inconel					
1		1500/3	1450	C	
2		1500/3 +10/100	2730	C	
3		1500/3 +10/100	428	C	BT

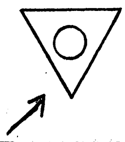
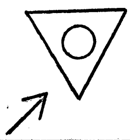
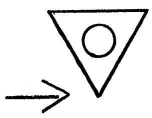
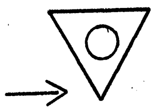
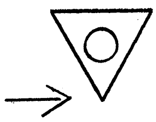
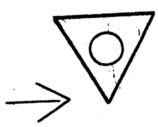
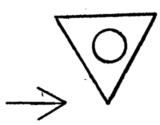
TEST LOG (cont)

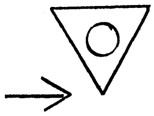
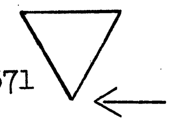
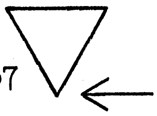
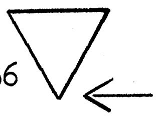
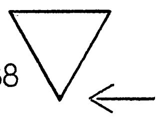
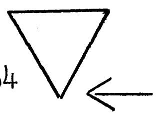
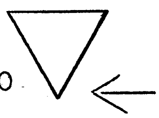
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Inconel (cont)					
4		1700/5	3167	C	T2/500 T1/3/1400
5		1700/5	1819	C	T2/500 T1/3/1400
6		1600/4	7449	C	
7		1700/5	4706	C	T2/500 T1/3/1400
8		1700/5	2090	C	T1/3/1400 PTI
9		1700/5	6465	C	T2/800
10		1700/5	3680	C	T1/3/1400 PT10

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Inconel (cont)					
11	.028 	1700/5	2860	C	T1/3/1400 PT5
12	.030 	1700/5	1884	C	T1/3/1400 C20/1700
13	.025 	1700/5	2500	C	T1/3/1400 PT1
14	.030 	1700/5	2527	C	T1/3/1400 PT5
15	.030 	1700/5	2804	C	T1/3/1400 PT10
16	.025 	1700/5	3590	C	T1/3/1400 PTO
17		1700/5	2270	C	T1/3/1400 PTI

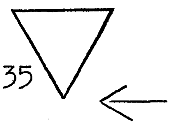
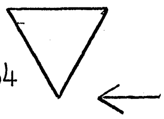
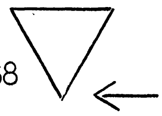
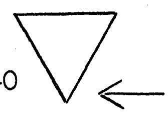
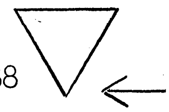
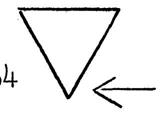
TEST LOG (cont)

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
Inconel (cont)					
18		1700/5	2576 3015	PC C	T1/3/1400 PT5
19	.025 	1700/5	1830	C	T1/3/1400 PT10
20	.030 	1700/5	2898	C	T1/3/1400 PT0
21					
22	.035 	1700/5	4339 6866	FC? C	T1/3/1400 flex. pipe to nozzle
23	.035 	1700/5	2250	C	T1/3/1400
24					
25	.035 	1700/5	3538 4229	FC C	T1/3/1400

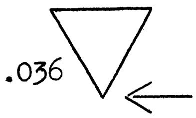
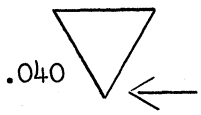
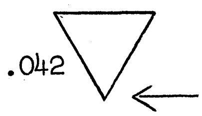
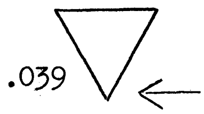
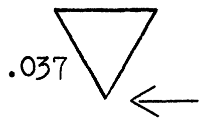
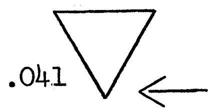
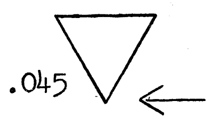
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
S-816 Alloy (wrought)					
1		1500/4 P700 No load	 1788 18391	 O C	A 0.08 N +100/5108 +100/10000
2		1500/4 P1100 to P700	2657	F	A 0.08 N
3		1700/4	2256	C	
4		1700/4	2250	C	
5		1600/4	3870	C	
6		1500/4	2630	C	
7		1500/4	13280	C	

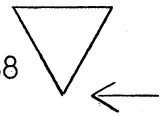
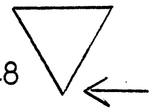
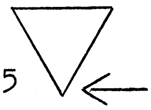
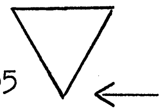
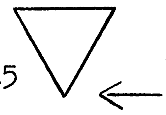
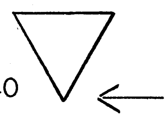
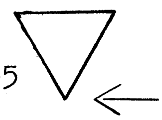
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
S-816 Alloy (wrought) (cont)					
8		1600/4	7497	C	
9	.0371 	1800/5	1069-	C	T 1/2150 W 16/1800
10	.037 	1700/5	2426	C	T 1/2150 W 16/1800
11	.036 	1600/5	5130	C	T 1/2150 W 16/1800
12	.0388 	1800/5	956-	C	T 1/2150 W 16/1800
13	.034 	1700/5	1903+	C .003 short	T 1/2150 W 16/1800
14	.0350 	1800/5	1146-	C	T 1/2150 W 16/1800

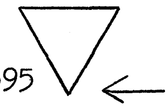
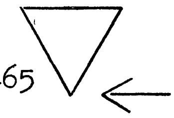
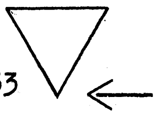
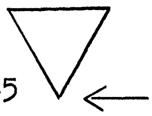
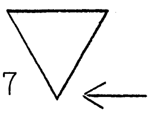
Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
S-816 Alloy (wrought) (cont)					
15	▽ .036 ←	1600/4	4600	C	T {1/2150 W; 16/1800} I
16	▽ .0335 ←	1600/4	3620	C	T {1/2150 W; 16/1800} I Average test temp. was 1615°F
17	▽ .0362 ←	1700/5	1956^-	C	T {1/2150 W; 16/1800} I
18	▽ .0384 ←	1800/5	784	C	T {1/2150 W; 16/1800} I
19	▽ .0345 ←	1700/5	2300^-	C	T {1/2150 W; 16/1800} I
20	▽ .0331 ←	1600/5	3100^-	C	T {1/2150 W; 16/1800} I Average test temp. was 1660°F
21	▽ .032 ←	1700/5	2190	C	T {1/2150; 16/1800} II P {1700/60; 1200/23; 1000}

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
S-816 Alloy (wrought) (cont)					
22	.035 	1700/5	2050	C	T {1/2150 16/1800} II P {1700/60 1200/23 600}
23	.034 	1700/5	1414	C	T {1/2150 16/1800} II P {1700/60 1200/23 1182}
N-155 Alloy (wrought)					
1	.038 	1700/5	3764 3878 4949	FC C 2C	T {1/3/2200 W 50/1400} I
2	.040 	1700/5	3211	C	T {1/3/2200 W 50/1400} I
3	.038 	1700/5	3248	C	T {1/3/2200 W 50/1400} I
4	.034 	1800/5	1508	C	T {1/3/2200 W 50/1400} I

TEST LOG (cont)

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
N-155 Alloy (wrought) (cont)					
5		1600/5	3886	O	T { 1/3/2200 W 50/1400 } I Removed for check; No crack
6		1700/5	3105	C	T { 1/3/2200 W 50/1400 } I
7		1800/5	1818	C	T { 1/3/2200 W 50/1400 } I
8		1700/5	3195	C	T { 1/3/2200 W 50/1400 } I
9		1700/5	2888	C	T { 1/3/2200 W 50/1400 } I
10		1600/5	10124	O	T { 1/3/2200 W 50/1400 } I
11		1800/5	2052	C	T { 1/3/2200 W 50/1400 } I

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
N-155 Alloy (wrought) (cont)					
12	.038 	1800/5	1228	C	T {1/3/2200 W 50/1400} II
13	.048 	1800/5	1095	C	T {1/3/2200 W 50/1400} II
14	.035 	1800/5	1042	C	T {1/3/2200 W 50/1400} II
15	.0385 	1800/5	990	C	T {1/3/2200 W 50/1400} II
16	.0415 	1800/5	1130	C	T {1/3/2200 W 50/1400} II
17	.040 	1700/5	2229	C	T {1/3/2200 W 50/1400} II
18	.0365 	1700/5	1995	C	T {1/3/2200 W 50/1400} II

Specimen Number (1)	Cross Section (2)	Cycle (3)	Number of Cycles (4)	Type of Failure (5)	Remarks (6)
N-155 Alloy (wrought) (cont)					
19	.0395 	1600/5	5153	C	T {1/3/2200 W 50/1400} II
20	.0465 	1700/5	2320	C	T {1/3/2200 W 50/1400} II
21	.0433 	1600/5	3530	C	T {1/3/2200 W 50/1400} II
22	.045 	1600/5	7000	C	T {1/3/2200 W 50/1400} II
23	.047 	1600/5	6728	C	T {1/3/2200 W 50/1400} II

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3 9015 02514 8332