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COMPARATIVE TENSILE AND FATIGUE PROPERTIES AT ROOM TEMPERATURE AND AT -423°F OF SOME WELDED CENTAUR TANK JOINT CONFIGURATIONS

under NAS 3-3232

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INTRODUCTION

In support of the Centaur Lightweight Tank Development Program, a program of testing of ten welded stainless steel joint design configurations was carried out to evaluate comparative fatigue behaviour and load bearing capacity of each joint configuration at room temperatures and at -423°F. (boiling liquid hydrogen). The test program was planned and carried out to isolate various parameters by comparing equivalent joint configurations while allowing independent variation of alloy composition (301 and 310 stainless), skin gage (.010 and .016), with and without nickel enriched spot welds, and variation of spot weld patterns (3 row and 2 row staggered, 2 row tandem). The experimental results of all tests run are presented graphically and in tabular form in Figures 1 through 17 (S-logN curves), and in Tables I through X.

EXPERIMENTAL

Materials. All welded joint specimens used in this program were fabricated from a single heat and coil of each of the three gage and alloy combinations evaluated (.016-301XFH, .010-301XFH, and .016-310XFH). The chemistry of these three heats and coils is listed in Table XI. Base material tensile properties were determined by tensile coupons taken from areas immediately adjacent to the skin panels at intervals not exceeding 18 inches throughout each coil as joint specimens were prepared. Center splice doublers in butt-welded joint specimens were taken from scrap material adjacent to skin panels where possible. All welding throughout the program was performed by Department 759 using certified welding schedules.

Appreciable differences in metallurgical behaviour was noted during the course of testing between the .016-301XFH (Ht-13562) and the .010-301XFH

(Ht J62879) at cryogenic temperature. Base material tensile coupons of the .016-301 XFH tested at $-423^{o}F$ typically failed by ductile fracture after considerable slip deformation extending over the entire gage length of the specimen, giving typical elongations of up to 15% in the longitudinal direction. The .010-301 XFH on the other hand failed typically by brittle shear type fracture with little or no plastic deformation apparent. Elongations were 0 - 1.5% in the longitudinal direction. Although the .010 gage material behaviour can be ascribed to a high sensitivity at $-423^{o}F$ to any notch-like edge imperfections that may have been present in the tensile coupons tested, the exact cause of this higher notch sensitivity in the .010 gage than the .016 gage material is obscure. It must be concluded, however, that this brittle behaviour at $-423^{o}F$ probably has introduced some bias into the fatigue results obtained from specimens fabricated from the .010 gage 301 XFH material which could be seriously misleading if not taken into account when comparing fatigue characteristics.

Configurations of tank joints tested were selected by the Centaur Stress Group and are illustrated by reductions of the original drawings included in the Appendix. A list of the ten joints tested with a brief description of configuration and material is included as Table XII for brief summary.

Test Procedures

Static and fatigue cycling tests were conducted per Materials Test Laboratory Standard Test Procedure ML-563-1-62-103. Fatigue rate was 6 cycles per minute; static strain rate was 0.001 in/in/min.

Fatigue and static tests were conducted on horizontal, hydraulic powered rams with an effective area of 10.1 sq. in. each. Cyclic and static loads were controlled and recorded by an electro-hydraulic console.

Tests conducted at -423°F utilized liquid hydrogen as the environment. This was accomplished by enclosing the test section of the specimen in a vacuum jacketed cryostat. The specimen and cryostat were then placed in insulated tanks attached to the hydraulic rams. The tanks were then filled with liquid nitrogen and liquid hydrogen was introduced into the vacuum jacketed cryostat. A constant flow of liquid hydrogen was maintained during all applicable tests.

RESULTS AND DISCUSSION

In general, no appreciable difference was noted in the fatigue behaviour of the three row staggered, two row staggered and two row tandem butt-welded-spliced configurations either at room temperature or at -423°F. A trend of decreasing static tensile strengths was noted in going from three row staggered to two row staggered to two row tandem, as can be seen in Fig. 11. At room temperature, less decrease in static strength was noted. (Figure 11a).

In the matter of effect of gage variation from .016 to .010 in the 301 XFH, none of the tests revealed any noticeable variation in fatigue behaviour, either at room temperature or -423°F, in equivalent joint configurations except as the particular heat of .010-301 XFH used exhibits higher base tensile properties than the .016-301 XFH. (Figures 16, 16a, 17, 17a).

The most striking effect on both fatigue and static tensile behaviour was produced by the addition of .003 nickel foil between the skin and splice doubler prior to spot welding in the .010 gage 301 XFH specimens. A comparison of Figures 13 and 14 reveals a close similarity in the slope, shape, and displacement of the S-N curve with nickel enrichment of the 301 spot welds in one case (Fig. 13), and variation due to an increase of 14% in the nickel content of the base alloy in the second (Fig. 14). The implication is that for an .010 gage 301 XFH skin enriched by .003 nickel foil inserts, enough nickel is diffused to the base material immediately adjacent to the weld nugget to achieve something close to type 310 CRES behaviour in fatigue at -423°F.

An interesting side product of this series of tests is the convergence of the S-N curves exhibited in Figure 13. This convergence and intersection at approximately 150 KSI-1000 cycles reveals a fatigue characteristic of nickel enriched welded joints not hitherto observed; namely, that over the stress level of particular interest in the Centaur tank design, addition of nickel foil in the joint is of no particular advantage since a joint either with or without nickel would be expected to fail at about 1000 cycles if cycled from zero to 150 KSI. It must be emphasized, however, that behaviour exhibited by Figure 13 is based on comparatively limited data and considerably more testing would be needed to verify this statistically as a basis of design. Also, although fatigue behaviour at 150 KSI is not particularly enhanced on the basis of this particular heat of material, cross tension strength is considerably enhanced by nickel dilution, so both behaviours must be considered.

METALLOGRAPHIC EXAMINATION

As a quality control back-up, four specimens were selected at random from each configuration after testing and the outer row of spot welds on the failed side of the joint macro-sectioned. Measurements of nugget diameters and percent penetration were made in each case and average values are presented in Table XIII.

CONCLUSIONS

The following conclusions can be stated:

A. Variation of number of rows of spot welds from three to two in the butt-welded joints appears to have no significant effect on fatigue behaviour over the ranges tested either at room temperature or at $-423^{\circ}F$, although some decrease in static tensile properties takes place.

B. No significant difference in fatigue behaviour was noted due to variation in gage of skin material for equivalent joint configurations.

C. Appreciable improvement in high stress level fatigue behaviour and static tensile properties is obtained by nickel enrichment of spot welds in 301 butt-welded configurations. Low stress level fatigue behaviour (0-150 KSI) is not particularly enhanced by nickel enrichment.

TABLE I

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0086-803

STATIC

SPECIMEN	Temp. (°F)	F_{tu} (KSI)	% F_{tu} of Base Material
E1-86-803-301-S-RT-1	R.T.	200	92.1
E1-86-803-301-F1-423-2(S-RT)	R.T.	200	92.1
E1-86-803-301-S-423-1	-423	195	63.6
E1-86-803-301-S-423-2	-423	186	60.6

FATIGUE

SPECIMEN	Temp. (°F)	σ_{max} (KSI) (R = 0)	% F_{tu} of Base Mat'l	Cycles to Fail
EI-86-803-301-F1-RT-1	R.T.	180	83.0	51
E1-86-803-301-F2-RT-1	R.T.	180	83.0	88
F1-86-803-301-F-423-1	-423	180	58.8	15
E1-86-803-301-F1-423-1	-423	180	58.7	4
F1-86-803-301-F2-423-1	-423	150	49.0	90
F1-86-803-301-F2-423-2	-423	150	49.0	234
F1-86-803-301-F-423-2	-423	135	44.2	172

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI) R.T.	F_{tu} (KSI) -423°F
E1	Transverse	217.4	307.1
F1	Transverse	217.3	305.8

TABLE II

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0086-805

STATIC

SPECIMEN	Temp. (°F.)	F_{tu} (KSI)	% F_{tu} of Base Material
1-86-805-310-S-RT-1	R.T.	176	94.6
2-86-805-310-X1(S-RT)	R.T.	177	94.6
1-86-805-310-S-RT-2	R.T.	176	94.6
1-86-805-310-S-423-1	-423	266	92.7
2-86-805-310-X2(S-423)	-423	225	79.3

FATIGUE SPECIMEN	Temp. (°F.)	σ_{max} (KSI-R=0)	% F_{tu} of Base Material	Cycles to Failure
1-86-805-310-F2-RT-1	R.T.	145	78.0	169
1-86-805-310-F2-RT-2	R.T.	145	78.0	263
1-86-805-310-F1-RT-1	R.T.	160	86.0	95
1-86-805-310-F1-RT-2	R.T.	160	86.0	89
1-86-805-310-F1-423-1	-423	180	62.7	1009
1-86-805-310-F2-423-1	-423	180	62.7	1784

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI) R.T.	F_{tu} (KSI) -423°F
1	Longitudinal	186.4	286.8
2	Longitudinal	186.9	283.7

TABLE III

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0088-803

STATIC

SPECIMEN	Temp. (°F.)	F_{tu} (KSI)	% F_{tu} of Base Material
AC-88-803-301-X(S-RT)	R.T.	206	95.0
AB-88-803-301-S-RT-1	R.T.	204	95.8
AB-88-803-301-S-423-1	-423	213	71.5
AB-88-803-301-S-423-2	-423	207	69.5

FATIGUE

SPECIMEN	Temp. (°F.)	σ_{max} (KSI-R=0)	% F_{tu} of Base Material	Cycles to Failure
AB-88-803-301-F1-RT-1	R.T.	180	84.5	321
AB-88-803-301-F2-RT-1	R.T.	180	84.5	288
AB-88-803-301-F1-423-1	-423	180	60.4	18
AB-88-803-301-F1-423-2	-423	180	60.4	18
AB-88-803-301-F2-423-1	-423	150	50.3	252
AC-88-803-301-F2-423-2	-423	150	50.8	235
AC-88-803-301-F-423-1	-423	135	45.8	792
AC-88-803-301-F-423-2	-423	135	45.8	627

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI)	
		R.T.	-423°F
AB	Longitudinal	213.3	298.4
AC	Longitudinal	214.6	295.0

TABLE IV

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0088-805

STATIC

SPECIMEN	Temp.(°F)	F_{tu}(KSI)	%F_{tu} of Base Material
5-88-805-310-S-RT-1	R.T.	178	100.0
5-88-805-310-F2-RT-1(S-RT)	R.T.	162	90.6
5-88-805-310-S-423-1	-423	272	94.5

FATIGUE

SPECIMEN	Temp.(°F)	σ_{max} (KSI-R=0)	%F_{tu} of Base Material	Cycles to Failure
5-88-805-310-F1-RT-1	R.T.	145	81.0	216
5-88-805-310-F1-RT-2	R.T.	145	81.0	294
5-88-805-310-S-RT-2(F-RT)	R.T.	160	89.3	105
5-88-805-310-F2-RT-2	R.T.	160	89.3	88
5-88-805-310-F1-423-1	-423	180	62.5	2122
6-88-805-310-F2-423-1	-423	180	65.0	1949
6-88-805-310-X1(F-423)	-423	200	72.3	942
6-88-805-310-X2(F-423)	-423	200	72.3	1219

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu}(KSI) R.T.	F_{tu}(KSI) -423°F.
5	Longitudinal	178.9	288.0
6	Longitudinal	180.2	277.3

TABLE V

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0096-5

STATIC

SPECIMEN	Temp. (°F.)	F_{tu} (KSI)	% F_{tu} of Base Material
G-96-5-301-S-RT-1	R.T.	210	100
G-96-5-301-S-423-1	-423°F	237	76.8
G-96-5-301-S-423-2	-423°F	260	84.2

FATIGUE

SPECIMEN	Temp. (°F.)	σ_{max} (KSI-R=0)	% F_{tu} of Base Material	Cycles to Failure
G-96-5-301-F1-RT-1	R.T.	180	87.0	304
G-96-5-301-F2-RT-1	R.T.	180	87.0	269
G-96-5-301-F1-423-1	-423	180	58.3	208
G-96-5-301-F2-423-1	-423	180	58.3	250
G-96-5-301-F1-423-2	-423	150	48.6	524
G-96-5-301-F2-423-2	-423	150	48.6	1039

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI) R.T.	F_{tu} (KSI) -423°F.
G	Longitudinal	206.9	309.3

TABLE VI

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0096-801

STATIC

SPECIMEN	Temp. (°F.)	F_{tu}(KSI)	% F_{tu} of Base Material
4-96-801-301-S-RT-1	R.T.	197	93.0
4-96-801-301-S-RT-2	R.T.	206	97.2
4-96-801-301-S-423-1	-423	302	100.0
4-96-801-301-S-423-2	-423	307	100.0

FATIGUE

SPECIMEN	Temp.(°F)	σ_{max} (KSI-R=0)	% F_{tu} of Base Material	Cycles to Failure
AA-96-801-301-F1-RF-1	R.T.	180	85.0	363
AA-96-801-301-F-X1	-423	200	-	711
AA-96-801-301-F-X2	-423	200	-	442
AA-96-801-301-F1-423-1	-423	180	-	943
AA-96-801-301-F1-423-2	-423	180	-	798
AA-96-801-301-F-423-2	-423	150	-	1869

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu}(KSI)	
		R.T.	-423°F.
4	Longitudinal	212.1	289.8
AA	Longitudinal	211.9	Not available

TABLE VII

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0096-803

STATIC

SPECIMEN	Temp. (°F.)	F_{tu} (KSI)	% F_{tu} of Base Material
V1-96-803-301-S-RT-1	R.T.	197	91.2
W1-96-803-301-X1(S-RT)	R.T.	199	92.0
V1-96-803-301-S-423-1	-423	268	--
V1-96-803-301-S-423-2	-423	276	--

FATIGUE

SPECIMEN	Temp.(°F.)	σ_{max} (KSI-R=0)	% F_{tu} of Base Material	Cycles to Failure
V1-96-803-301-F2-RT-1	R.T.	180	83.4	232
V1-96-803-301-F1-RT-1	R.T.	180	83.4	271
V1-96-803-301-F2-423-1	-423	150	-	611
W1-96-803-301-F2-423-2	-423	150	-	888
V1-96-803-301-F1-423-1	-423	180	-	295
V1-96-803-301-F1-423-2	-423	180	-	280
W1-96-803-301-F-423-1	-423	200	-	81
W1-96-803-301-F-423-2	-423	200	-	96

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI) R.T.	F_{tu} (KSI) -423°F.
V1	Longitudinal	216.1	Not available
W1	Longitudinal	216.2	Not available

TABLE VIII

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0096-807

STATIC

SPECIMEN	Temp. (°F.)	F_{tu} (KSI)	% F_{tu} of Base Material
S-96-807-301-S-RT-1	R.T.	213	97.9
S-96-807-301-S-423-1	-423	224	74.5
S-96-807-301-S-423-2	-423	268	89.0
T-96-807-301-F-423-2(S-423)	-423	217	69.8

FATIGUE

SPECIMEN	Temp.(°F.)	σ_{max} (KSI-R=0)	% F_{tu} of Base Material	Cycles to Failure
S-96-807-301-F1-RT-1	R.T.	180	82.5	169
S-96-807-301-F2-RT-1	R.T.	180	82.5	190
S-96-807-301-F1-423-1	-423	180	59.8	28
S-96-807-301-F2-423-1	-423	180	59.8	32
T-96-807-301-F1-423-2	-423	150	48.2	119
T-96-807-301-F2-423-2	-423	150	48.2	304
T-96-807-301-F-423-1	-423	130	41.8	957

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI) R.T.	F_{tu} (KSI) -423°F.
S	Longitudinal	217.6	300.9
T	Longitudinal	218.9	311.4

TABLE IX

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0096-811

STATIC

SPECIMEN	Temp. (°F.)	F_{tu} (KSI)	% F_{tu} of Base Material
AD-96-811-301-S-RT-1	R.T.	192	89.3
AE-96-811-301-X1(S-RT)	R.T.	198	92.0
AD-96-811-301-S-423-1	-423	253	--
AD-96-811-301-S-423-2	-423	254	--

FATIGUE

SPECIMEN	Temp. (°F.)	σ_{max} (KSI-R=0)	% F_{tu} of Base Material	Cycles to Failure
AD-96-811-301-F1-RT-1	R.T.	180	87.8	324
AD-96-811-301-F2-RT-1	R.T.	180	87.8	216
AE-96-811-301-F-423-1	-423	200	-	50
AE-96-811-301-F-423-2	-423	200	-	59
AD-96-811-301-F1-423-1	-423	180	-	129
AD-96-811-301-F1-423-2	-423	180	-	187
X-96-811-301-F1-423-2	-423	150	49.3	368
X-96-811-301-F2-423-2	-423	150	49.3	749

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI) R.T.	F_{tu} (KSI) -423°F.
AD	Longitudinal	205.6	Not available
AE	Longitudinal	215.4	Not available
X	Longitudinal	208.6	304.6

TABLE X

TENSILE AND FATIGUE DATA, JOINT CONFIGURATION VS-0096-815

STATIC

SPECIMEN	Temp. (°F.)	F_{tu} (KSI)	% F_{tu} of Base Material
T-96-815-301-S-RT-1	R.T.	213	97.3
T-96-815-301-S-423-1	-423	240	77.2
T-96-815-301-S-423-2	-423	225	72.3

FATIGUE

SPECIMEN	Temp. (°F.)	σ_{max} (KSI - R=0)	% F_{tu} of Base Material	Cycles to Failure
T-96-815-301-F1-RT-1	R.T.	180	82.3	351
U-96-815-301-F2-RT-1	R.T.	180	83.5	303
T-96-815-301-F1-423-1	-423	180	57.9	30
U-96-815-301-F2-423-1	-423	180	58.1	29
U-96-815-301-F1-423-2	-423	150	48.5	227
U-96-815-301-F2-423-2	-423	150	48.5	200
U-96-815-301-F-423-1	-423	135	43.6	536
U-96-815-301-F-423-2	-423	135	43.6	648

BASE MATERIAL TENSILE PROPERTIES

PANEL	DIRECTION	F_{tu} (KSI) R.T.	F_{tu} (KSI) -423°F.
T	Longitudinal	218.9	311.4
U	Longitudinal	215.8	309.6

TABLE XI

CHEMICAL ANALYSIS

	C	Mn	P	S	Si	Ni	Cr	N_2	Fe
.016-301 XFH Ht 13562, CL C-3	0.09	1.39	0.030	0.013	0.50	7.23	17.23	-	Bal.
.010-301 XFH Ht J62879, CL 19420	0.07	1.27	____	not reported	____	7.3	17.3	-	Bal.
.016-310 XFH Ht 99785, CL 10132-N65	.06	1.57	____	not reported	____	21.9	24.0	.048	Bal.

TABLE XII

LIST AND DESCRIPTION OF JOINT CONFIGURATIONS TESTED

	GD/A Dwg. No.	Dash No.	Joint Description	Skin Material
1.	VS-0086	803	Spot-Seam-Spot, Circumferential	.016-301 XFH w/o Nickel
2.	VS-0086	805	Spot-Seam-Spot, Circumferential	.016-310 XFH w/o Nickel
3.	VS-0088	803	2 Row Tandem, Longitudinal	.016-301 XFH w/o Nickel
4.	VS-0088	805	2 Row Tandem, Longitudinal	.016-310 XFH w/o Nickel
5.	VS-0096	5	3 Row Staggered, Longitudinal	.010-301 XFH w/o Nickel
6.	VS-0096	801	3 Row Staggered, Longitudinal	.010-301 XFH with Nickel
7.	VS-0096	803	3 Row Staggered, Longitudinal	.010-301 XFH w/o Nickel
8.	VS-0096	807	3 Row Staggered, Longitudinal	.016-301 XFH w/o Nickel
9.	VS-0096	811	2 Row Staggered, Longitudinal	.010-301 XFH w/o Nickel
10.	VS-0096	815	2 Row Staggered, Longitudinal	.016-301 XFH w/o Nickel

TABLE XIII

AVERAGE NUGGET DIAMETERS AND DEPTH OF PENETRATION

IN OUTER ROW SPOT WELDS

Joint Configuration	Skin Gage	Average Nugget Diameter	Average % Penetration
VS-0086-803	.016	0.093	57.7
VS-0086-805	.016	0.111	60.3
VS-0088-803	.016	0.097	55.5
VS-0088-805	.016	0.128	54.4
VS-0096-5	.010	0.085	58.7
VS-0096-801	.010	0.096	50.0
VS-0096-803	.010	0.071	27.2
VS-0096-807	.016	0.081	67.7
VS-0096-811	.010	0.067	38.0
VS-0096-815	.016	0.084	67.0

SEMI-LOGARITHMIC 359-96
KEUFFEL & ESSER CO.
7 CYCLES X 60 DIVISIONS

FIGURE 1

S-N Curves, VS-0086-803 **Joint Configuration**

.016-301 XFH, Spot-Seam-Spot, Circumferential, W/O Nickel

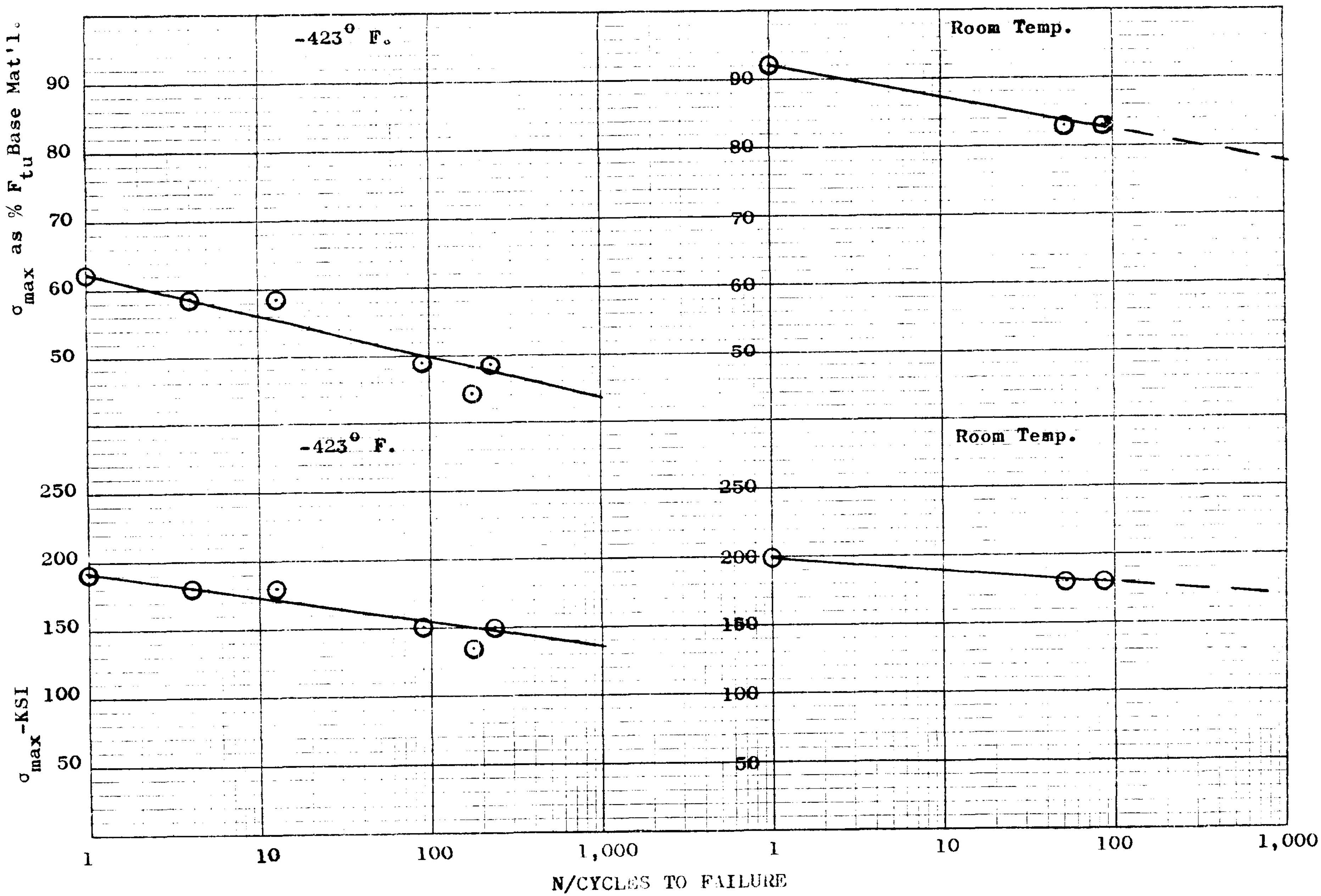
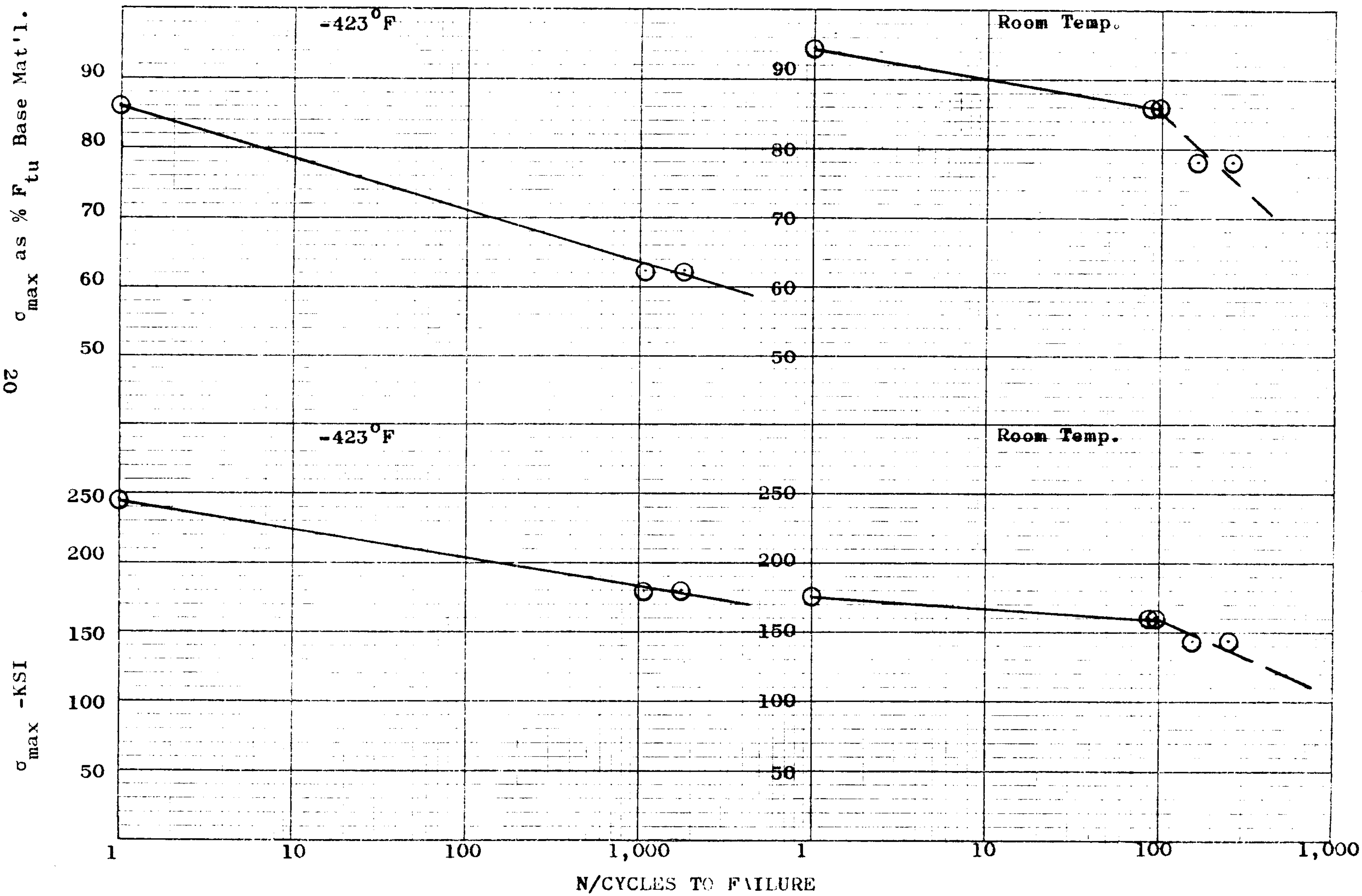


FIGURE 2

S-N Curves, VS-0086-805 **Joint Configuration**

.016-310 **XFH,** Spot-Seam-Spot, Circumferential, **W/O Nickel.**



SEMI-LOGARITHMIC 359-96
KEUFFEL & ESSER CO.
7 CYCLES X 60 DIVISIONS

FIGURE 3

S-N Curves, VS-0088-803 **Joint Configuration**

.016-301 XFH, 2 Row Tand., Longitudinal, W/O Nickel.

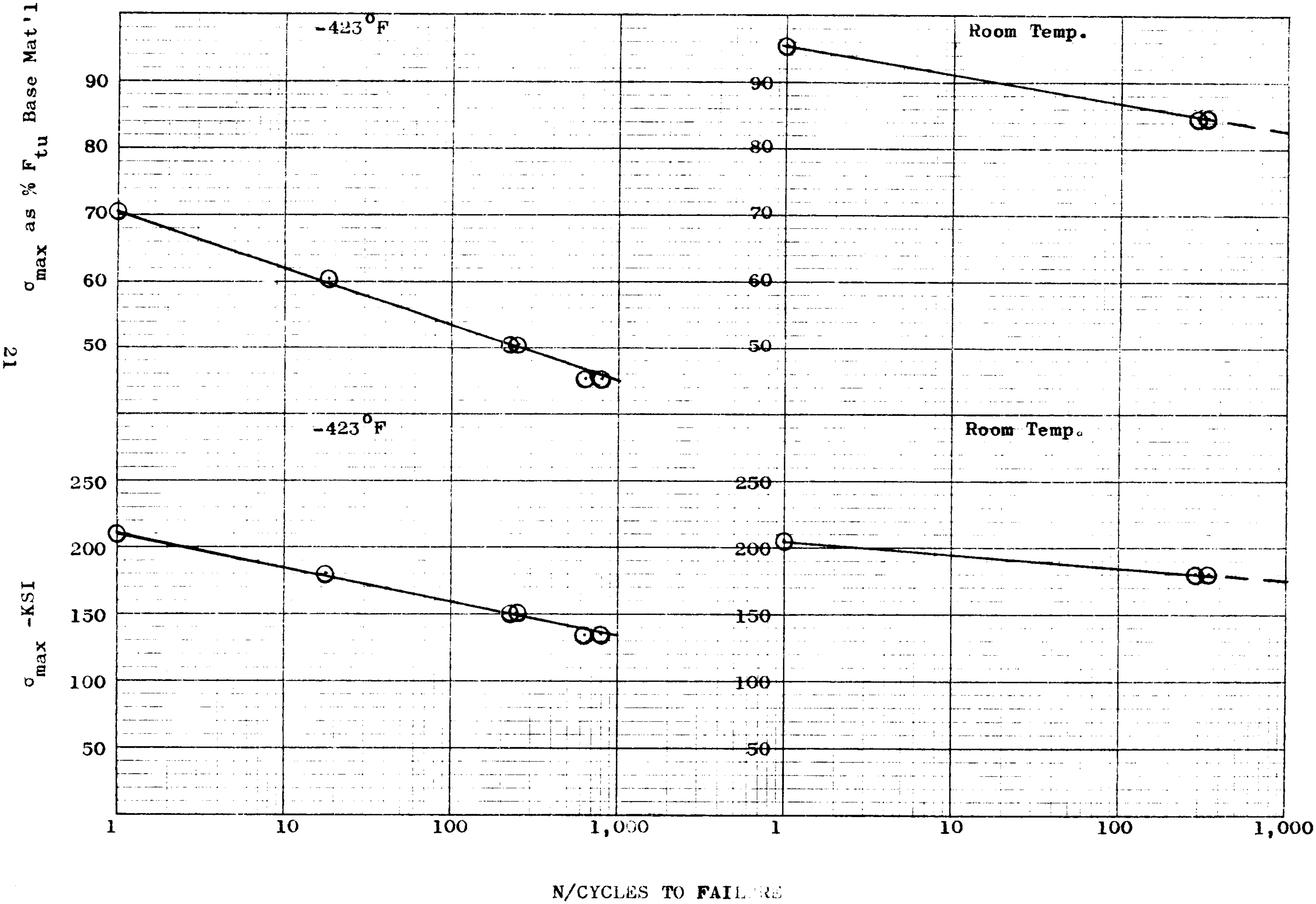


FIGURE 4

S-N Curves, VS-0088-805 Joint Configuration

.016-310 XFH, 2 Row Tand., Longitudinal, W/O Nickel.

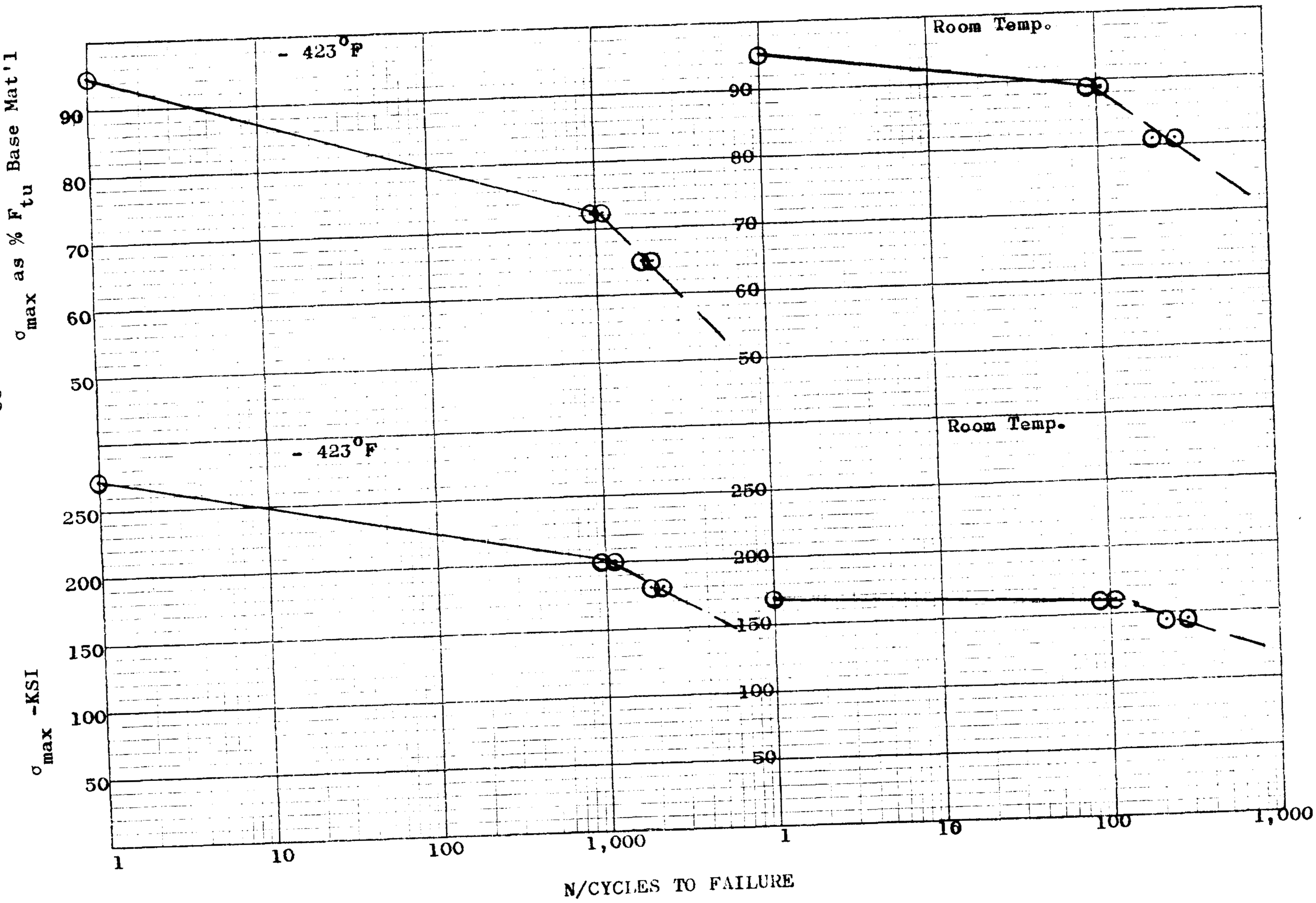
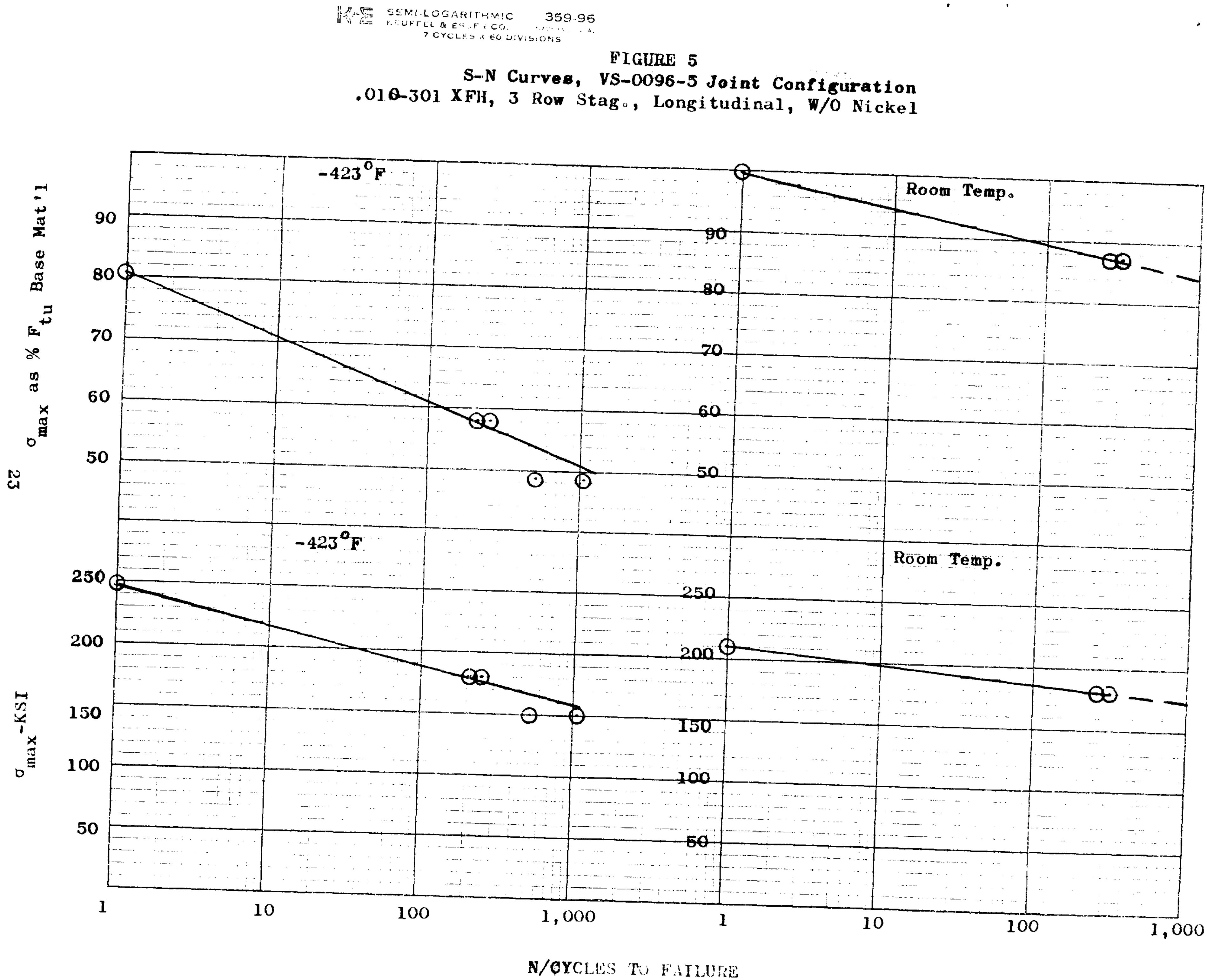


FIGURE 5

S-N Curves, VS-0096-5 Joint Configuration

.010-301 XFH, 3 Row Stag., Longitudinal, W/O Nickel



SEMI-LOGARITHMIC 359-96
KEUFFEL & ESSER CO.
7 CYCLES X 60 DIVISIONS

FIGURE 6
S-N Curves, VS-0096-801 Joint Configuration
.010-301 XFI , 3 Row Stag., Longitudinal, With Nickel

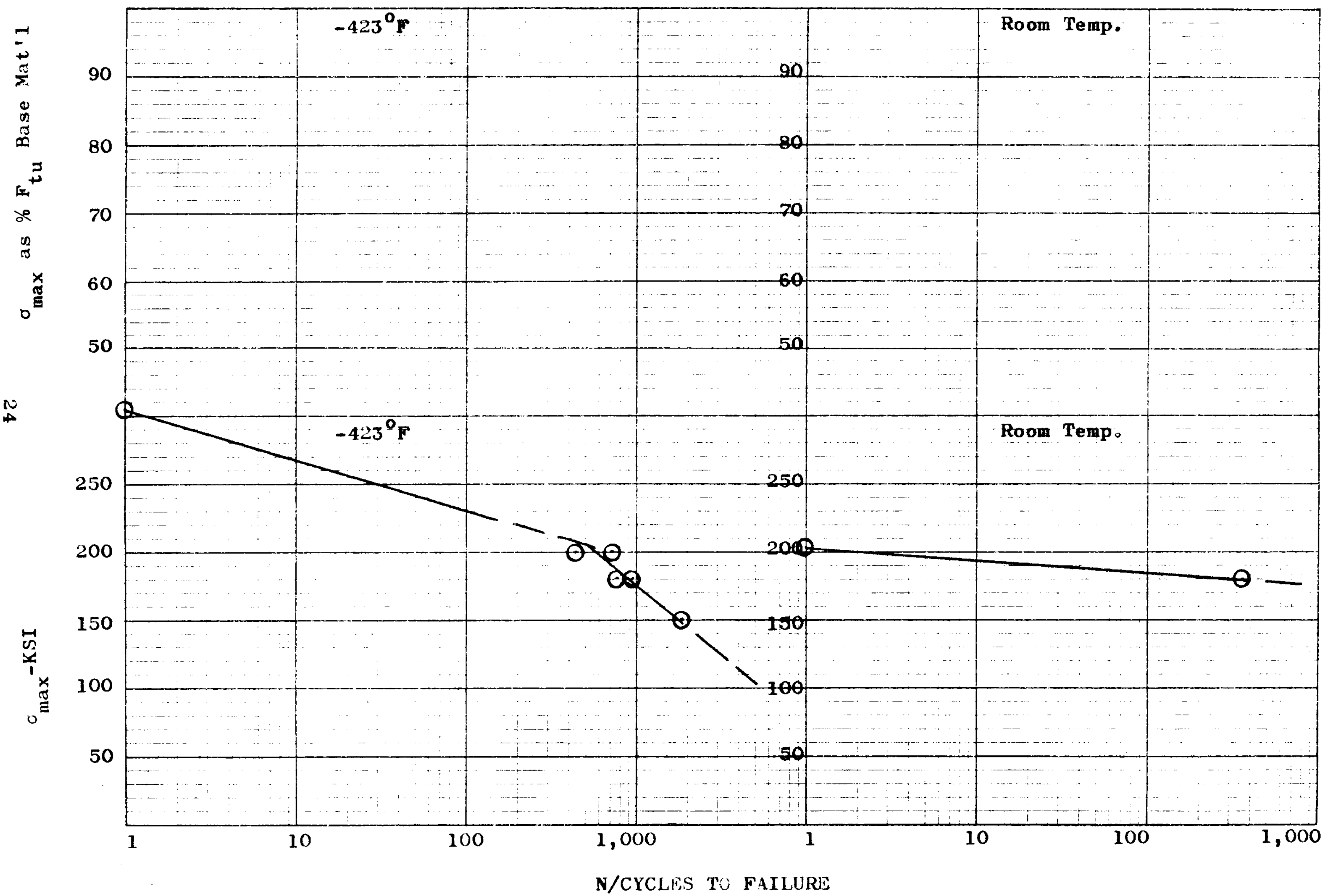
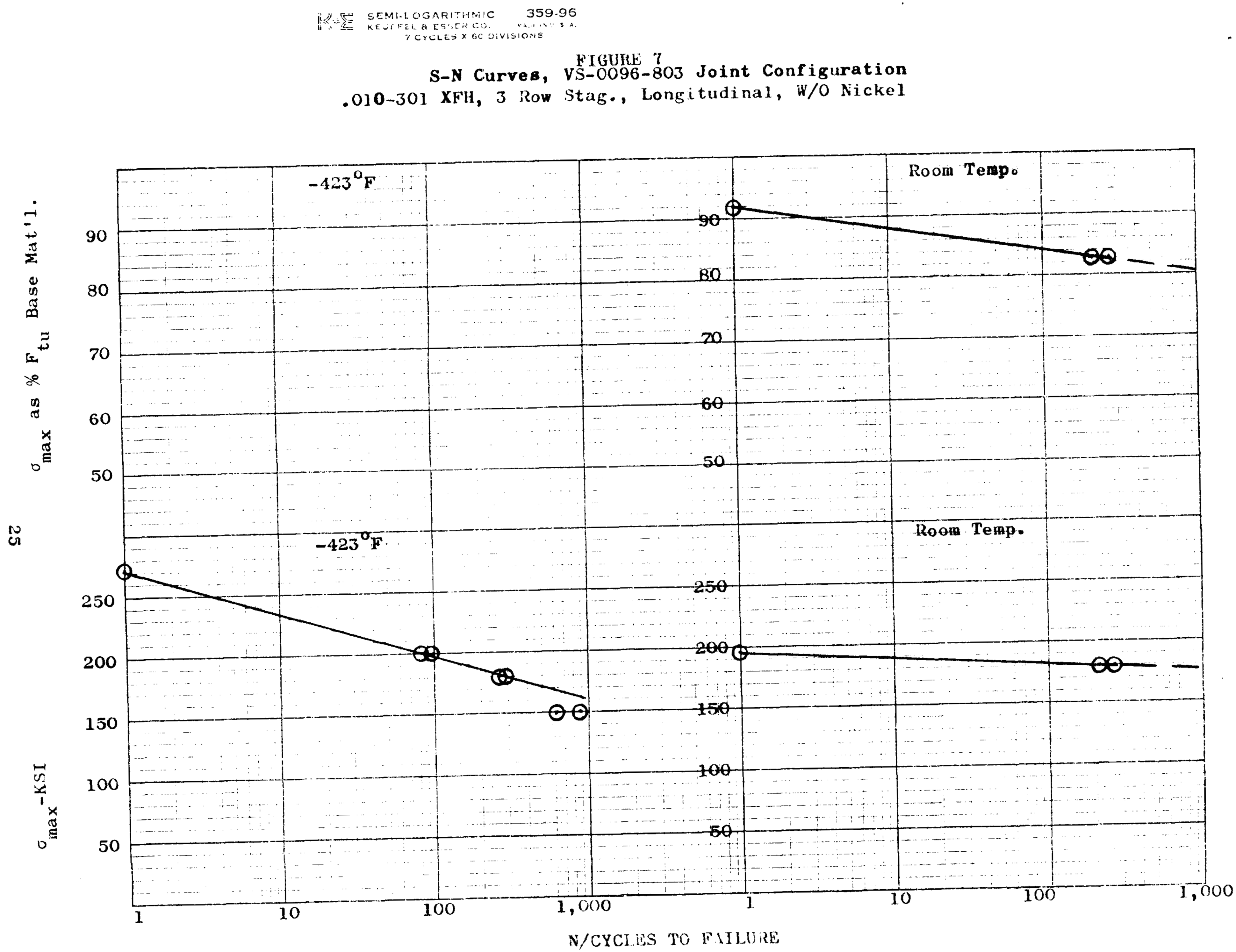


FIGURE 7

S-N Curves, VS-0096-803 **Joint Configuration**

.010-301 **XFH,** 3 Row Stag., Longitudinal, W/O Nickel



SEMI-LOGARITHMIC 359-96
KEUFFEL & ESSER CO.
7 CYCLES X 60 DIVISIONS

FIGURE 8
S-N Curves, VS-0096-807 **Joint Configuration**
.016-301 XFH, 3 Row Stag., Longitudinal, W/O Nickel

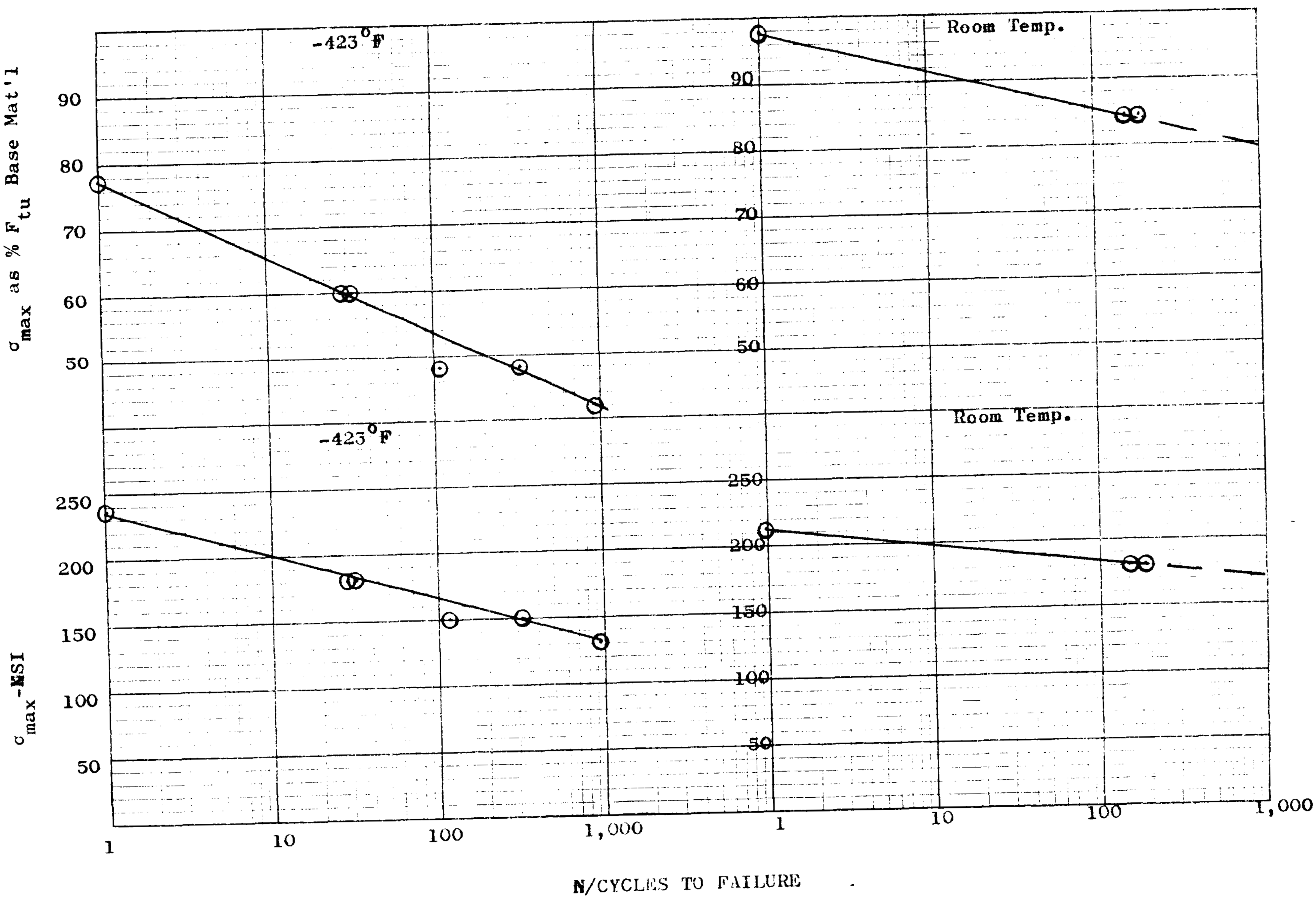


FIGURE 9

S-N Curves, VS-0096-811 **Joint Configuration**

.010-301 XFH, 2 Row Stag., Longitudinal, W/O Nickel

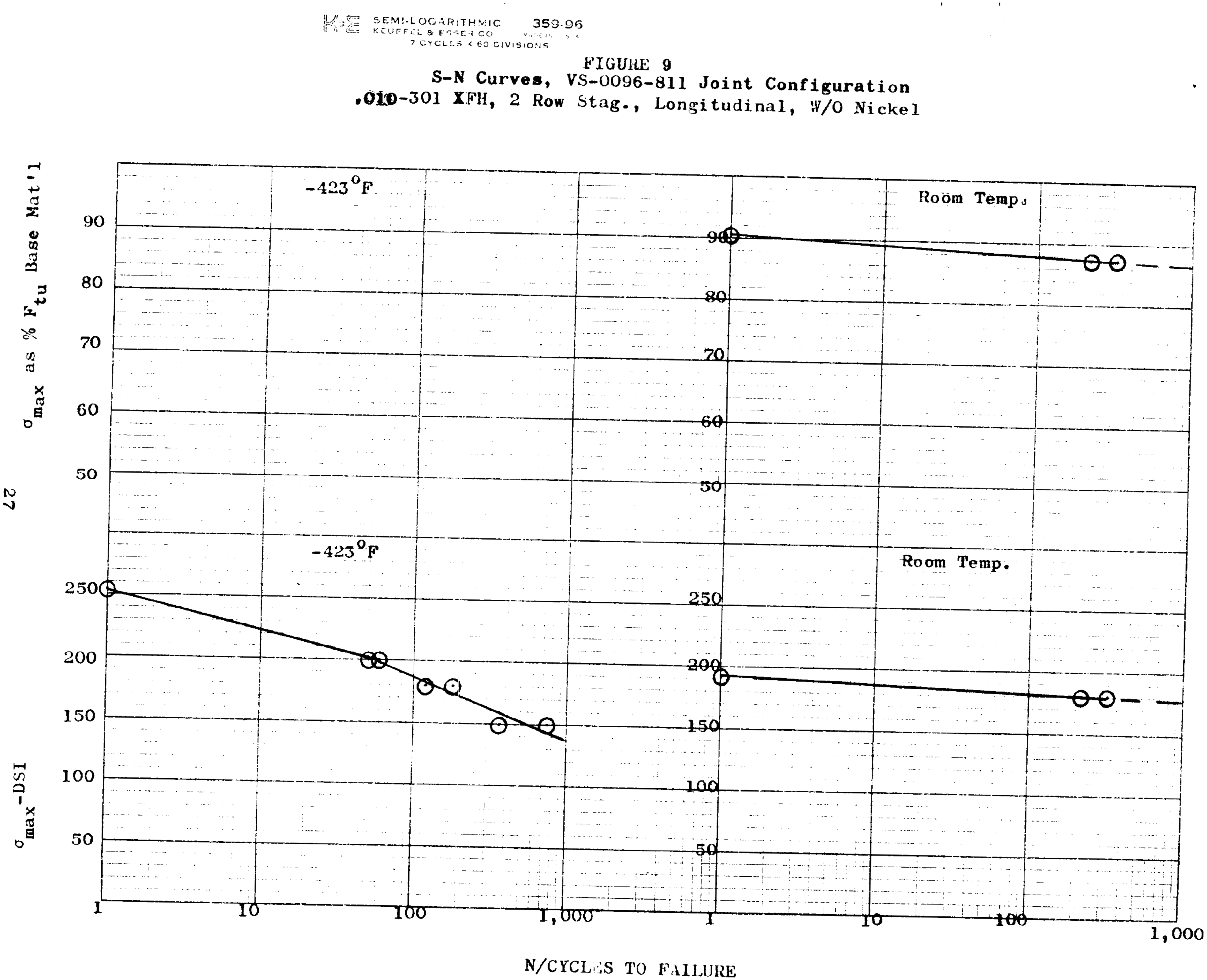


FIGURE 10

S-N Curves, VS-0096-815 Joint Configuration

.016-301 XFH, 2 Row Stag., Longitudinal, W/O Nickel

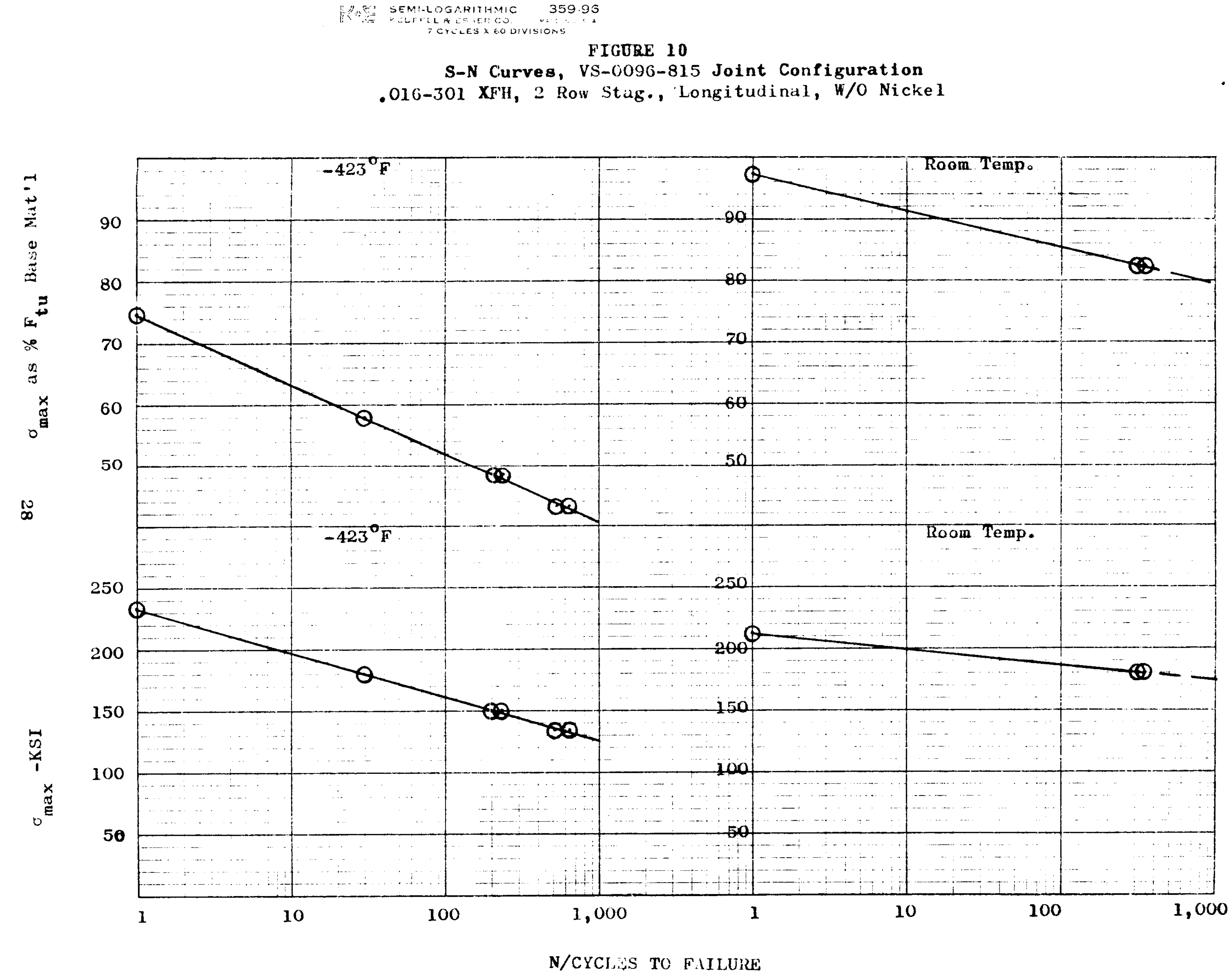


FIGURE 11

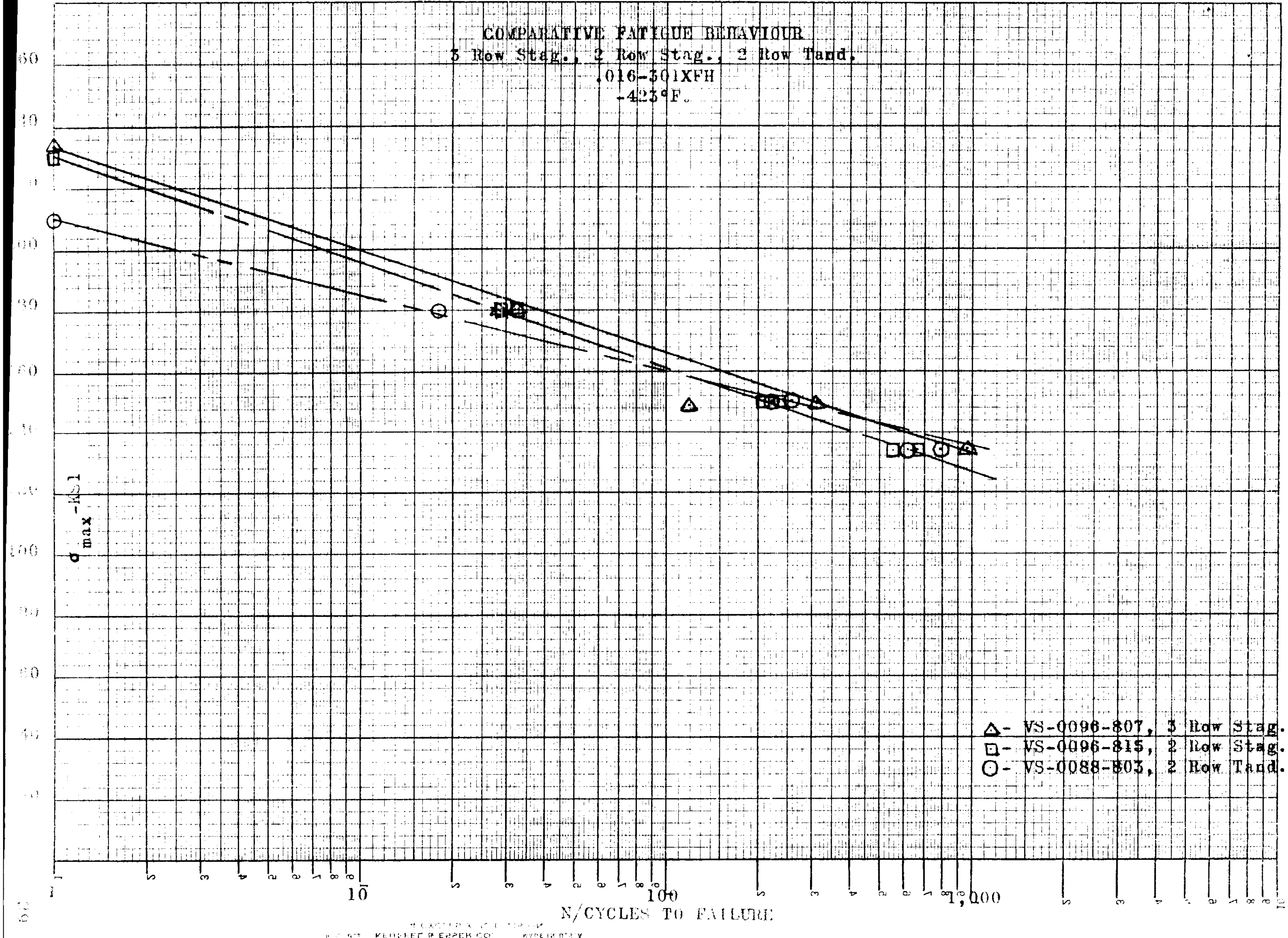

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., 2 Row Stag., 2 Row Tand.
.016-301XFH
-423°F.
σ max -KSI
N/CYCLES TO FAILURE
10
100
1,000
△- VS-0096-807, 3 Row Stag.
□- VS-0096-815, 2 Row Stag.
○- VS-0088-803, 2 Row Tand.
SEMI LOGARITHMIC 329-81
KEUFFEL & ESSER CO.

FIGURE 11a

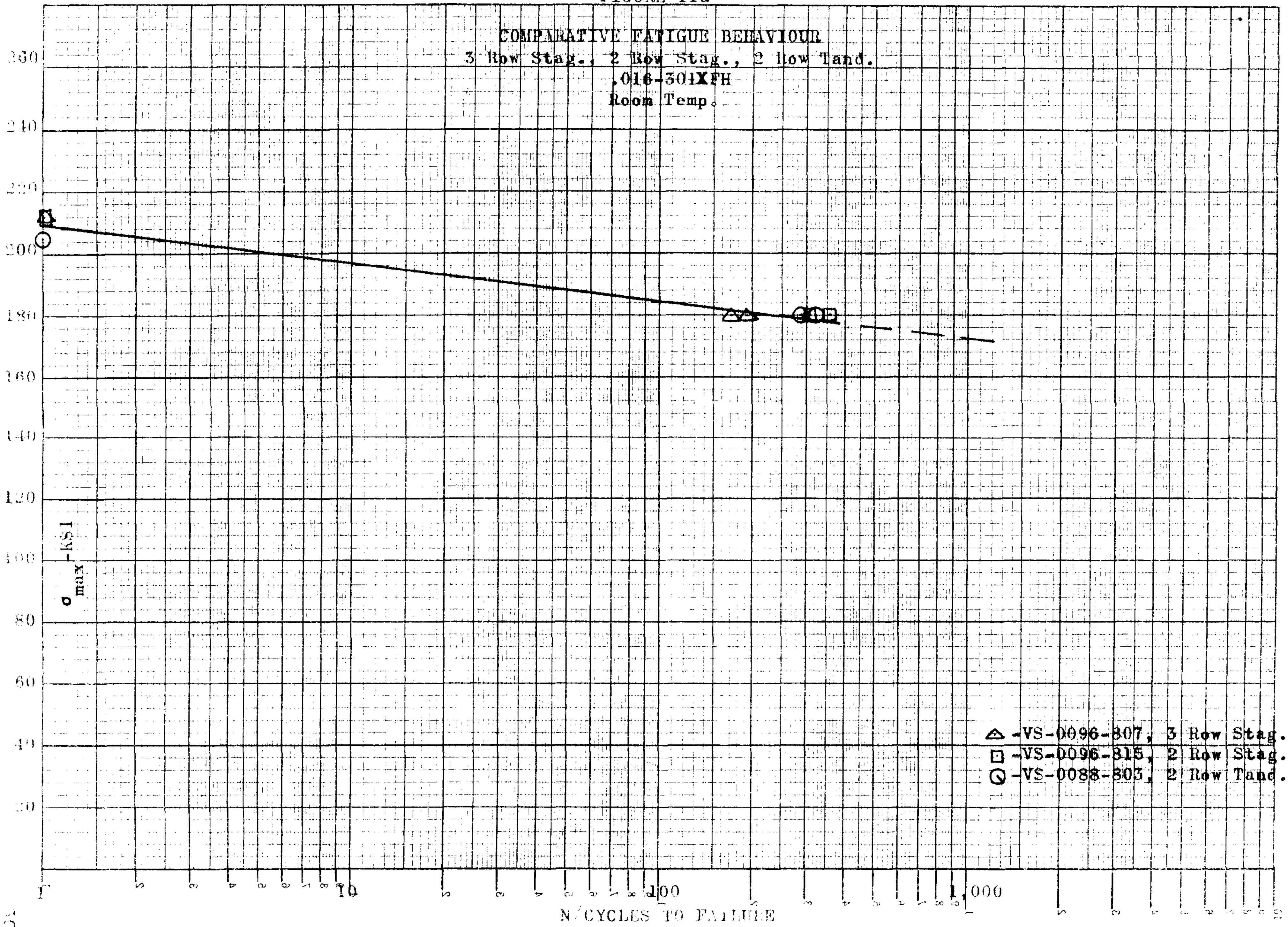

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., 2 Row Stag., 2 Row Tand.
.016-301XFH
Room Temp.
-VS-0096-807, 3 Row Stag.
-VS-0096-815, 2 Row Stag.
-VS-0088-803, 2 Row Tand.
σ max -KSI
N/CYCLES TO FAILURE
10
100
1,000
80
60
40

FIGURE 12

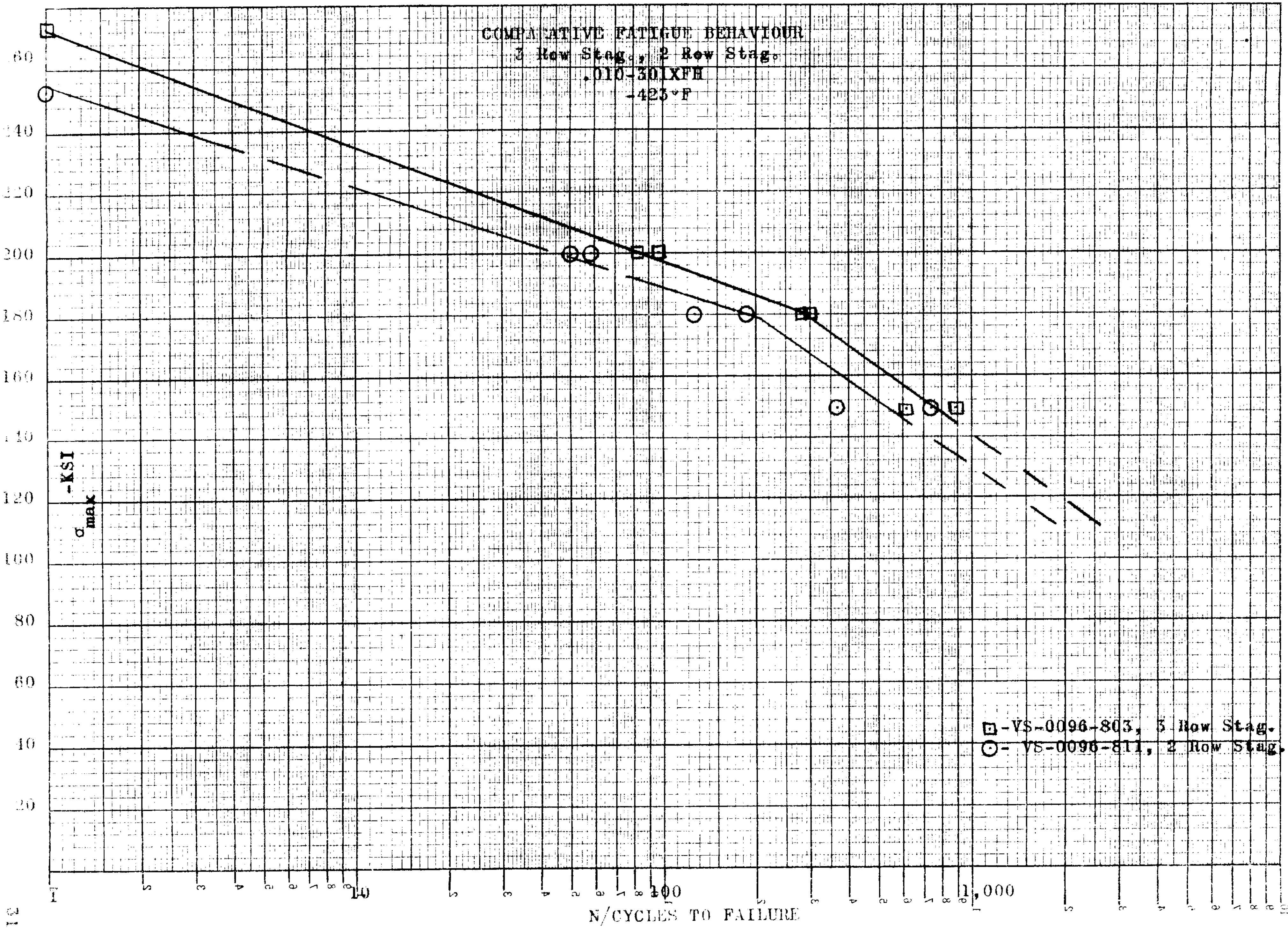

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., 2 Row Stag.
.010-301XFH
-423°F
□-VS-0096-803, 3 Row Stag.
⊙- VS-0096-811, 2 Row Stag.
σ_{max} -KSI
N/CYCLES TO FAILURE
1
10
100
1,000
160
140
120
200
180
160
140
120
100
80
60
40
20

FIGURE 12a

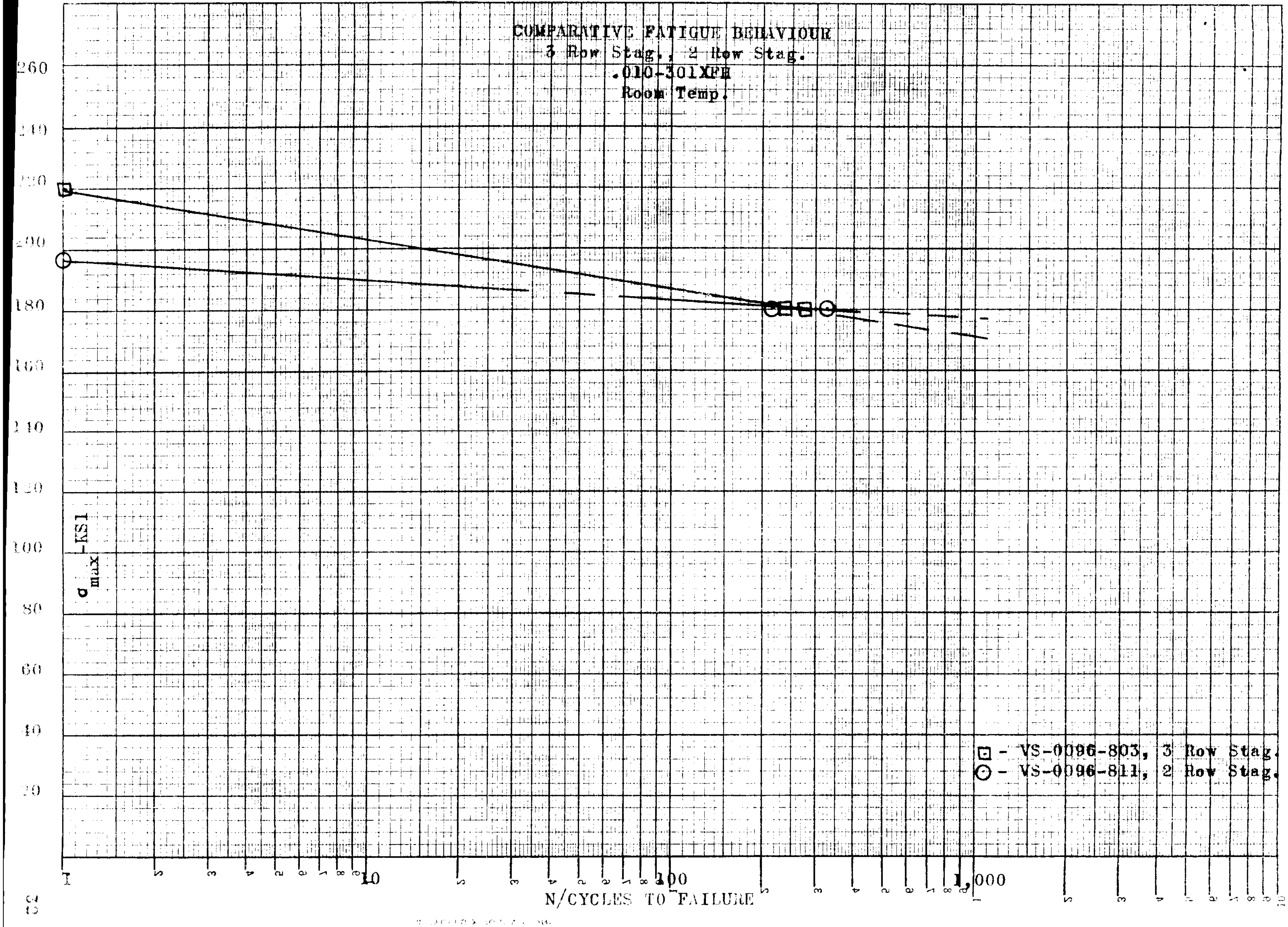

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., 2 Row Stag.
.010-301XFH
Room Temp.
260
240
220
200
180
160
140
120
100
80
60
40
20
σ_{max}-KSI
1
10
100
1,000
N/CYCLES TO FAILURE
□ - VS-0096-803, 3 Row Stag.
⊙ - VS-0096-811, 2 Row Stag.
SEMI-LOGARITHMIC 359 81

FIGURE 13

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., .010-501XFH, With & Without Nickel
-423°F.

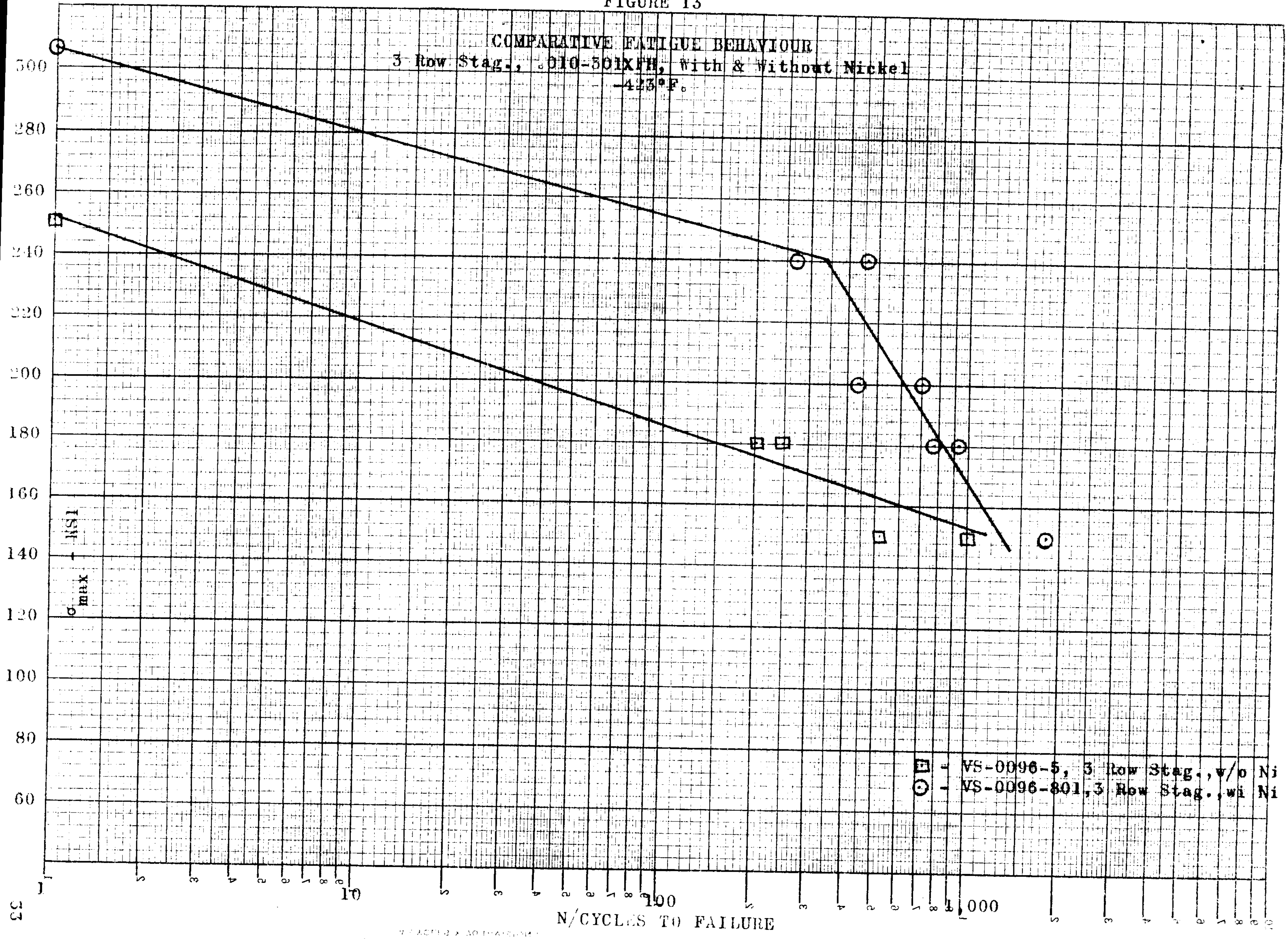


FIGURE 13a

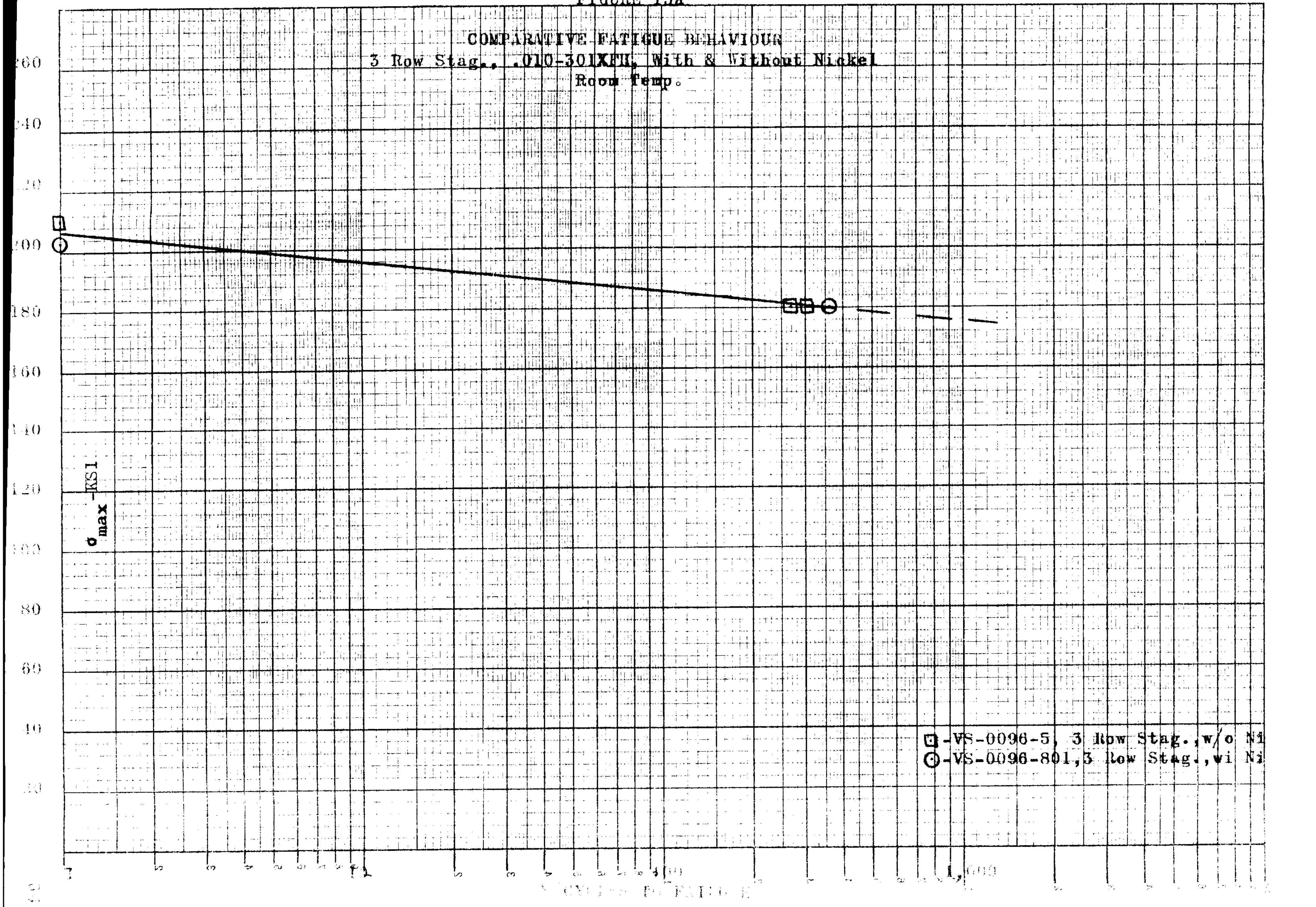
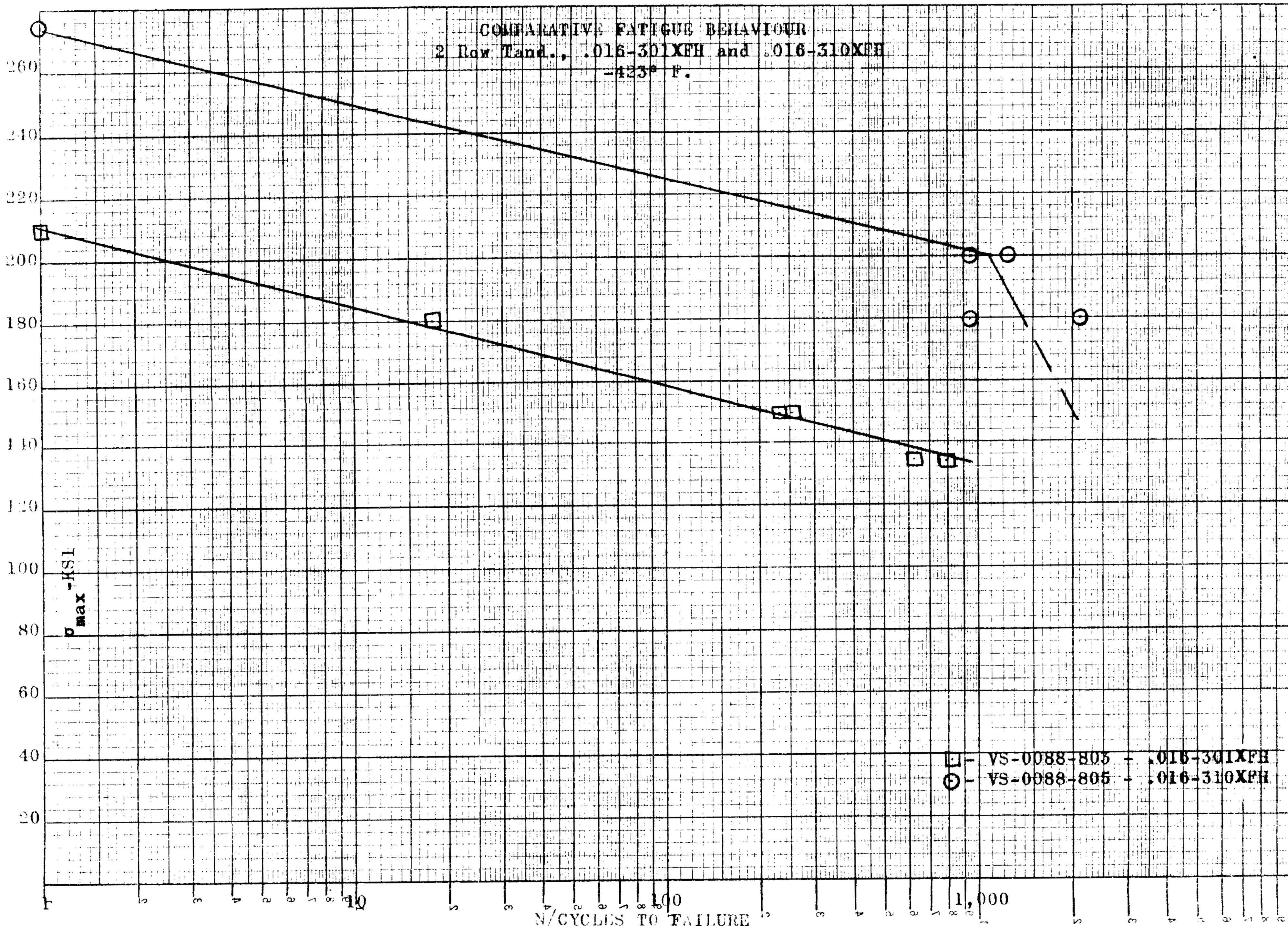

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., .010-301XFH, With & Without Nickel
Room Temp.
260
240
200
180
160
140
120
80
60
σ_{max}-KSI
100
1,000
-VS-0096-5, 3 Row Stag.,w/o Ni
-VS-0096-801,3 Row Stag.,wi Ni

FIGURE 14



COMPARATIVE FATIGUE BEHAVIOUR
2 Row Tand., .016-301XFH and .016-310XFH
-423° F.
σmax -KSI
260
240
220
200
180
160
140
120
100
80
60
40
20
1
10
100
1,000
N/CYCLES TO FAILURE
□ - VS-0088-803 - .016-301XFH
⊙ - VS-0088-805 - .016-310XFH

FIGURE 14a

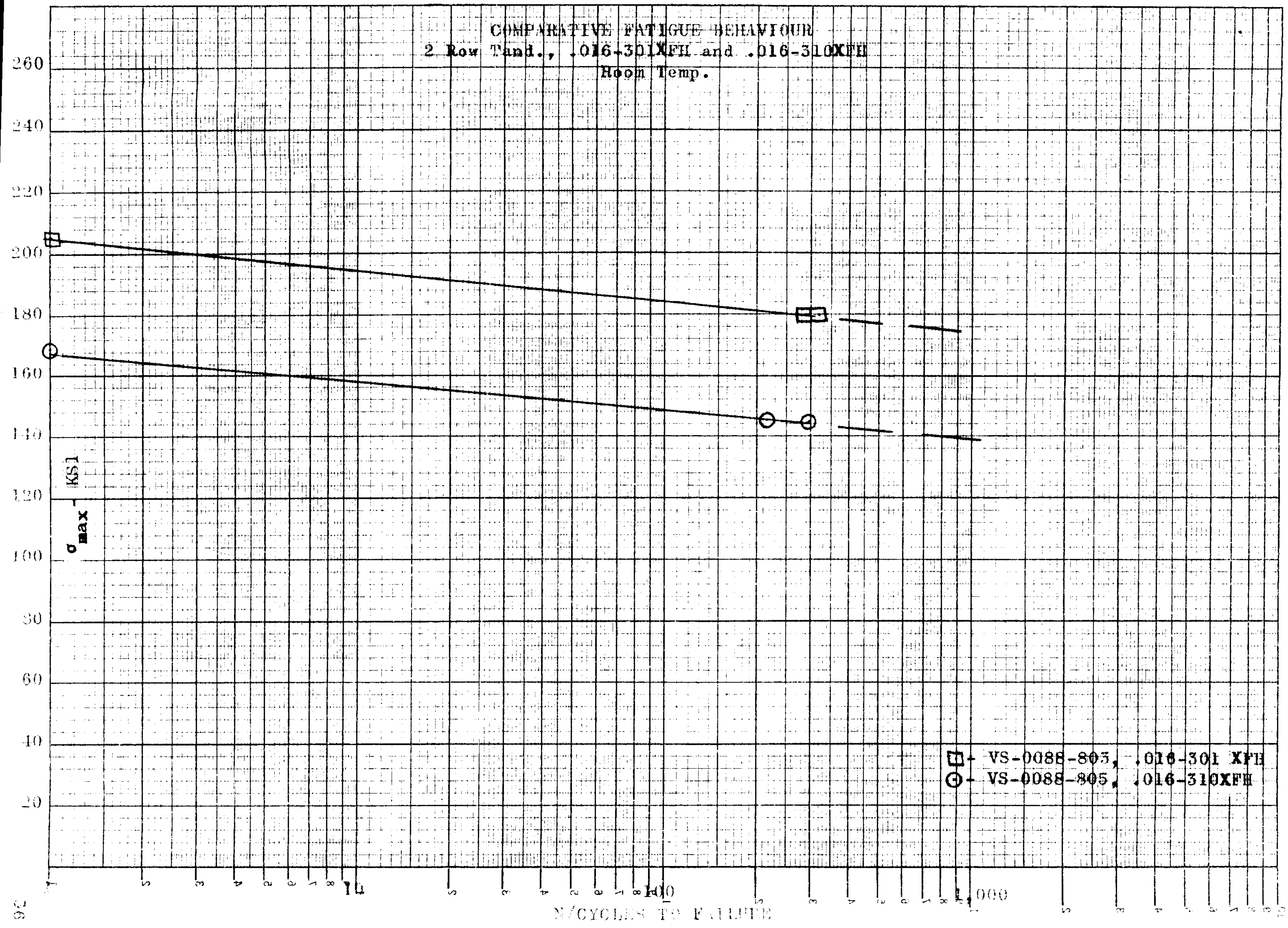

COMPARATIVE FATIGUE BEHAVIOUR
2 Row Tand., .016-301XFH and .016-310XFH
Room Temp.
260
240
220
200
180
160
140
120
100
80
60
40
20
σmax - KSI
1
10
100
1,000
N/CYCLES TO FAILURE
VS-0088-805, .016-301 XFH
VS-0088-805, .016-310XFH

FIGURE 15

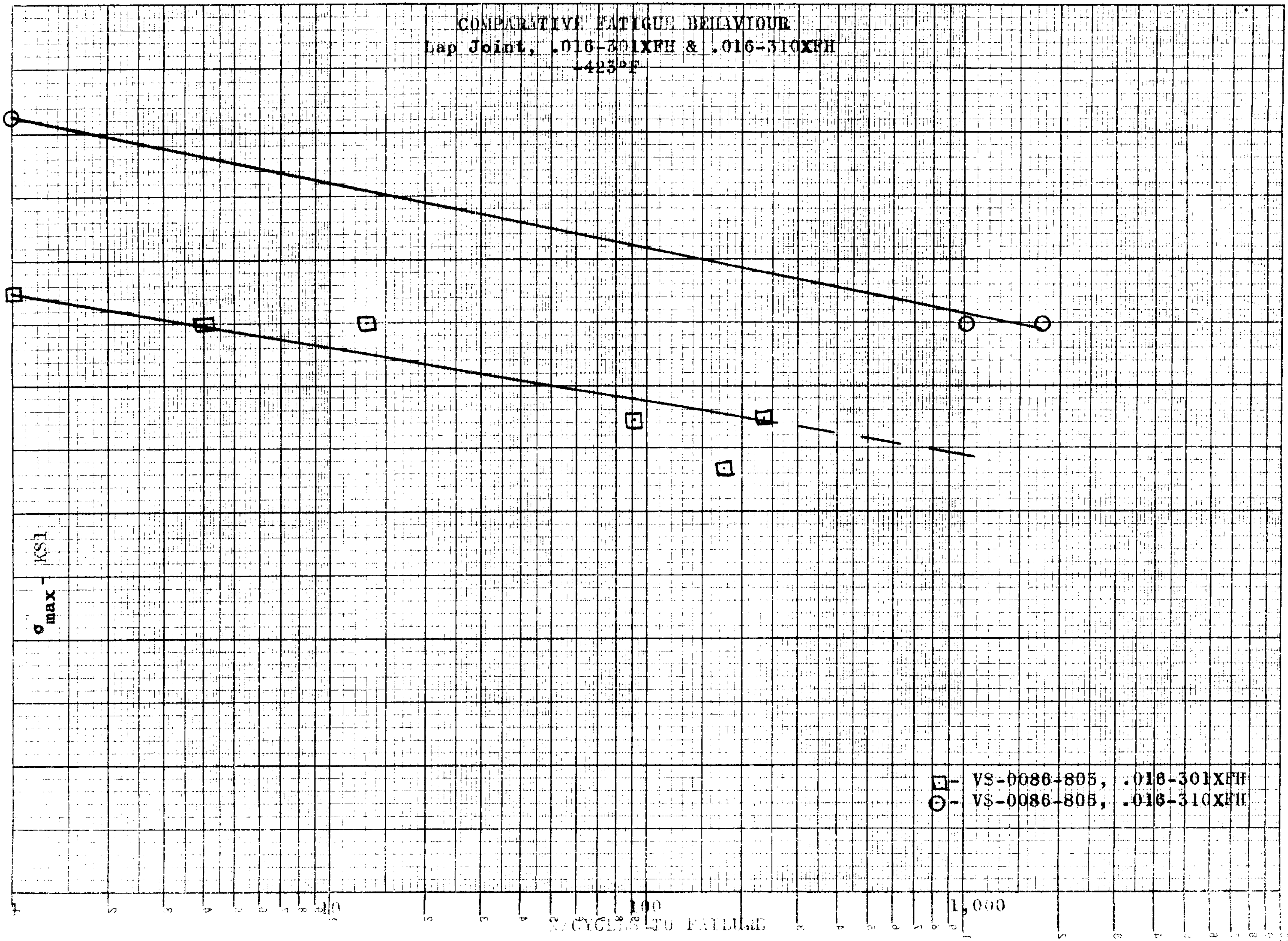

COMPARATIVE FATIGUE BEHAVIOUR
Lap Joint, .016-301XFH & .016-310XFH
-423°F
σ_{max} - KSI
240
220
200
180
160
140
120
100
80
60
40
20
10
100
1,000
N, CYCLES TO FAILURE
- VS-0086-805, .016-301XFH
- VS-0086-805, .016-310XFH

FIGURE 15a

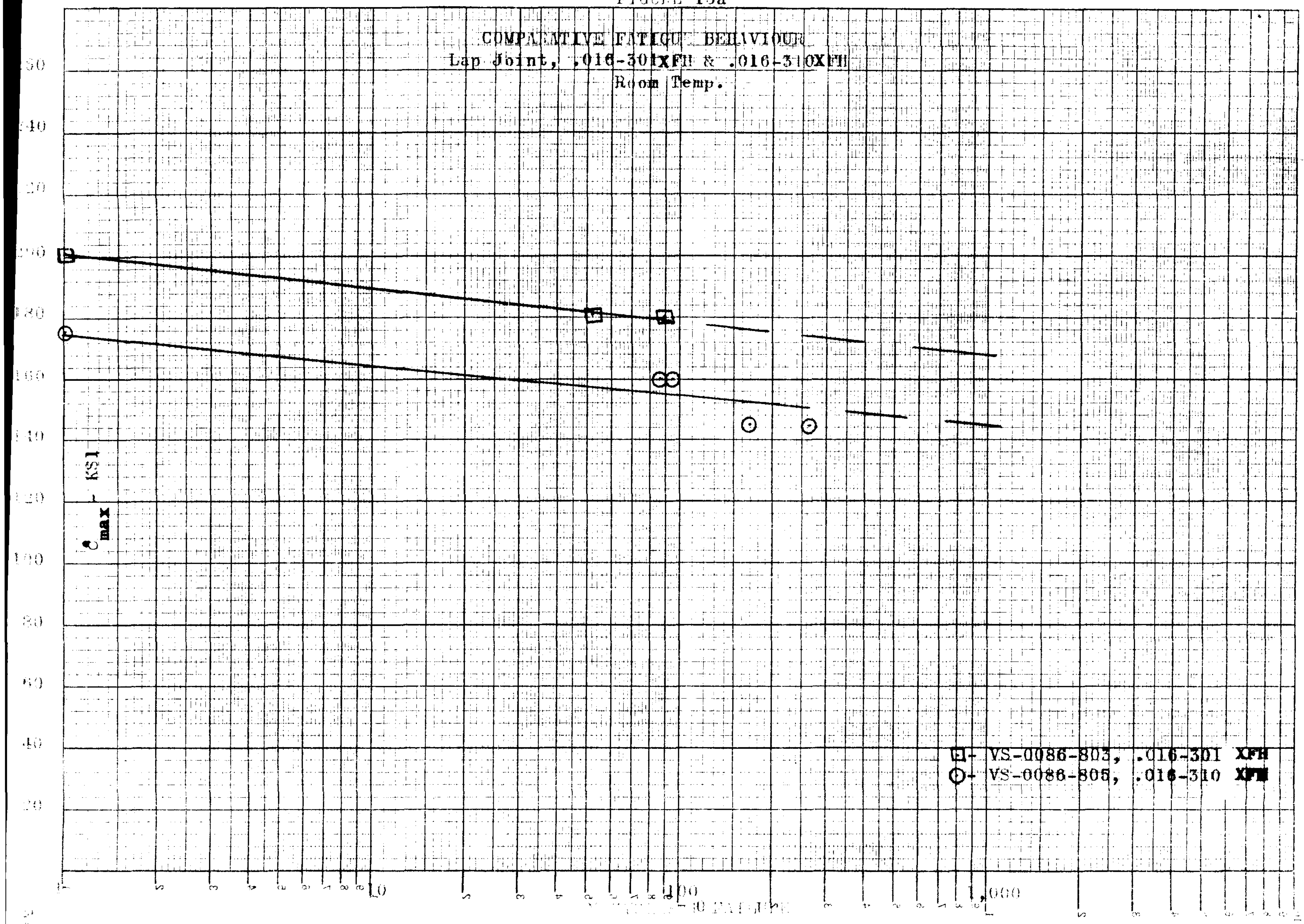

COMPARATIVE FATIGUE BEHAVIOUR
Lap Joint, .016-301XFH & .016-310XFH
Room Temp.
160
140
120
100
80
60
40
20
10
100
1,000
σ_{max} - KSI
□- VS-0086-803, .016-301 XFH
⊙- VS-0086-805, .016-310 XFH

FIGURE 16

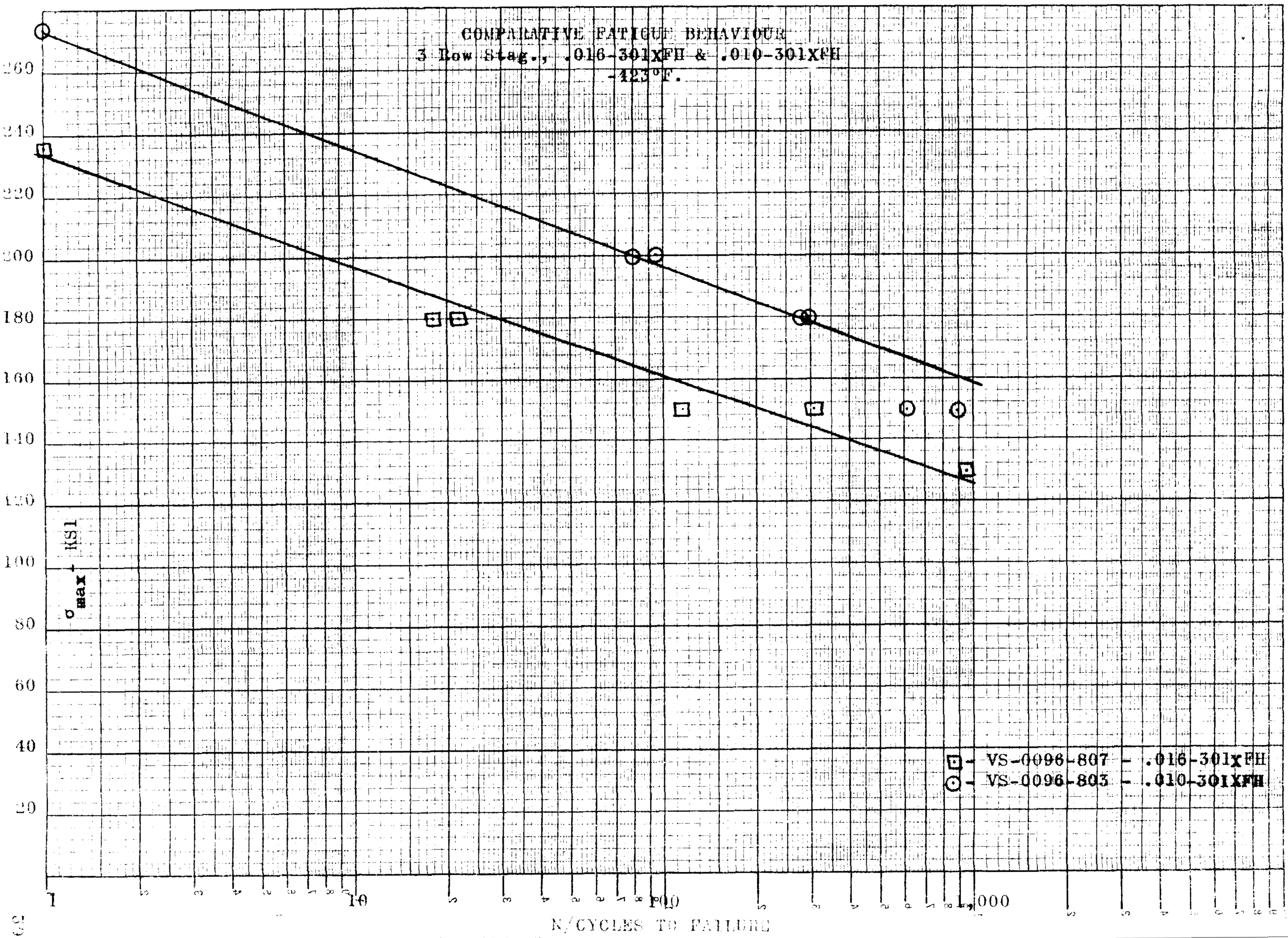

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., .016-301XFH & .010-301XFH
-423°F.
260
240
220
200
180
160
140
120
100
80
60
40
20
σmax - KSI
1
10
100
1,000
N/CYCLES TO FAILURE
- VS-0096-807 - .016-301XFH
- VS-0096-803 - .010-301XFH

FIGURE 16a

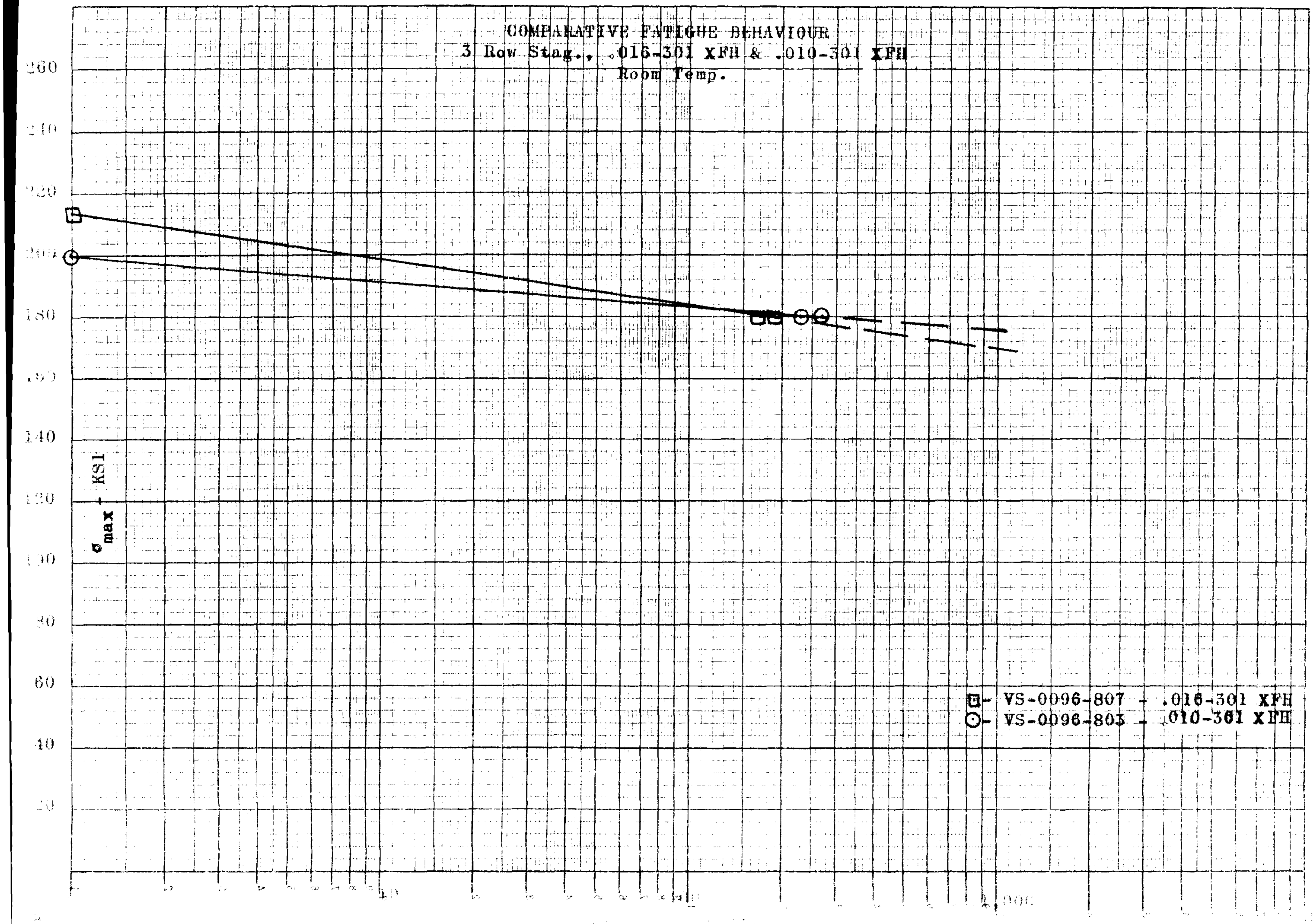

COMPARATIVE FATIGUE BEHAVIOUR
3 Row Stag., .016-301 XFH & .010-301 XFH
Room Temp.
260
240
220
200
180
160
140
120
100
80
60
40
20
σmax - KSI
10
100
1,000
□- VS-0096-807 - .016-301 XFH
⊙- VS-0096-803 - .010-301 XFH

FIGURE 17

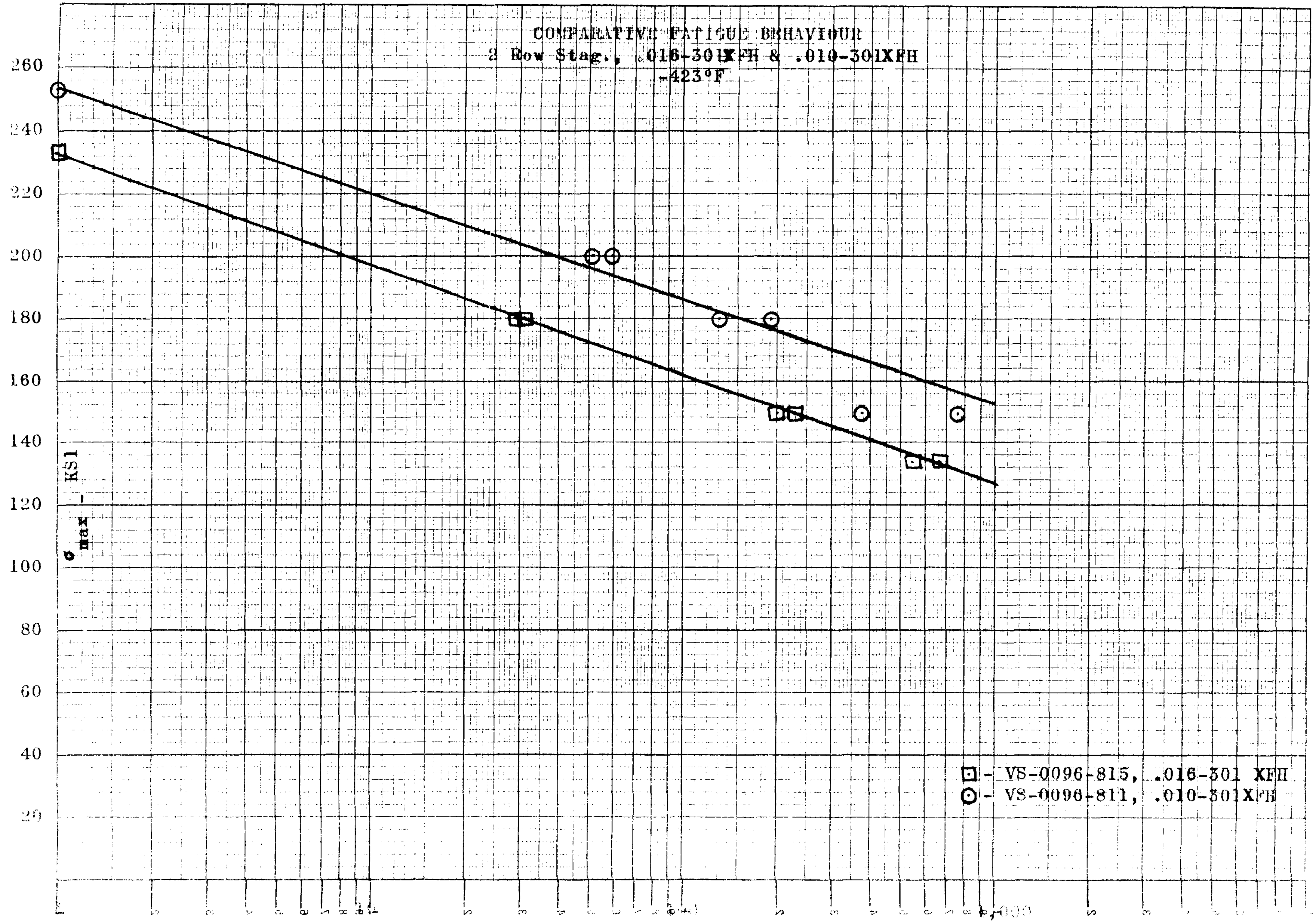
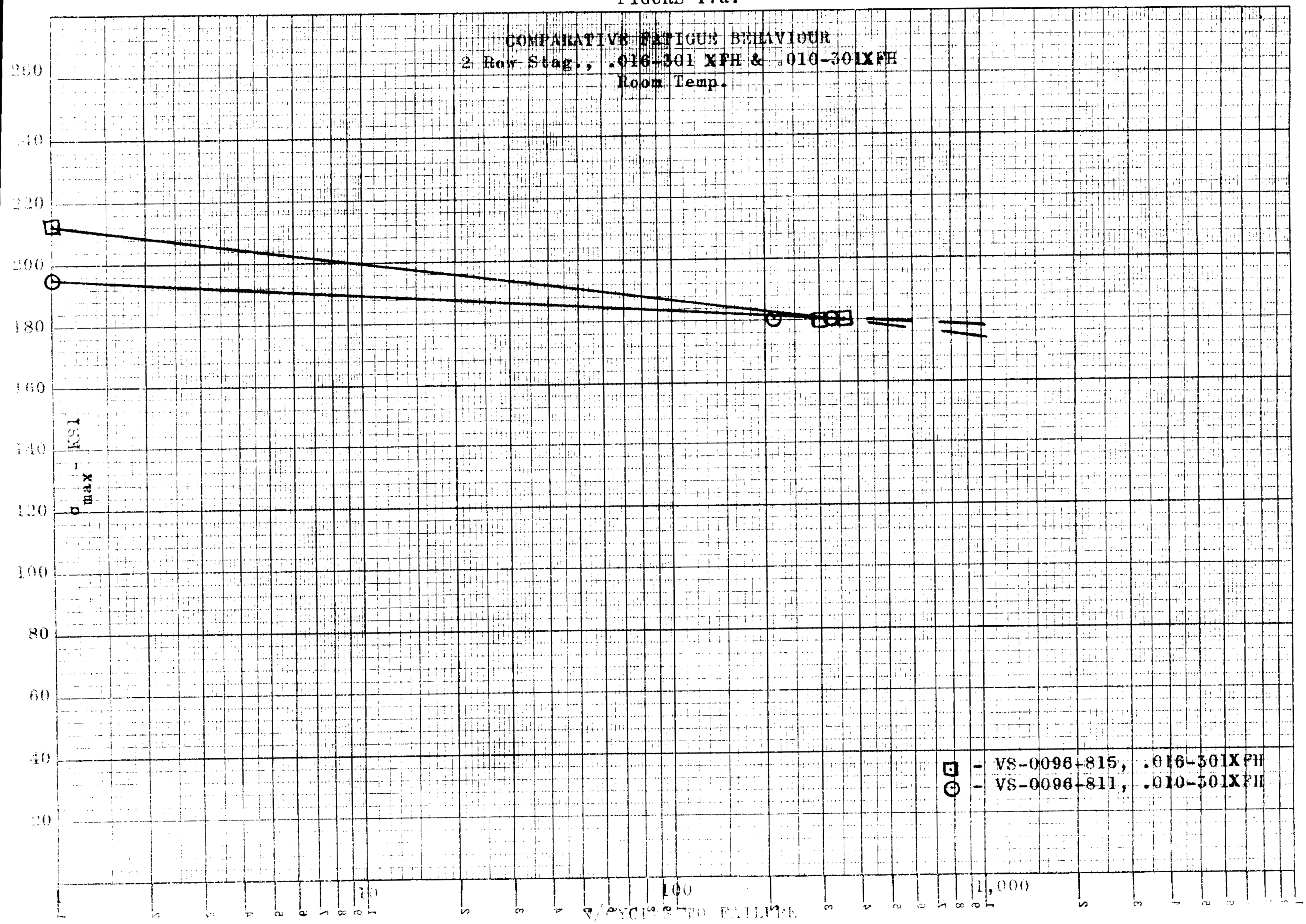

COMPARATIVE FATIGUE BEHAVIOUR
2 Row Stag., .016-301XFH & .010-301XFH
-423°F
260
240
220
200
180
160
140
120
100
80
60
40
20
σ max - KSI
□ - VS-0096-815, .016-301 XFH
⊙ - VS-0096-811, .010-301XFH

FIGURE 17a.


COMPARATIVE FATIGUE BEHAVIOUR
2 Row Stag., .016-301 XFH & .010-301XFH
Room Temp.
260
240
220
200
180
160
140
120
100
80
60
40
20
σ max - KSI
10
100
1,000
N/CYCLES TO FAILURE
- VS-0096-815, .016-301XFH
- VS-0096-811, .010-301XFH

APPENDIX

Joint Specimen Number Code

Drawing Number VS-0086

Drawing Number VS-0088

Drawing Number VS-0096

JOINT SPECIMEN NUMBER CODE:

A - 86 - 1 - 301 - S - RT - 1

Serial No. of Specimen

Room Temperature (or $-423^{\circ}F$)

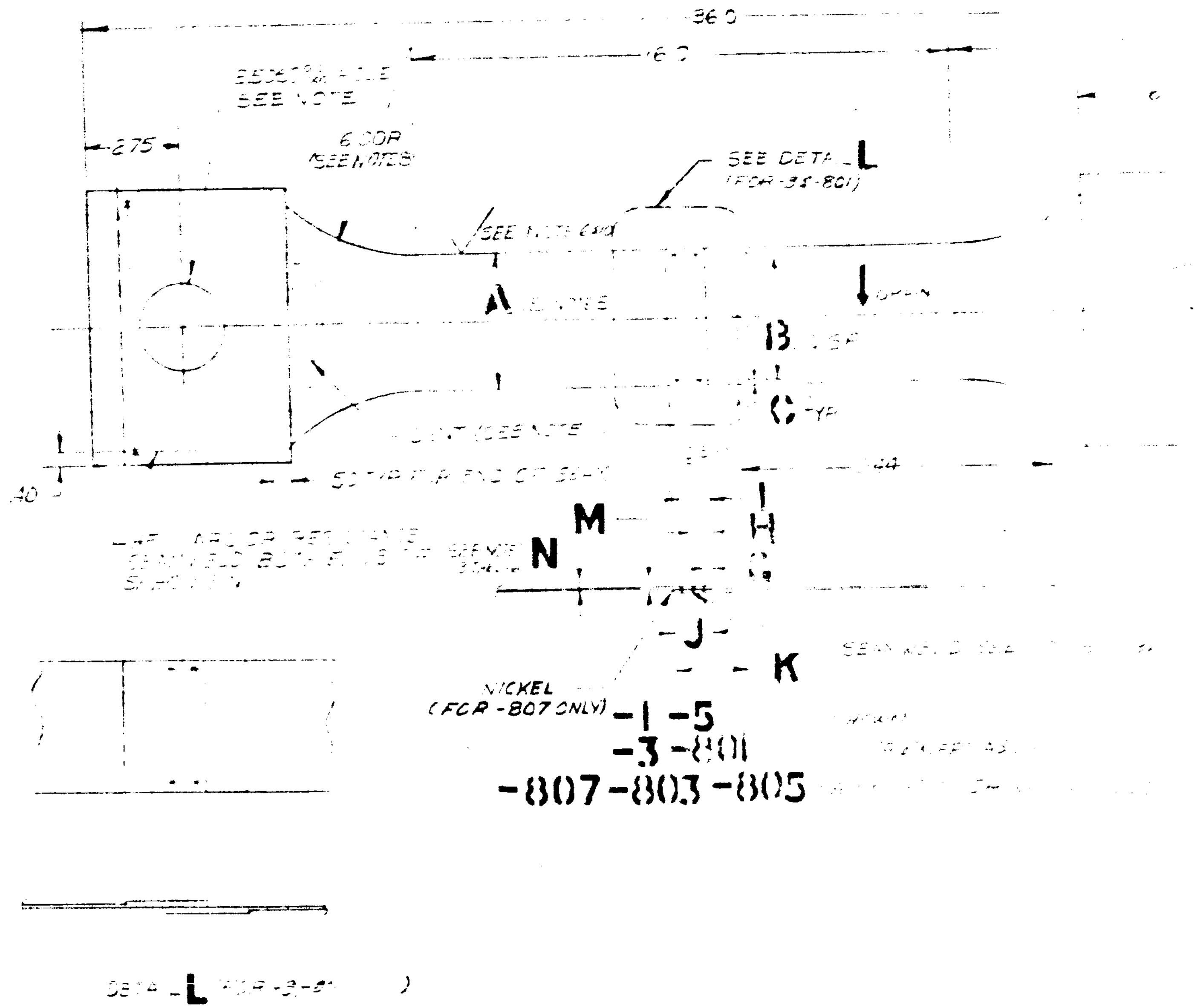
Static Test
(or F1, Fatigue at Stress Level 1)
(or F2, Fatigue at Stress Level 2)

Type 301 CRES (or Type 310)

-1 Assembly of Drawing

Drawing VS-0086 (or VS-0088 or VS-0096)

Panel Designation

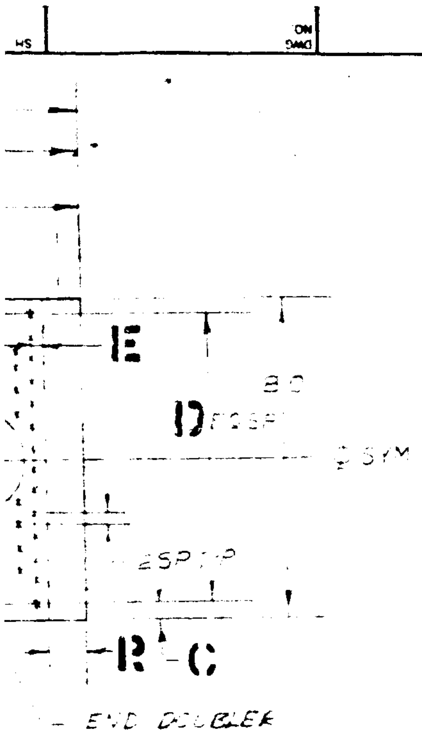


-807	4.0	9	.25	.3	.25	.25	.59	[illegible]	[illegible]
-803	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-801	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-3	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-1	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ASSY	A	B	C	D	E	G	H	J	K M N R

18. APPLY NICKEL PER [illegible]
17. RADIOGRAPH ALL WELDS [illegible] MIL-I-6865 FOR [illegible] ONLY. IDENT X-RAY [illegible]
16. SURFACE FINISH [illegible]
15. ALL ETCHED [illegible]
14. DYNAMIC ETCH [illegible]
13. CHEM MILLED [illegible]
12. FABRICATION [illegible] JOIN [illegible] [illegible] [illegible]
11. EDGES OF [illegible]
10. CHEM MILL [illegible]
9. NO NOTCHES [illegible]
8. HOLES [illegible]
7. EDGES OF [illegible]
6. TEST [illegible] TO BE [illegible]
5. TOL [illegible]
4. SPOTWELD AND SEAM [illegible]
3. SEAMWELD TEST [illegible]
2. METAL STAMP [illegible]

NOTES—

1



REVISIONS

SYM	DESCRIPTION	DATE	APPROVED
A	ADDED NOTE 17 REVISED NOTE 11 ADDED "5 X-RAY"		
B	ADDED -803 & -805		
C	ADDED -807 & NOTE 18.		

DWG "X-RAY"

CLASS A.

NOTE NO.	FIND NO	OPP DASH	SHN NO.	DESCRIPTION	STOCK SIZE	MATERIAL SPECIFICATION	INITIAL COND OR HT TR	FINAL KSI	INSP CL

LIST OF MATERIALS

FOR PARTS LIST AND USAGE DATA SEE DOCUMENT SAME NUMBER PREFIXED PL

FOR INTERPRETATION OF DRAWING SEE 0-70900

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES

TOLERANCES .X ± 1 .XX ± .03 .XXX ± .010

ANGULAR PER 0-70902

ALL MACHINED SURFACES ✓

C CHG.

INTERCHANGEABILITY REQD

REPLACEABILITY REQD

BY

MATL

TOOLING

CHECK

STRESS

GR ENGR

DESIGN

DRAWN

CONTRACT NO.

ASTRONAUTICS APPROVAL

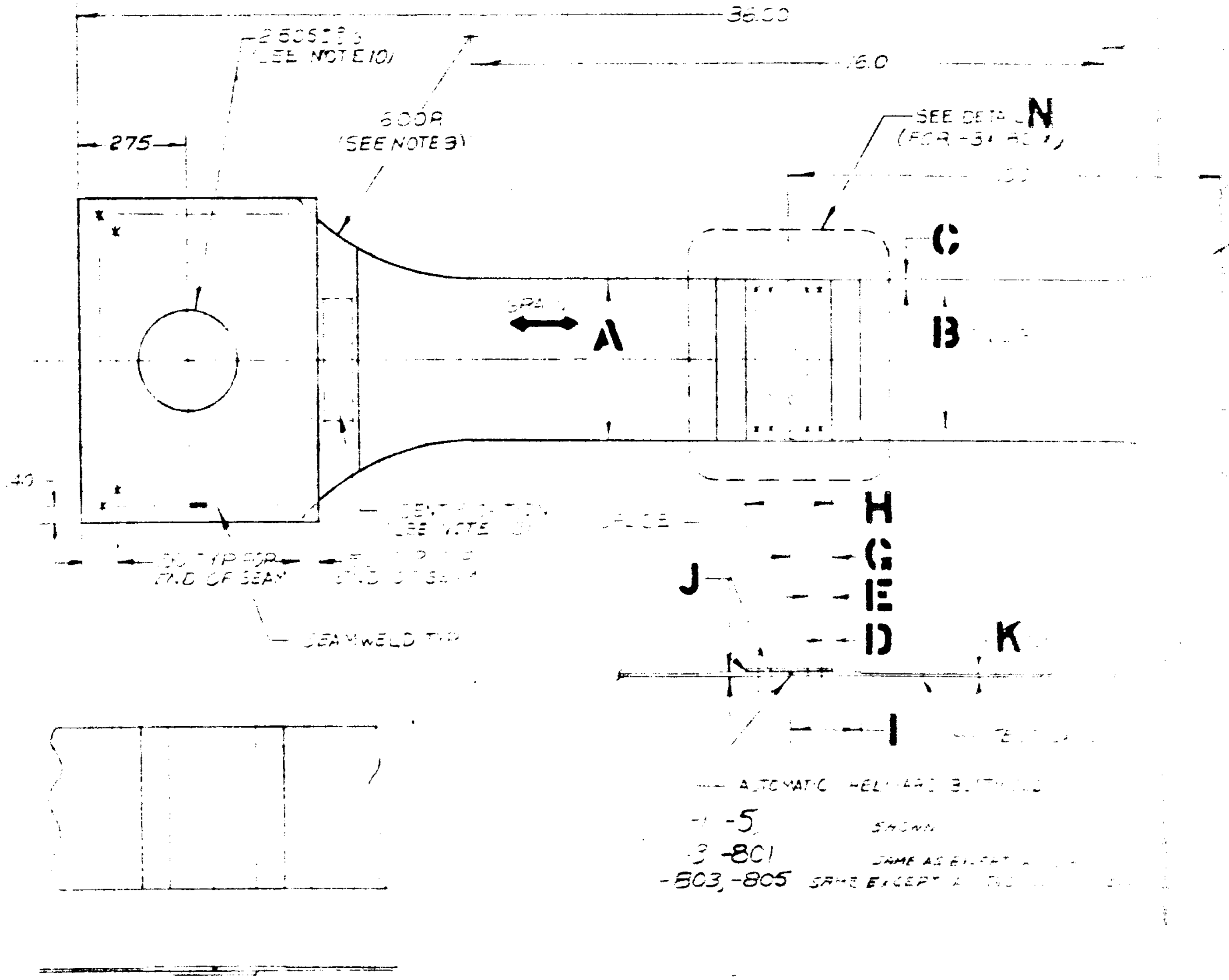
GENERAL DYNAMICS | ASTRONAUTICS

SAN DIEGO, CALIFORNIA

CODE IDENT NO.	SIZE	DRAWING NO.
05342	D	VS-0086

SCALE | RELEASED | SHEET

2



DETAIL N (FOR 3-801)

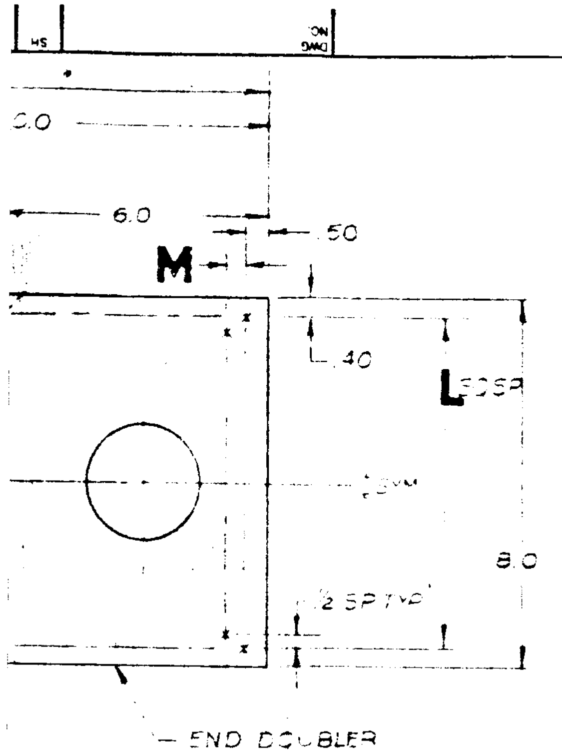
6. RADIOGRAPH ALL WELDS IN TEST SECTION PER MIL-I-6865 FOR INFORMATION & RECORD ... ONLY. IDENT X-RAY WITH SPECIMEN #
5. EACH SPECIMEN TO HAVE ... SPEC #, SPECIMEN #, DWG & X-RAY #
14. TOL. ON ...
3. ...
12. TEST SECTION WIDTH ... TAPER TO BE ... ENTER
11. EDGES OF SKIN MUST BE ... FROM BURRS.
... HOLES TO BE CENTERED WITH TEST SECTION WITHIN ...
... NO NOTCHES OR UNDERCUTS ...
8. EDGES OF TEST ... TO BE ...
7. HELI-ARC BUTTWELD ...
6. SURFACE FINISH NOT TO EXCEED ...
5. ALL ... TO BE CHEM ... MILLED
4. CHEM-MILLED THICKNESS TOL ... DYNAMIC ETCH PER ... 75031
3
2. FABRICATION SEQUENCE ...:
   A CHEM MILL TEST ...
   B JOIN SPECIMEN HALVES BY ... WELDING PER NOTE ...
   C DRILL END ... AND MACHINE ... SECTION PER NOTES 8, 9, 10, 11, & 12
   D ATTACH CENTER DOUBLERS & END ... BY SPOT & SEAM WELDING PER NOTES ...

... STAMPING OF PARTS NOT PERMITTED

[illegible]	4.20	[illegible]	59	[illegible]	24
[illegible]	4.20	[illegible]	59	[illegible]	[illegible]
[illegible]	4.24	[illegible]	[illegible]	[illegible]	.34
-5	4.20	[illegible]	[illegible]	[illegible]	.34
[illegible]	4.24	[illegible]	[illegible]	[illegible]	[illegible]
-1	4.24	[illegible]	[illegible]	[illegible]	[illegible]

ASSY A B C D E G H I J K L M

1



REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
A	ADDED NOTE 16. REVISED NOTE 5 "X-RAY". 3-20-3		
B	ADDED -803 -805 3-23-3		

-5 SPLICE

NOTE NO. | FIND NO. | OPP | SHN DASH NO. | DESCRIPTION | STOCK SIZE | MATERIAL SPECIFICATION

LIST OF MATERIALS

FOR PARTS LIST AND USAGE DATA SEE DOCUMENT SAME NUMBER

FOR INTERPRETATION OF DRAWING SEE 0-70900

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES

TOLERANCES	ALL MACHINED SURFACES
.X .XX .XXX	
±.1 ±.03 ±.010	✓
ANGULAR PER 0-70902	

INTERCHANGEABILITY REQD

REPLACEABILITY REQD

BY

MATL

TOOLING

CHECK

STRESS

GR ENGR

DESIGN

DRAWN

CONTRACT NO.

ASTRONAUTICS APPROVAL

GENERAL DYNAMICS | ASTRONAUTICS

SAN DIEGO, CALIFORNIA

CODE IDENT NO. 05342

SIZE D

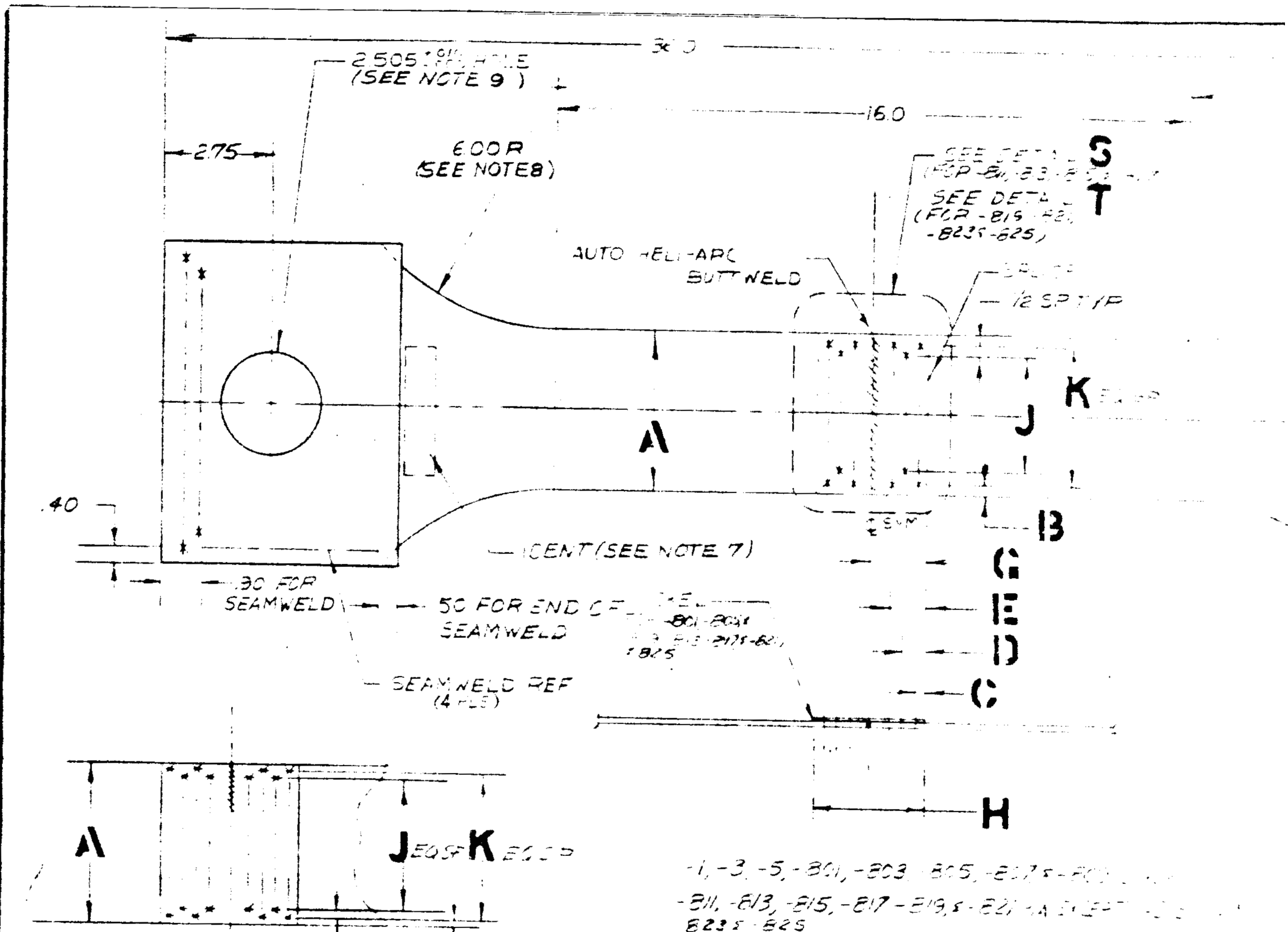
DRAWING NO.

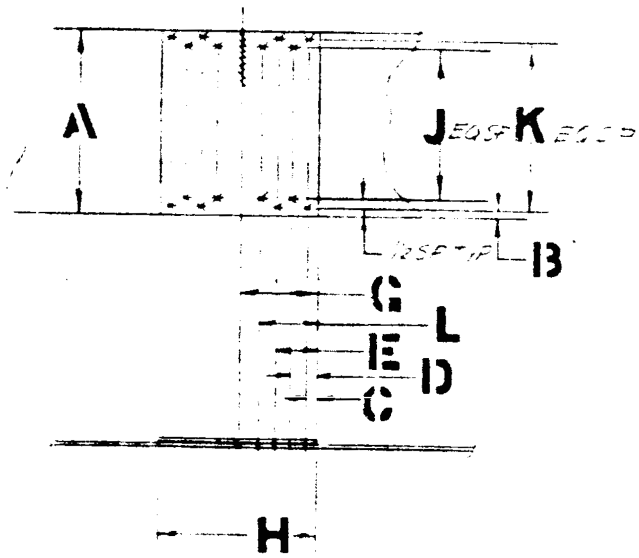
SCALE

RELEASED

SHEET

2





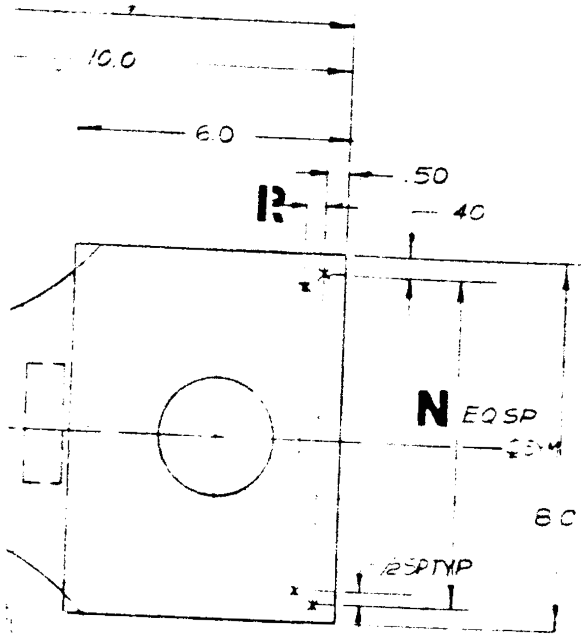
DETAIL T
FOR -819 & -821, -823 & -825

ASSY	A	B	C	D	E	G	H	J	K	L	N	R
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

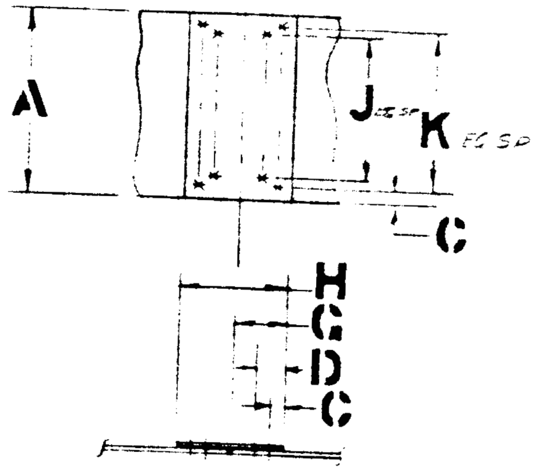
13 TOL ON LOCATION OF SPOTWELDS [illegible]
12 SPOTWELD & SEAMWELD PER MIL-W [illegible]
11 TEST SECTION WIDTH MINIMUM AT CENTER [illegible] TOTAL TAPER [illegible] FROM [illegible]
10 EDGES OF SKIN MUST BE SHARP [illegible] BURRS.
9 HOLES TO BE [illegible] WITH [illegible]
8 [illegible]
7 EACH SPECIMEN [illegible] GAGE, COIL [illegible] SPEC #, SPECIMEN #, DWG # & X-RAY #.
6 RADIOGRAPH ALL WELDS IN TEST [illegible] MIL-I-6865 FOR [illegible] ONLY IDENT [illegible] WITH SPEC [illegible]
5 APPLY NICKEL PER D-75099.
4 EDGES OF SKIN TO BE MACHINED [illegible]
3 HELI-ARC BUTTWELD PER D-75005
2 FABRICATION SEQUENCE IS AS FOLLOWS:
A [illegible] SPECIMEN [illegible] ARC BUTTWELDING [illegible]
B DRILL END HOLES [illegible] SECTION PER NOTES 4 & 9 [illegible]
C ATTACH CENTER [illegible] BY SPOTWELDING & SEAMWELDING [illegible]
1 IMPRESSION MARKS [illegible]

NOTES –

1



SYM	REVISIONS DESCRIPTION	DATE	APPROVED
A	ADDED -B09-B11-B13-B15-B17-B19-B21		
B	ADDED -B23 & -B25		



DETAIL S
FOR -B11, -B13, -B15, & -B17

NOTE NO.	FIND NO.	OPP	SHN	DESCRIPTION	STOCK SIZE	MATERIAL SPECIFICATION
		DASH NO				

LIST OF MATERIALS

FOR PARTS LIST AND USAGE DATA SEE DOCUMENT SAME NUMBER PREFIXED PL

FOR INTERPRETATION OF DRAWING SEE 0-70900	INTERCHANGEABILITY REQD	CHECK
UNLESS OTHERWISE SPECIFIED	REPLACEABILITY REQD	STRESS
DIMENSIONS ARE IN INCHES		GR ENGR
TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0-70902	ALL MACHINED SURFACES √	DESIGN
	BY	DRAWN
		CONTRACT NO.
"B" SIG	MATL	ASTRONAUTICS APPROVAL
	TOOLING	

GENERAL DYNAMICS | ASTRONAUTICS
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