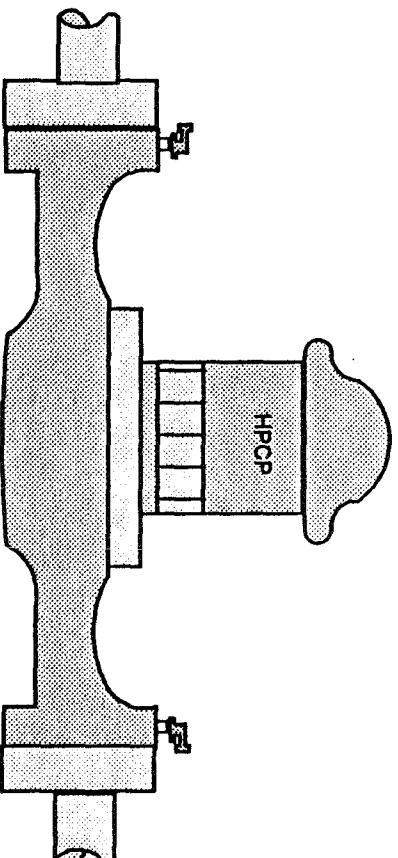


MECHANICAL MAINTENANCE FUNCTIONAL TEAM

YEAR FORMED: 1982 NUMBER OF QI STORIES COMPLETED: 6

THEME: HIGH PRESSURE CIRCULATING PUMP (HPCP) MECHANICAL SEAL FAILURES



TEAM CODE: 110003

QI STORY NUMBER: 025438

TEAM LEADER: MARYIS CHAMPION:

MECHANIC, F.P.L. SINCE 1972

TEAM MEMBERS: LARRY WOOTEN:

MECHANICAL MAINTENANCE PLANNING DEPARTMENT;
F.P.L. SINCE 1970

RON BECKER:

APPRENTICE ELECTRICIAN, F.P.L. SINCE 1970

CHUCK TAYLOR:

MECHANICAL MAINTENANCE CREW SUPERVISOR;
F.P.L. SINCE 1970

KEN RIGDON (SPONSOR):

I&C AND ELECTRICAL ASSISTANT SUPERINTENDENT;
F.P.L. SINCE 1969

GREG WHITE:

MACHINIST, F.P.L. SINCE 1971

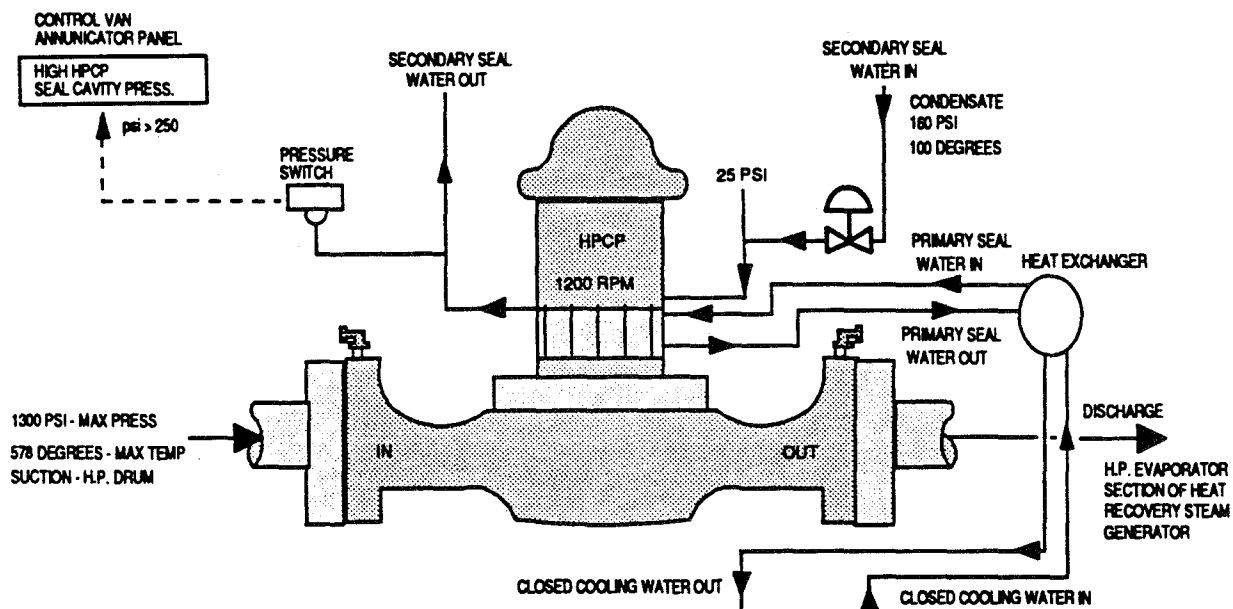
TECHNICAL ADVISOR: ROXANE KENNEDY

SENIOR PLANT ENGINEER, F.P.L. SINCE 1985

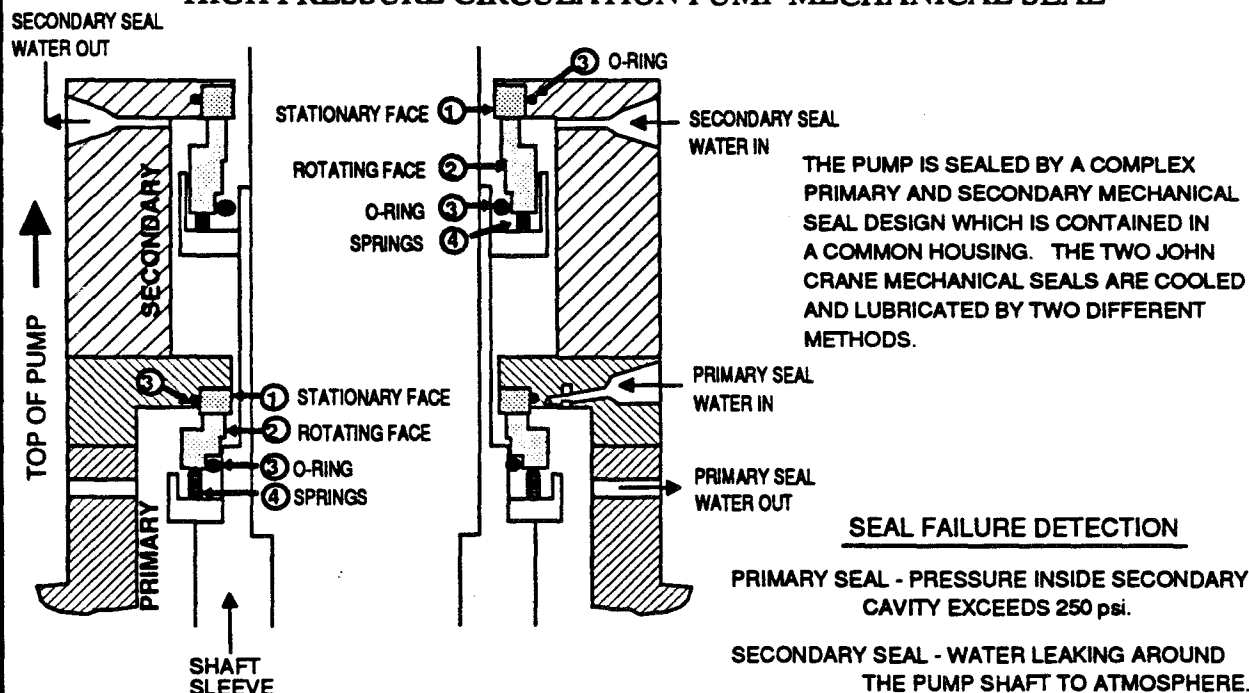
CURRENT SITUATION

IN ORDER TO BETTER UNDERSTAND THE PROBLEM, WE SHOULD EXPLAIN THE FUNCTION AND THE OPERATING VARIABLES OF THE HIGH PRESSURE CIRCULATION PUMP.

HIGH PRESSURE CIRCULATION PUMP

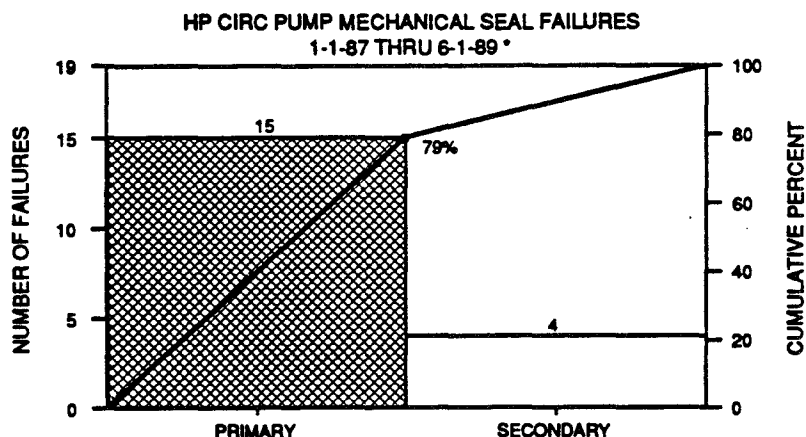


HIGH PRESSURE CIRCULATION PUMP MECHANICAL SEAL



CURRENT SITUATION

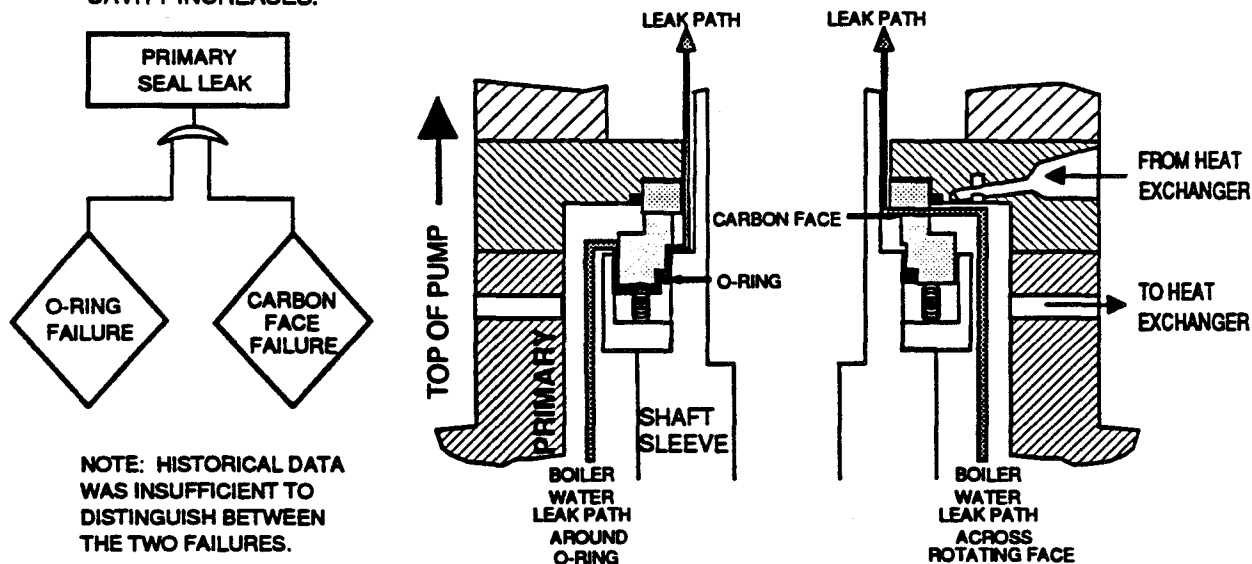
THE MECHANICAL SEAL FAILURES WERE STRATIFIED BY SEAL TYPE.



CONCLUSION: 79 % OF THE MECHANICAL SEAL FAILURES ARE CAUSED BY THE PRIMARY SEAL.

* NOTE: DATA PRIOR TO 1987 WAS INSUFFICIENT TO DETERMINE WHICH SEAL FAILED.

IN ORDER FOR THE PRIMARY SEAL TO FAIL, WATER MUST PASS FROM THE PRIMARY CAVITY TO THE SECONDARY CAVITY. WHEN THIS OCCURS, THE PRESSURE IN THE SECONDARY CAVITY INCREASES.



PROBLEM STATEMENT

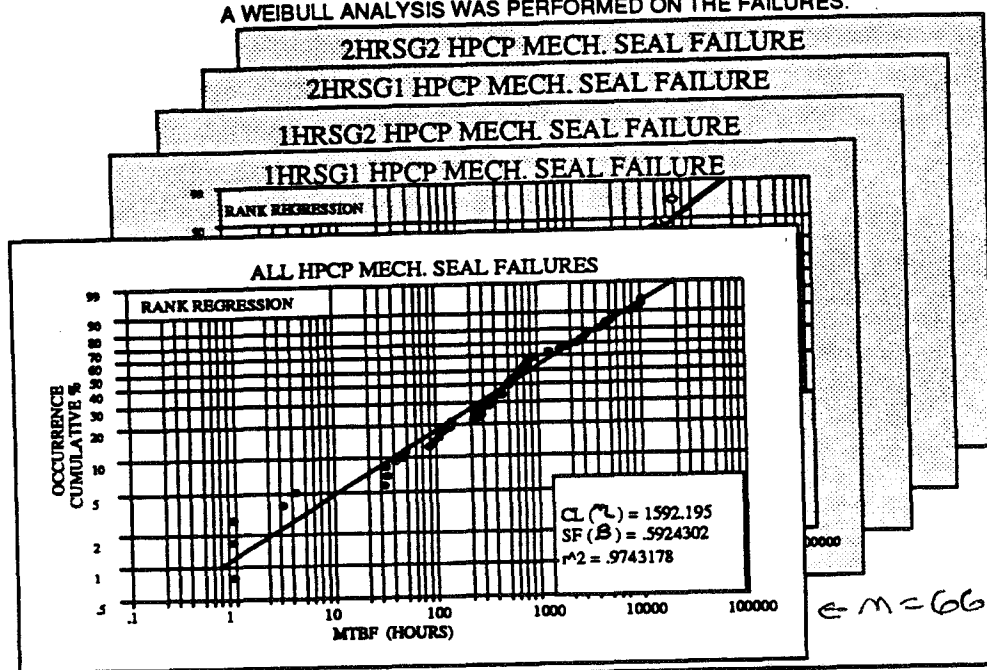
HIGH PRESSURE CIRCULATION PUMP PRIMARY MECHANICAL SEAL O-RING/CARBON FACE FAILURES AT PUTNAM PLANT HAVE CAUSED 15 UNIT OUTAGES DURING THE PERIOD 01/01/87 TO 06/01/89.

TARGET: HIGH PRESSURE CIRCULATION PUMP PRIMARY MECHANICAL SEAL TO LAST FROM OVERHAUL TO OVERHAUL (15,000 HOURS).

METHODOLOGY: THIS TARGET WILL SATISFY OUR CUSTOMER'S NEEDS OF SUPPLYING POWER ON DEMAND AT VARYING LOADS.

ANALYSIS

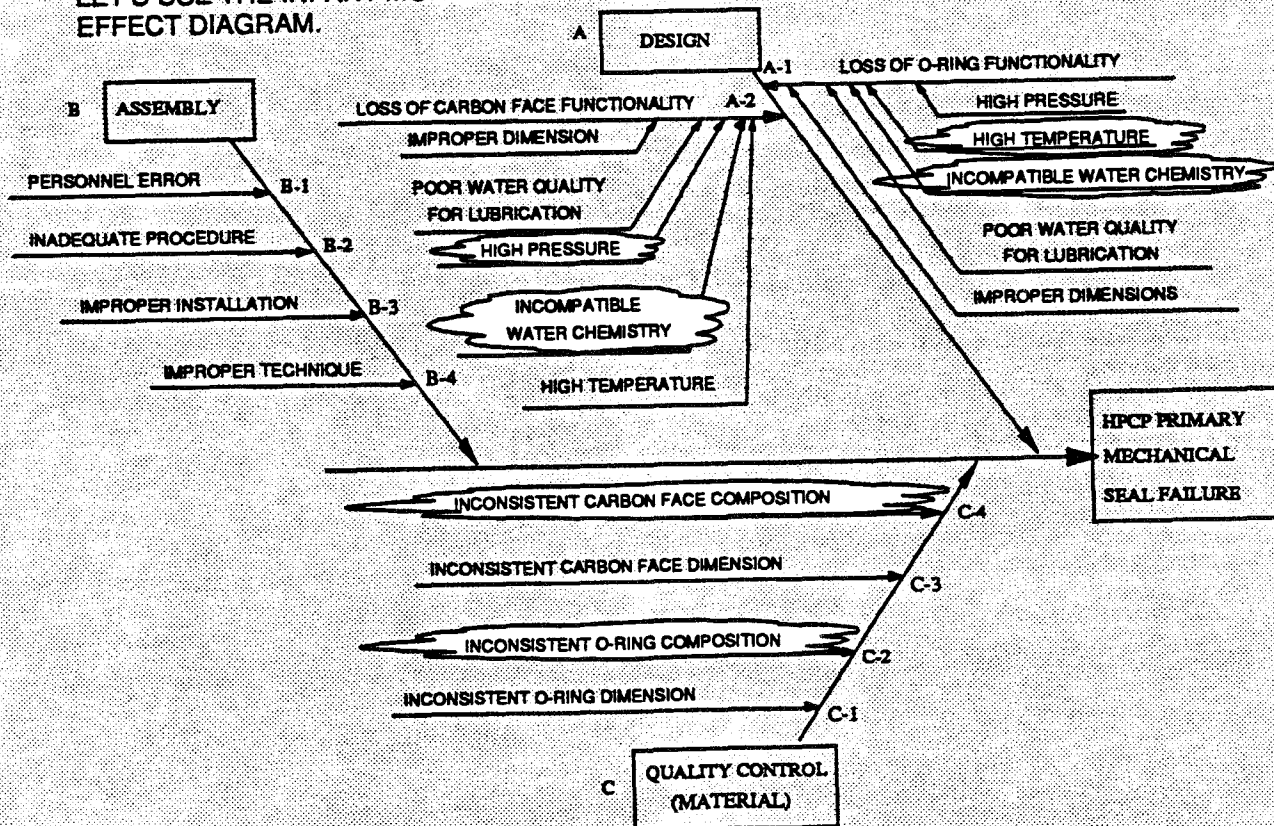
LET'S START BY DETERMINING THE FAILURE MODE.
 A WEIBULL ANALYSIS WAS PERFORMED ON THE FAILURES.



CONCLUSION: WEIBULL INDICATES THE FAILURE MODE IS INFANT MORTALITY.

INFANT MORTALITY MODE INDICATES YOU ARE EXPERIENCING THE FAILURES BECAUSE OF DESIGN, ASSEMBLY OR QUALITY CONTROL DEFICIENCY (MATERIAL).

LET'S USE THE INFANT MORTALITY CATEGORIES TO CONSTRUCT OUR CAUSE AND EFFECT DIAGRAM.

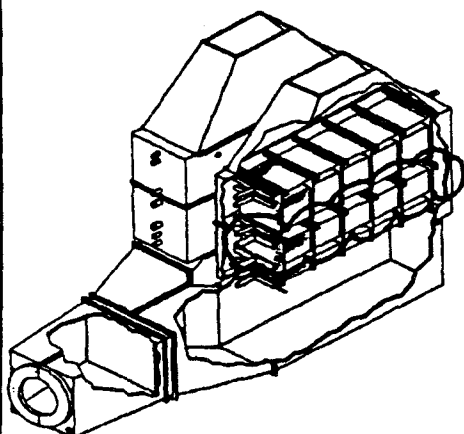


ANALYSIS

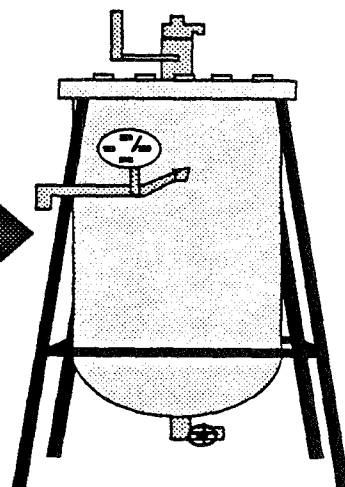
A DESIGN

A-1 LOSS OF O-RING FUNCTIONALITY
 HIGH PRESSURE
 HIGH TEMPERATURE
 INCOMPATIBLE WATER CHEMISTRY

A DESIGN OF EXPERIMENT WAS DEVELOPED TO DETERMINE IF TEMPERATURE AND WATER CHEMISTRY ARE ROOT CAUSES FOR LOSS OF O-RING FUNCTIONALITY.



BECAUSE OF THE OPERATING CONSTRAINTS OF THE BOILER IN TERMS OF TEMPERATURE, PRESSURE, WATER CHEMISTRY AND AVAILABILITY, A VESSEL HAD TO BE CONSTRUCTED FOR THE EXPERIMENT.



A SERIES OF TESTS WERE THEN PERFORMED UNDER THE FOLLOWING CONDITIONS:

O-RING DIMENSIONAL TEST NO. 1

O-RING DIMENSIONAL TEST NO. 1

O-RING DIMENSIONAL TEST NO. 1

O-RING DIMENSIONAL TEST NO. 2

O-RING DIMENSIONAL TEST NO. 3

O-RING DIMENSIONAL TEST NO. 4

O-RING DIMENSIONAL TEST NO. 5

START TIME _____ STOP TIME _____

DATE _____ TEMPERATURE _____

WATER CONDITION

BOILER WATER	☐
CONDENSATE	☒

NOTE

- (A) & (B) ARE AXIALLY ORIENTED.
- (C) & (D) ARE RADially ORIENTED.

O-RING NUMBER	A	B	C	D	E	F	G	H
11	.144	.125	.144	.128	.143	.130	.143	.127

CONTROL: ENVIRONMENT - AIR TEMPERATURE - AMBIENT

EXPERIMENT: ENVIRONMENT - BOILER WATER
 TEMPERATURE - 200, 300, 400, 500, & 600 degrees F

EXPERIMENT: ENVIRONMENT - CONDENSATE
 TEMPERATURE - 200, 300, 400, 500, & 600 degrees F

ANALYSIS

TO UNDERSTAND IF TEMPERATURE, CHEMISTRY, AND/OR THE INTERACTION BETWEEN TEMPERATURE AND WATER CHEMISTRY IS THE CAUSE OF THE RADIAL DIAMETER DISTORTION, WE NEED TO PERFORM A 2-WAY ANOVA.

STEPS IN 2-WAY ANOVA WITH REPETITION

TO TEST IF TEMP & WATER CHEM HAVE AN EFFECT ON RADIAL DIAMETER OF VITON O-RINGS.

ANOVA TABLE (TWO-WAY WITH REPETITION) EQUAL OBSERVATION PER CELL

SOURCE	SS	df	MS	F ₀
Factor A (TEMP)	0.00135	4	0.0003375	125
Factor B (CHEM)	0.00115	1	0.0011500	426
Interaction (AxB)	0.00052	4	0.0001300	48
Error	0.00008	30	0.0000027	
Total	0.0031	39		

I = 5 Factor A Levels J = 2 Factor B Levels K = 2 REPLICATIONS PER CELL N_T = 12 J x K

A. Perform the F-Test for Factor A

- Look up the table value for $F_{(df_A, df_E)} = 2.69$
- Enter the table value on the picture:
- Test: H_0 : The factor _____ does not have an effect on _____ (MSA = MSE)
 H_A : The factor TEMPERATURE does have an effect on Radial diameter of Viton o-rings (MSA > MSE)

If F-table > F₀, DO NOT REJECT H₀. If F-table < F₀, REJECT H₀.

DECISION: **REJECT H₀**

B. Perform the F-Test for Factor B

- Look up the
- Enter the
- Test: H

If F-table > F₀.

C. Perform the

- Look up the
- Enter the
- Test: H

If F-table > F₀.

WE MAY VISUALIZE THE RESULTS OF THE ANOVA THROUGH THE FOLLOWING GRAPHS:

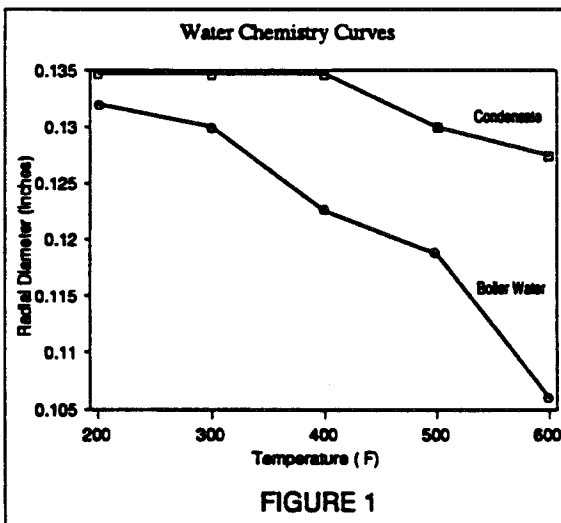


FIGURE 1

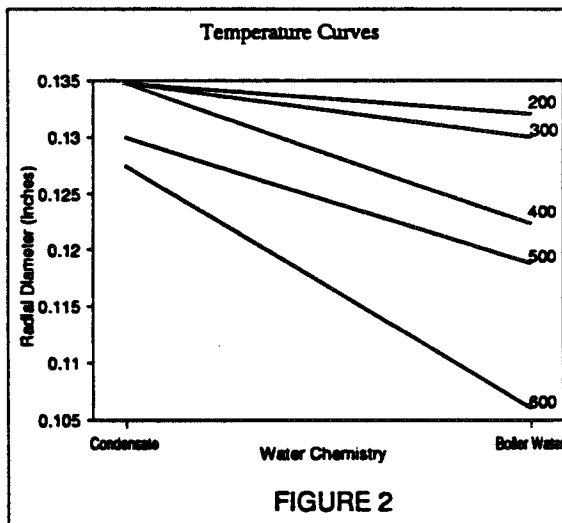


FIGURE 2

SINCE THE LINES ARE NOT HORIZONTAL, THERE IS A RELATIONSHIP BETWEEN TEMPERATURE AND RADIAL DIAMETER (FIG. 1) AS WELL AS CHEMISTRY AND RADIAL DIAMETER (FIG. 2). EVIDENCE OF TEMPERATURE AND CHEMISTRY INTERACTION MAY BE SEEN BY COMPARING THE LINES IN FIGURE 1 OR 2. SINCE THE LINES ARE NOT PARALLEL, THERE IS AN EFFECT ON RADIAL DIAMETER WHEN THESE TWO FACTORS ARE TOGETHER.

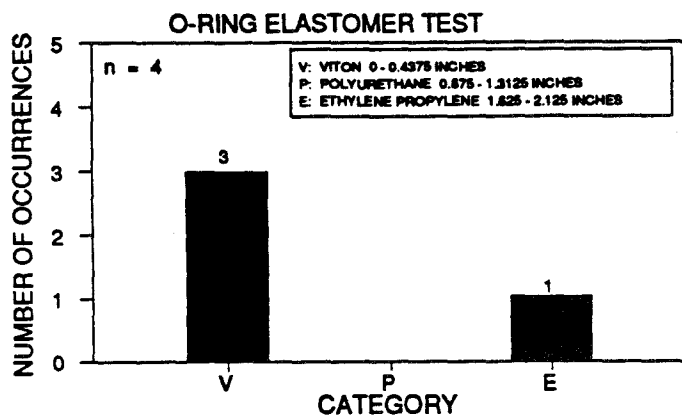
FINDINGS: TEMPERATURE, WATER CHEMISTRY, AND THE INTERACTION BETWEEN THESE TWO CAUSE RADIAL DIAMETER DISTORTION ON THE O-RINGS (LOSS OF O-RING FUNCTIONALITY).

ROOT CAUSE VERIFIED: THE VITON O-RING IS NOT COMPATIBLE FOR THIS TEMPERATURE AND WATER CHEMISTRY ENVIRONMENT.

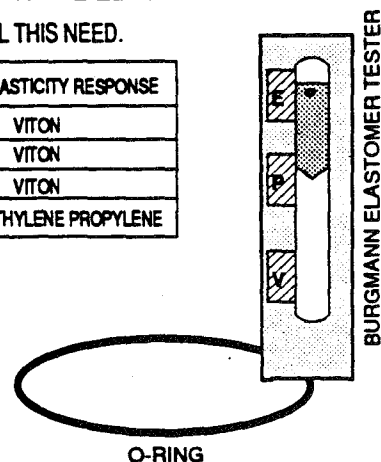
ANALYSIS

TO PURSUE LOOKING INTO THE QUALITY CONTROL PROBLEM FURTHER, THE TEAM NEEDED A NON-DESTRUCTIVE TEST THAT WOULD YIELD SIMILAR RESULTS AS IN THE ELASTICITY TEST.

THE BURGMANN ELASTOMER TEST WAS FOUND TO FULFILL THIS NEED.



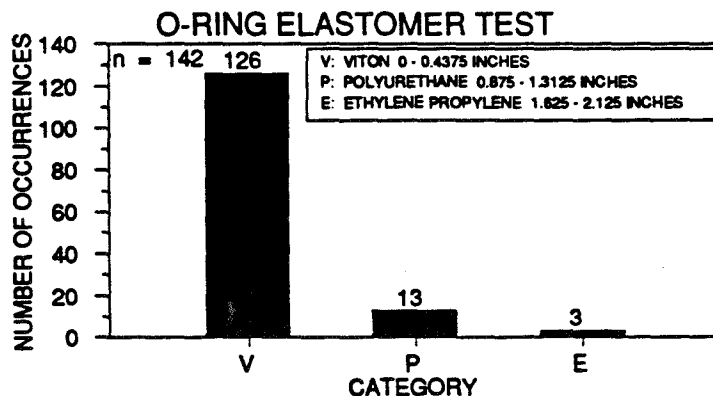
O-RING #	ELASTICITY RESPONSE
#7	VITON
#8	VITON
#9	VITON
#10	ETHYLENE PROPYLENE



FINDINGS: THE BURGMANN ELASTOMER TEST YIELDED SIMILAR RESULTS AS THE ELASTICITY TEST PERFORMED EARLIER. O-RING #10 PERFORMS LIKE ETHYLENE PROPYLENE RATHER THAN VITON. ALL O-RINGS SHOULD HAVE RESPONDED LIKE VITON.

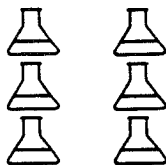
CONCLUSION: POTENTIAL QUALITY CONTROL PROBLEM.

LET'S NOW PERFORM THIS TEST ON THE O-RINGS IN OUR STORES INVENTORY.



FINDINGS: 16 OF THE 142 O-RINGS RESPONDED LIKE MATERIALS OTHER THAN VITON.

A SAMPLE FROM EACH CATEGORY WAS CHEMICALLY TESTED.



FLUID COMPATIBILITY TABLE

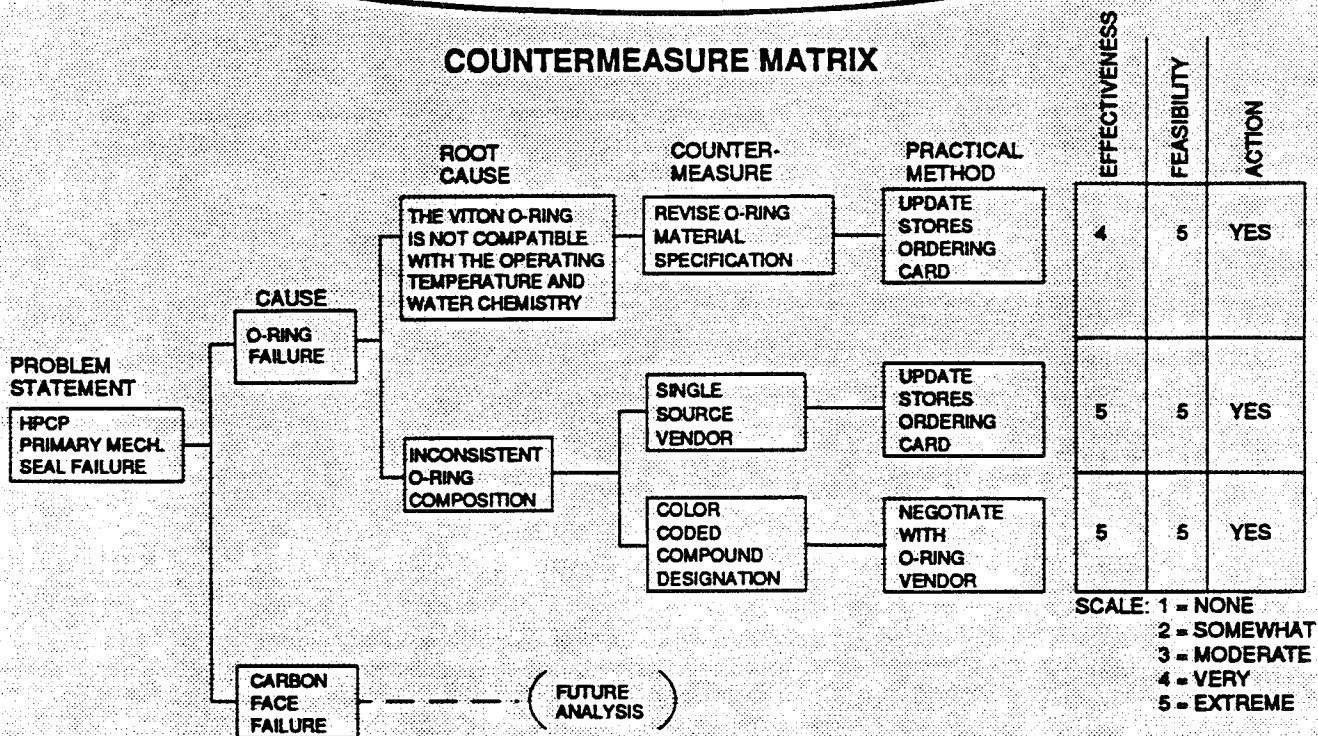
MATERIAL	SELECTED COMPATIBLE FLUID	TEST COMPATIBILITY RATING	
		OIL	ACID
VITON	OIL & ACID	SATISFACTORY	SATISFACTORY
POLYURETHANE	ACID	UNSATISFACTORY	SATISFACTORY
ETHYLENE PROP.	OIL	SATISFACTORY	UNSATISFACTORY

FINDINGS: CHEMICAL ANALYSIS CORRESPONDED WITH THE BURGMANN CATEGORIES.

SECOND ROOT CAUSE VERIFIED: QUALITY CONTROL PROBLEM - THERE IS INCONSISTENT O-RING COMPOSITION.

COUNTERMEASURES

COUNTERMEASURE MATRIX



ACTION PLAN

WHAT	WHO	WHEN	COMMENTS
1. DETERMINE WHICH O-RING IS COMPATIBLE WITH OUR OPERATING CHARACTERISTICS.	G.A. WHITE	MARCH 23, 1990	GO TO PAGE 11
2. IDENTIFY APPROPRIATE VENDOR / COLOR CODE COMPOUND	C.W. TAYLOR	MARCH 30, 1990	COLOR CODE IS NOT AVAILABLE FOR THIS O-RING COMPOUND. INDIVIDUAL PACKING WILL MEET OUR NEEDS.
3. CHANGE STORES CARD TO INCLUDE - TEMPERATURE SPECIFICATIONS - SINGLE SOURCE VENDOR	G.A. WHITE	APRIL 6, 1990	JOHN CRANE WILL BE OUR SINGLE SOURCE VENDOR.
4. CHANGE STORES O-RING NUMBER TO SEAL PART NUMBER.	G.A. WHITE	APRIL 6, 1990	COMPLETED 04/06/90
5. UPDATE PROCEDURES TO REFLECT NEW M&S NUMBER. REVISE SEAL OVERHAUL PROCEDURE TO INCLUDE TESTING OF O-RING MATERIAL AT TIME OF INSTALLATION.	D.L. WOOTEN G.A. WHITE	APRIL 13, 1990 APRIL 13, 1990	COMPLETED 04/06/90 COMPLETED 04/06/90
6. PREVENT STORES FROM ISSUING OR REORDERING THE VITON O-RING.	G.A. WHITE	MARCH 23, 1990	COMPLETED 03/23/90
7. INSTALL NEW O-RING: 1 HRSG 2 1 HRSG 1 2 HRSG 1 2 HRSG 2	C.W. TAYLOR	JULY 24, 1990 JULY 24, 1990 MAY 18, 1990 MAY 18, 1990	COMPLETED JULY 12, 1990 COMPLETED JULY 2, 1990 COMPLETED MAY 25, 1990 COMPLETED APRIL 23, 1990

COUNTERMEASURES

THE ORIGINAL EQUIPMENT MANUFACTURER (OEM) RECOMMENDED ETHYLENE PROPYLENE O-RINGS. A 3-WAY ANOVA WAS PERFORMED TO VALIDATE THE PERFORMANCE OF THE NEW O-RINGS.

STEPS IN 3-WAY ANOVA WITH REPETITION

TO TEST IF TEMPERATURE, MATERIAL & CHEMISTRY HAVE AN EFFECT ON O-RING RADIAL DIAMETER.

ANOVA TABLE (THREE-WAY WITH REPETITION) EQUAL OBSERVATION PER CELL

SOURCE	SS	df	MS	F ₀
Factor A	0.000875	4	0.000219	81.11
Factor B	0.000063	1	0.000063	23.33
Factor C				
Interaction (AxB)				
Interaction (AxC)				
Interaction (BxC)				
Interaction (AxBxC)				
Error				
Total				

a = 5 Factor A Levels
 b = 2 Factor B Levels

A. Perform the F-Test

1. Look up the table value

2. Enter the table value

3. Test: H_0 : The test

H_A : The test

If $F_{\text{table}} > F_0$, DO NOT

G. Perform the F-Test

1. Look up the table value

2. Enter the table value

3. Test: H_0 : The test

H_A : The test

If $F_{\text{table}} > F_0$, DO NOT

WE MAY VISUALIZE THE RESULTS OF THE ANOVA THROUGH THE FOLLOWING GRAPHS:

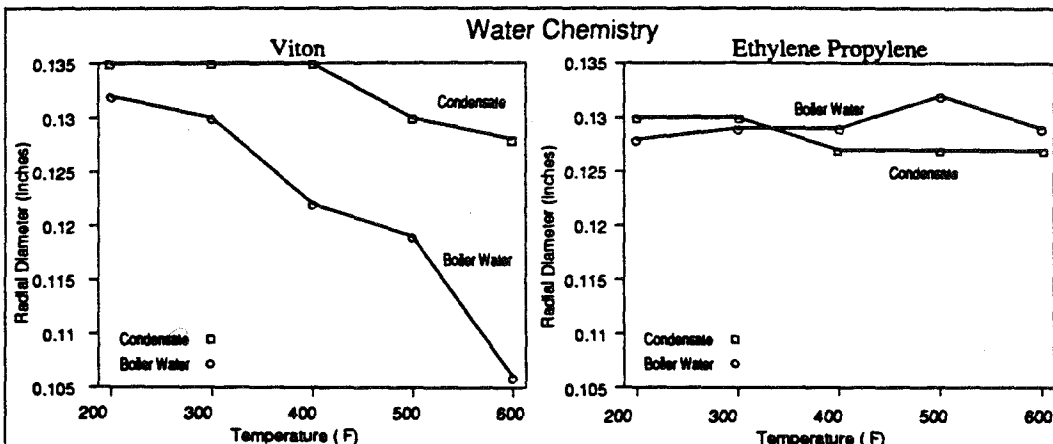


FIGURE 1A

FIGURE 1B

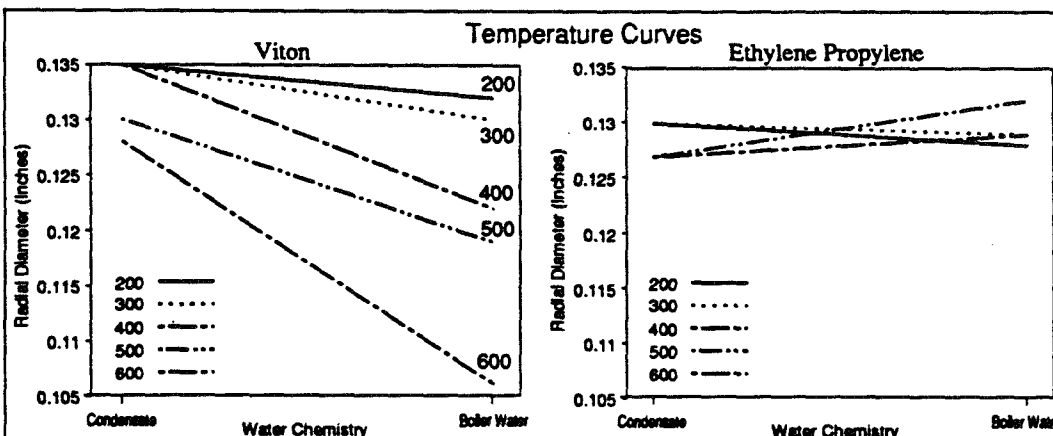


FIGURE 2A

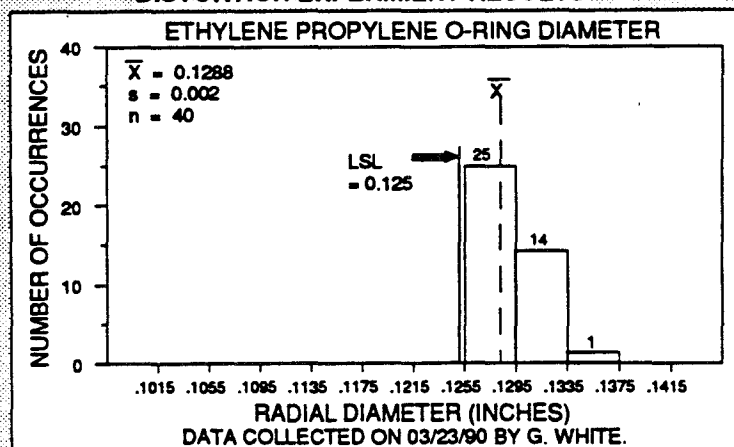
FIGURE 2B

FINDINGS: SINCE THE LINES IN FIGURES 1B AND 2B ARE NOT FLAT, WATER CHEMISTRY, TEMPERATURE AND THE INTERACTION OF THESE VARIABLES MAY HAVE SOME AFFECT ON THE RADIAL DIAMETER OF ETHYLENE PROPYLENE O-RINGS. HOWEVER, WE CAN SEE BY COMPARING FIGURE 1A TO 1B AND FIGURE 2A TO 2B THAT ETHYLENE PROPYLENE IS MORE COMPATIBLE WITH OUR OPERATING CHARACTERISTICS THAN VITON.

RESULTS

THE ANOVA IN COUNTERMEASURES STATISTICALLY VALIDATED THERE IS A SIGNIFICANT DIFFERENCE BETWEEN THE PERFORMANCE OF VITON AND ETHYLENE PROPYLENE O-RINGS. NOW LET'S COMPARE ETHYLENE PROPYLENE O-RING PERFORMANCE TO OUR SPECIFICATION LIMITS.

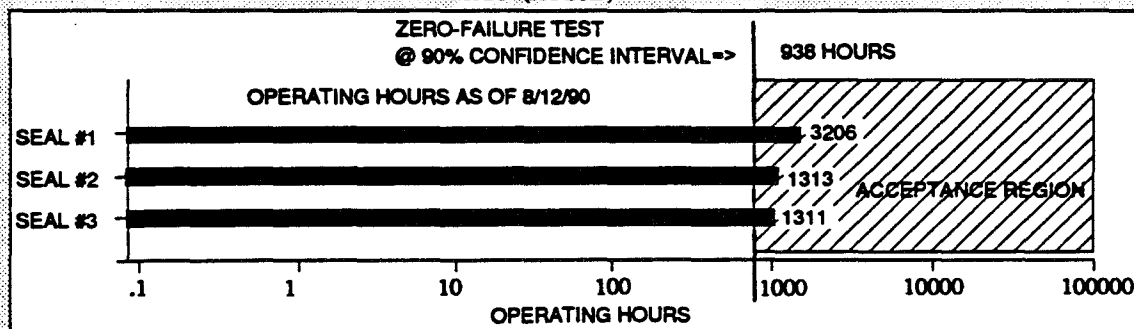
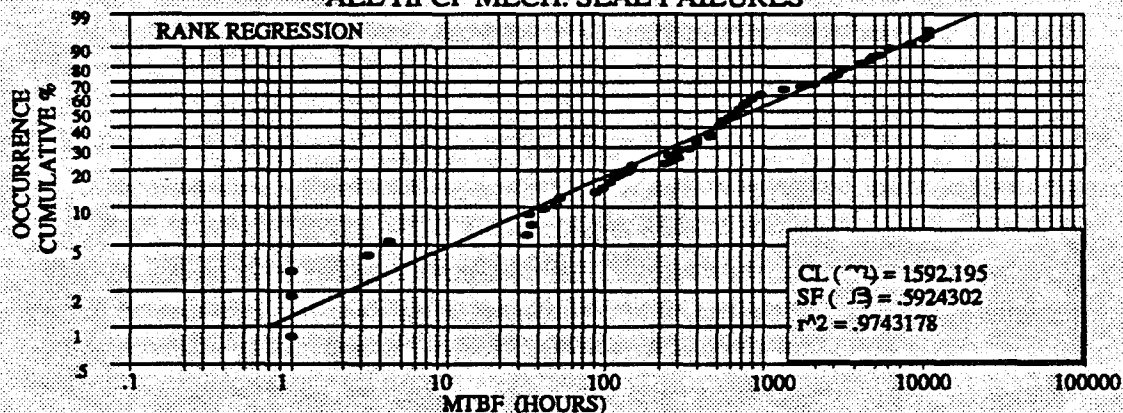
DISTORTION EXPERIMENT RESULTS



FINDINGS: ALL ETHYLENE PROPYLENE O-RINGS EXCEED THE SPECIFICATION LIMIT.

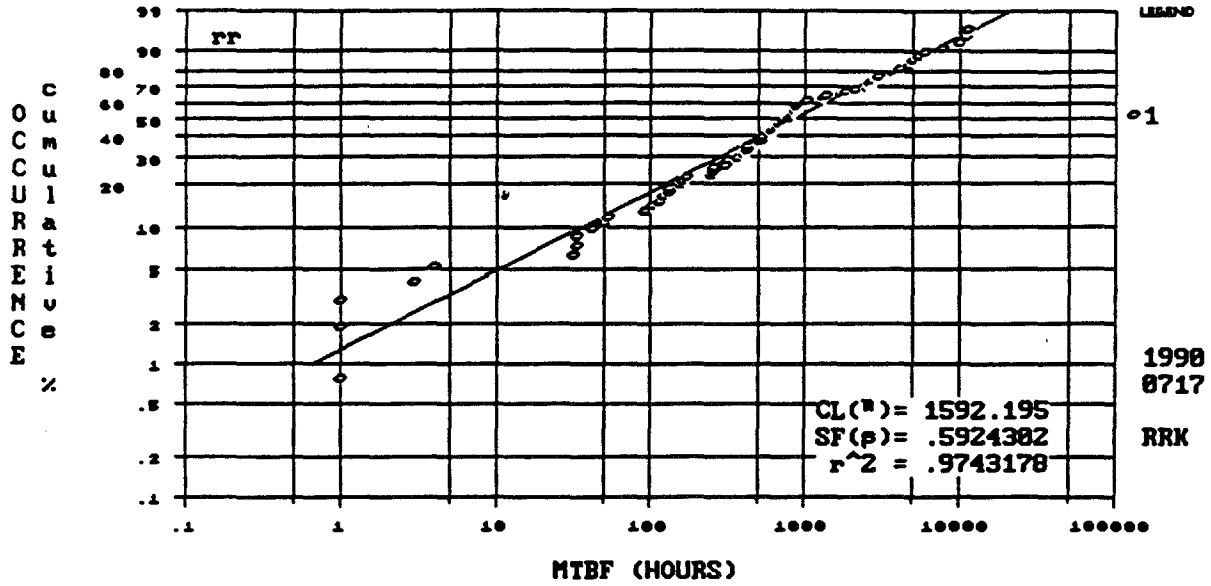
LET'S SEE HOW THE MECHANICAL SEALS WITH THE ETHYLENE PROPYLENE O-RINGS ARE PERFORMING RELATIVE TO HISTORICAL DATA.

ALL HPCP MECH. SEAL FAILURES



FINDINGS: A STATISTICALLY SIGNIFICANT IMPROVEMENT HAS BEEN MADE IN THE PERFORMANCE OF THE MECHANICAL SEALS UTILIZING ETHYLENE PROPYLENE O-RINGS.

ALL HPCP SEAL ALL FAILURE MODES



...rank table...	set	point	x-value	order	median rank
1	1	1	1	1	7.829977E-03
1	2	1	1	2	1.901566E-02
1	3	1	1	3	3.020134E-02
1	5	3	3	4.011628	4.151709E-02
1	6	4	4	5.023256	5.283285E-02
1	8	31	31	6.047072	6.428493E-02
1	9	33	33	7.070889	7.573701E-02
1	10	33	33	8.094705	8.718909E-02
1	11	42	42	9.118521	9.864117E-02
1	12	50	50	10.14234	.1100933
1	13	53	53	11.16615	.1215453
1	14	91	91	12.18997	.1329974

<ENTER> to continue ?

...rank table...	set	point	x-value	order	median rank
1	15	102	102	13.21379	.1444495
1	16	114	114	14.2376	.1559016
1	17	122	122	15.26142	.1673537
1	18	130	130	16.28523	.1788058
1	19	133	133	17.30905	.1902578
1	20	157	157	18.33287	.2017099
1	21	161	161	19.35669	.213162
1	22	169	169	20.3805	.2246141
1	23	247	247	21.40432	.2360662
1	24	253	253	22.42813	.2475183
1	25	259	259	23.45195	.2589704
1	26	302	302	24.47577	.2704224

<ENTER> to continue ?

...rank table...	set	point	x-value	order	median rank
1	27	308	308	25.49958	.2818745
1	28	310	310	26.5234	.2933266
1	30	356	356	27.564	.3049664
1	32	405	405	28.62223	.3168035
1	33	412	412	29.68047	.3286406
1	34	417	417	30.73871	.3404777
1	35	421	421	31.79695	.3523148
1	36	503	503	32.85518	.3641519
1	37	511	511	33.91342	.375989
1	38	523	523	34.97166	.3878262
1	39	526	526	36.0299	.3996633

1

40

588

37.08814

.4115004

<ENTER> to continue ?

...rank table...	set	point	x-value	order	median rank
1	41	606	38.14638	.4233375	
1	42	609	39.20462	.4351747	
1	43	619	40.26286	.4470118	
1	44	669	41.32109	.4588489	
1	45	678	42.37933	.470686	
1	46	682	43.43757	.4825231	
1	47	730	44.4958	.4943602	
1	48	746	45.55404	.5061973	
1	50	787	46.63809	.5183231	
1	51	832	47.72214	.530449	
1	52	847	48.80619	.5425748	
1	53	860	49.89024	.5547006	

<ENTER> to continue ?

...rank table...	set	point	x-value	order	median rank
1	54	876	50.97429	.5668265	
1	55	886	52.05833	.5789523	
1	56	965	53.14238	.5910781	
1	57	989	54.22643	.603204	
1	58	1012	55.31048	.6153298	
1	59	1323	56.39453	.6274556	
1	60	1333	57.47858	.6395814	
1	61	1361	58.56263	.6517073	
1	62	1688	59.64668	.6638331	
1	63	1788	60.73072	.6759589	
1	64	2065	61.81477	.6880847	
1	66	2567	62.94218	.7006955	

<ENTER> to continue ?

...rank table...	set	point	x-value	order	median rank
------------------	-----	-------	---------	-------	-------------