DUKE POWER COMPANY
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HAL B. TUCKER
VICE PRESIDENT
NUCLEAR PRODUCTION

TELEPHONE
(704) 373-4531

April 16, 1984

Docket

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Ms. E. G. Adensam, Chief
Licensing Branch No. 4

Re: Catawba Nuclear Station
Docket Nos. 50-413 and 50-414

Dear Mr. Denton:

On March 6-8, 1984 the NRC Staff and their consultants conducted an on-site audit of the environmental qualification of mechanical equipment at Catawba. As a follow-up to this audit and in response to question 9 of Ms. Elinor G. Adensam's letter of March 3, 1983, please find attached documentation packages for three types of mechanical equipment.

The cover sheet for each package notes the equipment name, manufacturer and model number, as well as accident and qualified environments and the qualification mandated replacement interval for each nonmetallic subcomponent. In addition, documentation references for the replacement interval and qualified environment are identified, and the pertinent portions of the references are provided.

It should be noted that the replacement interval is based on thermal and radiation degradation effects, and is derived from test data, industry experience, and/or manufacturer's recommendations. Inservice degradation is addressed through preventative maintenance and surveillance programs with equipment and component refurbishment and/or replacement based on known susceptibility to aging degradation. Additionally, these programs will be modified to incorporate, as necessary, information from EPRI research, NRC studies, NPRDS information, IE Bulletins, and industry research and testing.

Very truly yours,

H.B. Tucker /RSO

Hal B. Tucker

ROS/php

Attachment

cc: (w/o attachment)
Mr. James P. O'Reilly, Regional Administrator
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30303

A048
1/1

cc: (w/o attachment)
NRC Resident Inspector
Catawba Nuclear Station

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Attorney-at-Law
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Mr. Jesse L. Riley
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Charlotte, North Carolina 28207

(w/attachment)
Mr. Richard Boborgen
EG&G, Idaho
1520 Sawtelle Street
P. O. Box 1625
Idaho Falls, Idaho 83401

CATAWBA NUCLEAR STATION

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION PROGRAM

3 ITEM SUBMITTAL

A... CONTAINMENT PURGE SYSTEM CONTAINMENT ISOLATION VALVES

B... RHR PUMPS

C... PRESSURIZER POWER OPERATED RELIEF VALVES

CATAWBA NUCLEAR STATION
ENVIRONMENTAL QUALIFICATION OF SAFETY-RELATED MECHANICAL EQUIPMENT

1. EQUIPMENT IDENTIFICATION: Containment Purge Ventilation System (VP) Containment Isolation Valves

2. MANUFACTURER: Fisher Controls, Inc.

3. MODEL OR ID NUMBER(S): 24" Type 9220

4. ACCIDENT ENVIRONMENT:

PEAK TEMPERATURE: 240 DURATION AT PEAK: Continuous

RAD: 7.5×10^6

EXPOSED TO CONTAINMENT VESSEL CHEMICAL SPRAY ENVIRONMENT (BORIC ACID & SODIUM HYDROXIDE SOLUTION): Yes

5. QUALIFIED ENVIRONMENT:

MAT'L	TEMP	RAD	ACCEPTABLE FOR SPRAY	REPLACEMENT INTERVAL	REFS.
EPT (Parker E740-75)	300	1×10^7	Yes	N/A	1,2,3

6. COMMENTS: See Attachment 1

7. REFERENCES:

1. Parker O-Ring Fluid Compatability Chart
2. Fisher Nuclear Selection Guide 4NSG4
3. Barbarin, R. "Selecting Elastomeric Seals for Nuclear Service," Power Engineering, 5680 (December, 1977)

Attachment 1
Summary of Environmental Qualification
24" Fisher Containment Isolation Valves

1. Valve List (Units 1 & 2):

VP1B	VP4A	VP8B	VP11B	VP15A
VP2A	VP6B	VP9A	VP12A	VP16B
VP3B	VP7A	VP10A	VP13B	

2. Operator Qualification:

2.1 The valve pneumatic actuator contains several elastomers which are not listed on the summary sheet. These elastomers act as piston seals and their failure would not affect the safety function of the valve actuator assembly:

2.1.1 In the event of an accident, air is vented from the pneumatic cylinder by a class 1E solenoid valve.

2.1.2 The valves are forced to the closed position by the action of a mechanical spring in the actuator.

2.1.3 Failure of the elastomer piston seals would not impede the action described above.

3. Required Operability:

3.1 LOCA: The safety function of these valves is to isolate Containment Atmosphere in the event of a radiation release inside Containment. The listed accident doses and temperature are for the LOCA.

3.2 Main Steam Line Break: These valves are not required for the Main Steam Line Break Accident.

24" Fisher Containment Isolation Valves - Ref. #1

KEY Code	Polymer	BASIC PARKER O-RING COMPOUNDS	(1) TEMPERATURE RANGE °F	°C
A	Polyacrylate	A607-70	-5/+350	-21/+177
B	Butyl	B318-70	-75/+225	-59/+107
C	Neoprene	C557-70	-45/+300	-43/+149
E	Ethylene Propylene	E540-80	-70/+300	-57/+149
G	SBR	G244-70	-65/+225	-55/+107
L	Fluorosilicone	L677-70	-100/+350	-73/+176
N	Nitrile	N674-70	-30/+250	-34/+121
		N103-70	-65/+225	-55/+107
P	Polyurethane	P642-70	-40/+200	-40/+93
S	Silicone	S604-70	-65/+450	-54/+232
T	Polysulfide	1341-65	-70/+225	-57/+107
V	Fluorocarbon	V747-75	-15/+400	-26/+204

(1) These temperature ranges will apply to the majority of fluids for which the compound is recommended, but in some fluids the range may be different. See figure A3-6 of OR 5700.

COMPATIBILITY RATING

1. Satisfactory
2. Fair (Usually OK for static seal)
3. Doubtful (Sometimes OK for static seal)
4. Unsatisfactory
X. Insufficient Data

	RECOMMENDED O Ring COMPOUND NUMBER	DYNAMIC & STATIC											STATIC ONLY			
		Nitrile	Ethyl.-Prop.	Fluorocarb.	Neoprene	SBR	Polyacrylate	Polyureth.	Butyl	Butadiene	Isoprene	Nat. Rubber	Hypalon	Fluorosilic.	Silicone	Polysulfide
		N	E	V	C	G	A	P	B	D	I	R	H	L	S	T
B																
Bardol B	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	2	4	2
Barium Chloride	N674-70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barium Hydroxide	N674-70	1	1	1	1	1	4	4	1	1	1	1	1	1	1	1
Barium Salts	N674-70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barium Sulfide	N674-70	1	1	1	1	2	4	1	1	2	1	1	1	1	1	2
Bayol D	N674-70	1	4	1	2	4	1	4	4	4	4	4	4	1	4	2
Bayol 35	N674-70	1	4	1	2	4	1	2	4	4	4	4	4	1	4	3
Beer	E716-70	1	1	1	1	1	4	4	1	1	1	1	1	1	1	4
Beet Sugar Liquors	N674-70	1	1	1	2	1	4	4	1	1	1	1	1	1	1	4
Benzaldehyde	E540-80	4	1	4	4	4	4	4	1	4	4	4	4	4	4	4
Benzene	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	1	4	3
Benzenesulfonic Acid 10%	V747-75	4	4	1	2	4	4	4	4	4	4	4	1	2	4	4
Benzine	N674-70	1	4	1	2	4	1	2	4	4	4	4	3	1	4	1
Benzochloride	V747-75	4	1	1	4	4	4	X	2	4	4	4	4	1	X	4
Benzoic Acid	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	2	4	2
Benzophenone	V747-75	X	2	1	X	4	4	4	2	4	4	X	X	1	X	2
Benzyl Alcohol	V747-75	4	2	1	2	4	4	4	2	4	4	4	2	2	X	4
Benzyl Benzoate	V747-75	4	2	1	4	4	4	X	2	4	4	4	4	1	X	4
Benzyl Chloride	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	1	4	4
Black Point 77	N674-70	1	1	1	3	3	3	3	1	3	3	3	3	3	3	3
Black Sulphate Liquors (Ambient temperature)	V494-70	2	2	1	2	2	4	4	2	2	2	2	2	2	2	4
Blast Furnace Gas	S604-70	4	4	1	4	4	4	4	4	4	4	4	4	2	1	4
Bleach Liquor	S604-70	4	1	1	4	4	4	4	1	4	4	4	1	2	2	4
Borax	S604-70	2	1	1	4	2	2	1	1	2	2	2	4	2	2	4
Bordeaux Mixture	S604-70	2	1	1	2	2	4	4	1	2	2	2	1	2	2	4
→ Boric Acid	N674-70	1	1	1	1	1	4	1	1	1	1	1	1	1	1	4
Boron Fluids (HEF)	V747-75	2	4	1	4	4	4	4	4	4	4	4	4	2	4	2
Brake Fluid (Non Petroleum)	E603-70	3	1	4	2	1	X	X	2	X	X	X	2	4	3	4
Bray GG 130	V747-75	2	4	1	4	4	2	4	4	4	4	4	4	2	4	2
Brayco 719-R (VV-H-910)	S604-70	3	1	4	2	X	4	4	2	2	2	2	2	2	2	4
885 (MIL-L-6085A)	V747-75	2	4	1	4	4	2	1	4	4	4	4	4	2	4	2
Brayco 910	E515-80	2	1	4	2	2	3	3	1	1	1	1	1	4	4	4
Bret 710	E515-80	2	1	4	2	2	3	3	1	1	1	1	1	4	4	4
Brom - 113	N674-70	3	4	X	4	4	X	X	4	X	X	X	4	X	4	2
- 114	N674-70	2	4	2	2	4	X	X	4	4	4	4	2	X	4	1
Bromine	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	2	4	2
Bromine Pentafluoride	*	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Bromine Trifluoride	*	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Bromine Water	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	2	4	2
Bromobenzene	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	1	4	3
Bromochloro Trifluoroethane	V747-75	4	4	1	4	4	4	4	4	4	4	4	4	2	4	4
Bunker Oil	N674-70	1	4	1	4	1	1	2	4	4	4	4	4	1	2	1
Butadiene (Monomer)	V747-75	4	4	1	4	4	4	4	4	4	4	X	4	1	4	3
Butane	N674-70	1	4	1	1	3	1	4	4	4	4	4	2	1	4	1
Butane, 2,2-Dimethyl	N674-70	1	4	1	2	3	1	4	4	4	4	4	2	1	4	1
2,3-Dimethyl	N674-70	1	4	1	2	3	1	4	4	4	4	4	2	1	4	1
Butanol (Butyl Alcohol)	N674-70	1	2	1	1	1	4	4	2	1	1	1	1	1	2	2
1-Butene, 2-Ethyl	N674-70	1	[illegible]	1	4	4	1	4	4	4	4	4	4	3	4	1
Butter - Animal Fat	N[illegible]-75	1	1	1	2	4	1	1	2	4	4	4	2	1	2	4
N-Butyl Acetate	E540-80	4	2	4	4	4	4	4	2	4	4	4	4	4	4	4
Butyl Acetyl Ricinoleate	E540-80	2	1	1	2	4	X	4	1	4	4	4	2	2	X	X
Butyl Acrylate	1311-65	4	4	4	4	4	4	X	4	4	4	4	4	4	X	2
Butyl Alcohol	N674-70	1	2	1	1	1	4	4	2	1	1	1	1	1	2	2

*Recommend Parker Metal-V-Seals.

. 24" Fisher Containment Isolation Valves - Reference #2

Piston Ring and Seal Ring Materials for Class 600 Designs ED, ET, EWD, AND EWT

Part		Material	Gamma Radiation Limit (Rad)*	Maximum Service Temperature (°F)
Design ED and EWD Piston Ring		Graphite	Suitable for Radiation Service	800
Standard seal ring construction for Design ET thru 6 inches and all Design EWT	Seal ring	Carbon-filled TFE	1 x 10^6	450
		Optional UHMW polyethylene	1 x 10^8	200
	Backup ring	Viton (except for use with steam or hot water)	1 x 10^7	400
		Optional ethylene-propylene	1 x 10^7	300
		Optional nitrile	1 x 10^7	200
Spring-loaded seal ring construction (standard for 8 inch Design ET and optional for 1 thru 6 inch Design ET and all Design EWT	Seal ring	TFE with Hastelloy C spring	1 x 10^6 (consult factory for higher radiation limit)	450
	Backup ring (not used with 7 inch or larger port)	416 stainless steel	Suitable for radiation service	800
	Retaining ring (not used with 7 inch or larger port)	302 stainless steel	Suitable for radiation service	1100

*CAUTION - Evaluate the combined maximum radiation and maximum service temperature of the application before specifying a material.

Trim Materials for Class 600 Designs YD and YS

Body/Bonnet Material	Maximum Pressure Drop*	Trim Designation	Valve Plug	Cage	Seat Ring
ASME SA-216 Grade WCB or ASME SA-217 Grade WC9	Same as working pressure in 4NSG3 for Class 600 Design YD or YS	N-1	ASME SA-351 Grade CA15 Type 410 stainless steel	ACI CB-7CU Grade 17-4 PH stainless steel with H1075 heat-treat procedure	ASTM A582 heat-treated Type 416 stainless steel
	300 psi	N-2†	ASME SA-479 Type 316 stainless steel	ACI CB-7CU Grade 17-4 PH stainless steel with H1075 heat-treat procedure	ASME SA-479 Type 316 stainless steel
ASME SA-351 Grade CF8M	300 psi	N-3†	ASME SA-479 Type 316 stainless steel	ASME SA-351 Grade CF8M electrolized‡ stainless steel	ASME SA-479 Type 316 stainless steel

*Except on converging service for Design YS, where pressure drop limits shown in Bulletin 51.1:YD apply.

†Limited to 300°F with nonlubricating fluids such as superheated steam.

‡Electrolizing is a proprietary process of applying hard chromium alloy to the base material. The resulting surface does not gall, peel, or flake.

Trim Materials for Class 900 Design EP*

Body/Bonnet Material	Trim Designation	Primary Valve Plug	Pilot Plug	Cage and Seat Ring
ASME SA-216 Grade WCB or ASME SA-217 Grade WC9	N-1	ASME SA-479 Type 316L stainless steel with seat and guide hard-surfaced with ASW A5.13 CoCr-A cobalt-chrome	ASME SB-166 Inconel† 600 with seat and guide hard-surfaced with AWS A5.13 CoCr-A cobalt-chrome	ACI CB-7CU Grade 17-4 PH stainless steel with H1075 heat-treat procedure
ASME SA-351 Grade CF8M	N-2	ASME SA-479 Type 316L stainless steel with seat and guide hard-surfaced with AWS A5.13 CoCr-A cobalt-chrome	ASME SB-166 Inconel 600 with seat and guide hard-surfaced with AWS A5.13 CoCr-A cobalt-chrome	ASME SB-166 heat-treated Inconel 718

*Maximum pressure drop is 2000 psi.

†Trademark of International Nickel Co.

Selecting elastomeric seals for nuclear service

Compression set tests have proved more reliable than tensile tests in the selection of elastomer compounds for use as seals in a nuclear environment

Reference # 5
24" Fisher Containment Isolation Valves

By ROBERT BARBARIN, Parker Hannifin Corp./Seal Group

In the early 1960s, the primary test used in selecting elastomers for reactor seals was a tensile test conducted on unstressed slabs of the compounds after they had been subjected to irradiation. These standard tests had the unfortunate ability to make compounds look very appealing to the nuclear engineer while completely failing the primary requirements of seal engineers. Today, a test has been developed which promises to satisfy the demands of both engineers. This is a test to determine the compression set of seals which are simultaneously squeezed (as they would be when installed) and irradiated (as they may be when in service) over prolonged periods. The new data provide criteria by which compounds may be selected for long life, normally requiring replacement only during conservatively scheduled five-year reactor overhauls.

Typical applications for elastomeric seals in and around nuclear reactors include the static seals in pressurized conduits containing radioactive fluids, and the dynamic seals in structural hydraulic snubbers.

Compression set

Compression set may be defined as the percent by which a seal fails to return to its original dimension after compression, expressed as a percent of its deflection. This loss of dimensional memory is due to changes in the elastomer's arrangement and density of molecular cross-links. As the change in cross-linking progresses, the seal will gradually take on the shape of the confining groove and relax the force that it exerts on the confining surfaces.

Since this normally occurs before tensile property changes, the tensile tests are frequently omitted as contemporary criteria for nuclear seal compound selection.

Of the three major types of radiation from nuclear fission, only gamma rays are normally considered a hazard to elastomer seals that are completely enclosed in conventional metal grooves. Alpha and beta rays are effectively stopped by thin metal barriers. Gamma rays, however, easily penetrate the typical elastomeric seal glands and cause cumulative changes in the compounds (see Table 1).

All elastomers tested to date have shown excessive compression set at 10^8 rads, yet a number of compounds showed acceptable compression set at 10^7 rads of gamma radiation dosage.

Therefore, no elastomer known today should be considered for

Table 1. Effects of gamma radiation on the principal properties of elastomeric compounds most often considered for seals in and around nuclear reactors. Compression set tests were conducted at room temperature and 25% deflection, for the number of days noted, while under radiation from cobalt strips in air.

Generic or Base Polymer (Compound No.)	Radiation Dosage in Rads	Hardness in Pts on Shore "A" Scale (Pts Change)	Tensile Strength in Psi @ Break (% Change)	Elongation in % @ Break (% Change)	Modulus in Psi @ 100% Stretch (% Change)	Tear Strength in lb/in. (% Change)	Compression Set Test: Days Deflected	Compression Set Test: CS in % of Original Deflection
Silicone (S455-70)	Original	69	807	117	668	63	93	7.6
	10^7	72 (+3)	733 (-9)	89 (-24)	--	63 (0)	93	31.4
	10^8	85 (+16)	--	--	--	—	93	90.5
Silicone (S604-70)	Original	66	1010	149	695	70	93	3.8
	10^7	69 (+3)	1020 (+1)	129 (-13)	833 (+25)	62 (-11)	93	20.0
	10^8	85 (+19)	939 (-7)	31 (-79)	--	29 (-59)	93	92.4
Ethylene Propylene (E515-80)	Original	78	1450	213	689	164	93	16.2
	10^7	78 (0)	1220 (-16)	176 (-17)	740 (+7)	148 (-10)	93	46.6
	10^8	84 (+6)	1030 (-29)	79 (-63)	--	71 (-57)	93	96.2
Ethylene Propylene (E740-7~~0~~5)	Original	70	2080	233	554	174	93	6.7
	10^7	73 (+3)	2140 (+3)	194 (-17)	808 (+46)	163 (-6)	93	28.6
	10^8	79 (+9)	1700 (-18)	96 (-59)	--	70 (-60)	93	90.5
Fluorocarbon (V747-75)	Original	75	1510	190	634	128	93	14.7
	10^7	76 (+1)	1580 (+5)	130 (-32)	1120 (+77)	87 (-32)	93	66.7
	10^8	88 (+15)	1180 (-22)	29 (-85)	--	82 (-36)	93	93.3
Polyurethane (P642-70)	Original	66	3560	582	342	306	56	17.1
	10^7	67 (+1)	3570 (0)	491 (-16)	444 (+30)	374 (+22)	56	55.2
	10^8	66 (0)	1420 (-60)	201 (-65)	--	146 (-52)	56	91.4
Fluorosilicone (L677-70)	Original	68	1050	180	520	72	128	13.3
	10^7	72 (+4)	668 (-36)	97 (-46)	--	—	128	67.6
	10^8	84 (+16)	—	--	--	—	128	97.1

applications where 10^7 rads dosage will be exceeded between scheduled overhauls.

Table 1 documents several compounds frequently considered for nuclear seals, showing their original properties and those same properties after exposure to 10^7 rads. At this dosage, two silicones, two nitriles and one ethylene propylene compound exhibit acceptable compression set. A second ethylene propylene compound, as well as polyurethane, polyacrylate, fluorocarbon, and fluorosilicone, would not be recommended because they all tested out at marginal or excessive compression set. The results for polyurethane are particularly revealing; the tensile, tear and modulus tests were either unchanged or actually improved by 10^7 rads, but the compression set rose from approximately 17% to over 55%.

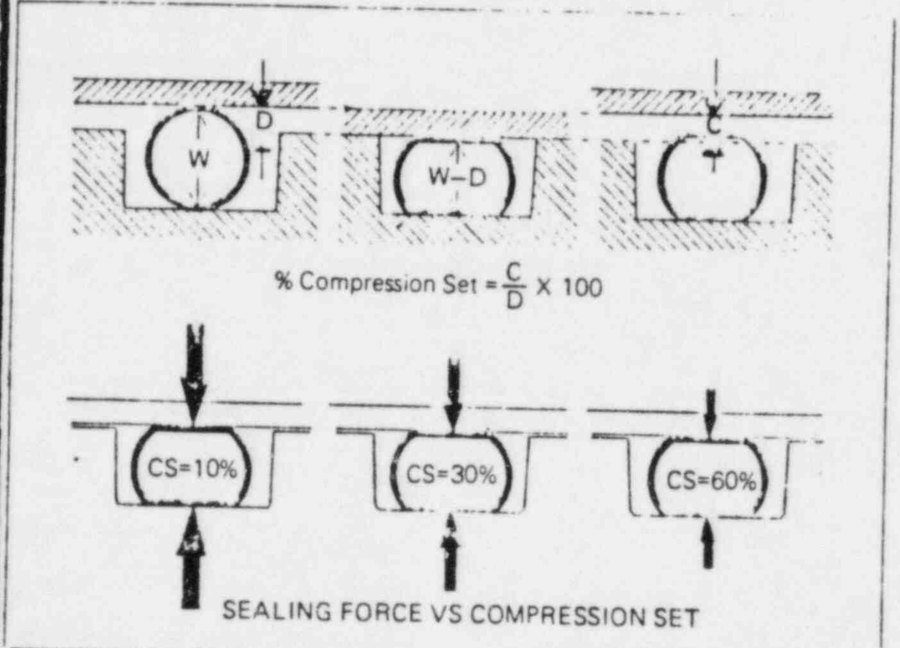

Figure 1. Compression set (the percentage of initial deflection which is unrecovered when a seal is released) directly affects the force that a compression seal can maintain on its sealing lines. This factor, which is increased by radiation, is a prime criterion for the selection of seals for reactors.

Temperatures and fluids

Service temperatures and/or fluids often degrade an elastomer faster and more severely than gamma radiation. This is illustrated clearly by comparisons between Tables 1 and 2. While Table 1 shows the effects of gamma radiation without fluid or temperature influences, Table 2 shows the effects of fluids and temperatures frequently encountered in nuclear reactor environments but without the gamma radiation. It is interesting to note that the polyurethane degradation documented in Table 2 was the result of temperature, but that it would doubtless have been attributed to radiation if it had occurred in a reactor.

The combined effects of radiation, temperature and fluid are seldom a simple addition of their individual effects, but are synergistic. However, knowledge of all three characteristics for each compound will help in the selection of the best compounds for testing.

Table 2. Effects of fluid immersion in principal reactor fluids on polyurethane and ethylene propylene elastomers considered for seals in and around nuclear reactors. Note severe effects of temperature excursions on properties of polyurethane compounds compared to the properties of most ethylene propylenes.

Generic or Base Polymer (Compound No.)	Immersion Test Fluid immersed 3 hrs @ 340F + 3 hrs @ 320F + 18 hrs @ 250F	Hardness in Pts on Shore "A" Scale (Pts Change)	Tensile Strength in Psi @ Break (% Change)	Elongation in % @ Break (% Change)	Modulus in Psi @ 100% Stretch (% Change)	Volume Change in %	Compression Set in % of Original Deflection
Polyurethane (P4611)	Original properties	95	7240	470	1590		
	GE SF 96 Silicone (200 c/s)	89 (-6)	4250 (-41)	537 (+14)	1370 (-14)	-0.8	119.2
	GE SF1154 Silicone	89 (-6)	3650 (-50)	550 (+17)	1400 (-12)	-0.3	cancelled
	Water	89 (-6)	4680 (-35)	576 (+23)	1180 (-26)	+2.3	96.5
Polyurethane (P642-70)	Original properties	66	3780	699	350		
	GE SF 96 Silicone (200 c/s)	Deteriorated				-1.7	cancelled
	GE SF1154 Silicone	Deteriorated				-2.2	cancelled
	Water	Deteriorated					
Ethylene Propylene (E740-75)	Original properties	73	2390	177	991		
	GE SF 96 Silicone (200 c/s)	73 (0)	2800 (+17)	207 (+17)	865 (-13)	-1.5	19.9
	GE SF1154 Silicone	70 (-3)	2660 (+11)	198 (+12)	800 (-19)	+3.0	17.8
	Water	74 (+1)	2600 (+9)	182 (+3)	873 (-12)	0.0	14.4
Ethylene Propylene (E652-90)	Original properties	88	2330	146	1230		
	GE SF 96 Silicone (200 c/s)	91 (+3)	2330 (0)	146 (0)	1500 (+22)	-2.5	44.9
	GE SF1154 Silicone	89 (+1)	2430 (+4)	143 (-2)	1490 (+21)	+0.4	cancelled
	Water	90 (+2)	2450 (+5)	145 (-1)	1430 (+16)	-1.0	42.0
Ethylene [illegible]ylene (E[illegible]29-65)	Original properties	61	1450	273	279		
	GE SF 96 Silicone (200 c/s)	61 (0)	1680 (+16)	317 (+16)	296 (+6)	-4.5	29.6
	GE SF1154 Silicone	60 (-1)	1520 (+5)	279 (+2)	290 (+4)	-2.1	28.4
	Water	61 (0)	1590 (+10)	298 (+9)	276 (-1)	-0.1	29.8
Ethylene Propylene (E692-75)	Original properties	74	1610	239	563		
	GE SF 96 Silicone (200 c/s)	72 (-2)	1350 (-16)	209 (-13)	578 (+3)	-3.4	25.4
	GE SF1154 Silicone	72 (-2)	1620 (+1)	219 (-8)	549 (-2)	+0.8	30.5
	Water	73 (-1)	1100 (-32)	171 (-28)	545 (-3)	+0.2	16.7

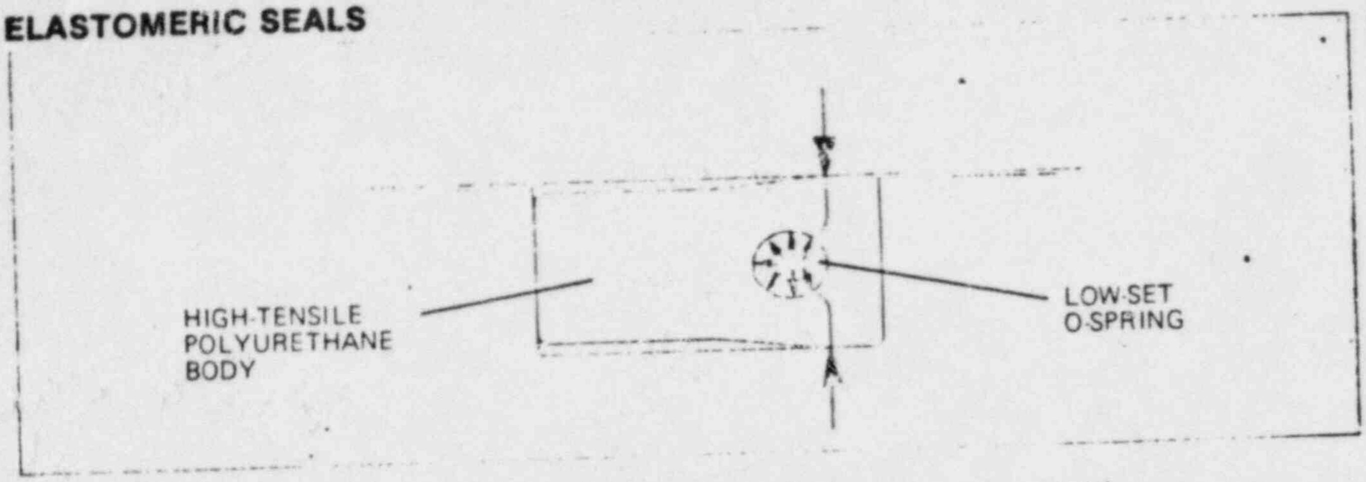

Figure 2. Excellent tensile, tear and modulus properties of polyurethane under radiation may be preserved by a design which compensates for poor compression set under radiation. An O-ring with superior compression set can be used as a spring to energize a polyurethane seal body with superior tensile properties.

Base polymers vs variations

It can be very misleading to ascribe either fluid, temperature or radiation resistant properties to a generic class of elastomers. Variations in compounding within the generic class can cause wide differences in properties. Early tests of nitriles, for example, discouraged their use in reactor environments for many years. However, later tests of other nitrile formulations showed that their compression set properties were among the best when subjected to gamma radiation.

Ethylene propylene is a case in point. The standard Parker E515-80 compound (see Tables 1 and 2) developed nearly twice the compression set and lost significantly more tensile and tear strength than E740-75—another ethylene propylene compound. The E740-75 material has compression set characteristics similar to the silicones and nitriles tested and also has much better resistance than the latter to water and silicone fluids commonly used in reactors.

Silicones are deceptive in that they show excellent compression set characteristics under radiation, but show poor resistance to water and the silicone fluids. This severely limits their usefulness in reactors.

Fluoroelastomers (fluorocarbons and fluorosilicones) have long been equated by many engineers with "the best available" primarily because of their outstanding temperature range. Not only do test results contradict this optimism, with neither recommended for more than 10^6 rads, but fluoroelastomers tend to degrade rapidly in water or steam. Also, some reactor specifications forbid the use of any materials containing fluorine or chlorine. Even if the fluid is compatible, and the radiation tolerance can be accepted at 10^6 rads, such specifications as the AEC's RDT M11-IT may prohibit their use.

Polyurethane takes a rather high compression set in radiation even though its unstressed physical properties hold up well at room temperature after 10^7 rads. It would not be a preferred material for O-rings or other compression type seals. It probably would serve well in an O-ring energized lip seal, however, if the O-ring is radiation-resistant (see Figure 2), or in lip type seals that are activated entirely by *continuous* fluid pressure.

While polyurethane compounds are not generally recommended for use in water fluids, it should be pointed out that the rapid deterioration of the P4611 and P642-70 compounds reported in Table 2 was due primarily to temperature.

Nitrile compounds' resistance to gamma radiation varies greatly, depending on the specific formulation. Thus far, N674-70 and N741-75 are unique in their ability to tolerate 10^7 rads with little compression set. These two formulations, therefore, may become quite useful in some nuclear applications. Even these formulations, however, could not be recommended for long-term use if the sealed fluid were hot air or other critical fluid/temperature combinations.

Polyacrylates are like polyurethanes in that they have a low tolerance for water, especially at higher temperatures, while being quite compatible with silicone fluids up to 350 F. Their compression set properties under radiation usually would suggest switching to the E740-75 ethylene propylene for reactor service.

Work to overhaul periods

Compounds that are recommended for service as seals in reactor environments should have ample remaining life at regularly scheduled overhaul intervals to permit routine replacement without stretching their projected life. Many engineers who inquire about seals ask for 20 to 40 years of service even though shutdown and overhaul is scheduled at 5- or 10-year intervals.

Designers working with elastomeric seals must learn to work to the overhaul periods and not to the reactor life. Even then, it is important to test elastomers under the combined degradation factors anticipated for each application to earn a high confidence factor.

No blanket recommendation can logically be made for the one best seal compound for nuclear reactors or non-nuclear applications. While the E740-75 ethylene propylene compound exhibits the best combination of radiation, fluid and temperature tolerance of all the known contenders for reactor seals, even this excellent compound should be evaluated under the combined conditions for the specific application. Tensile tests alone cannot predict elastomer's response to radiation environments. This may not only lead away from the optimum material, but may lead to a compound that develops excessive compression set early in its exposure to gamma radiation.

END

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CATAWBA NUCLEAR STATION
ENVIRONMENTAL QUALIFICATION OF SAFETY-RELATED MECHANICAL EQUIPMENT

1. EQUIPMENT IDENTIFICATION: Residual Heat Removal Pumps 1A, 1B

2. MANUFACTURER: Ingersoll Rand through Westinghouse NSSS

3. MODEL OR ID NUMBER(S): 8 x 20 WDF

4. ACCIDENT ENVIRONMENT:

PEAK TEMPERATURE: 212 DURATION AT PEAK: 2½ hrs.

RAD: 1.8×10^6

EXPOSED TO CONTAINMENT VESSEL CHEMICAL SPRAY ENVIRONMENT (BORIC ACID & SODIUM HYDROXIDE SOLUTION): No

5. QUALIFIED ENVIRONMENT:

MAT'L	TEMP	RAD	ACCEPTABLE FOR SPRAY	REPLACEMENT INTERVAL	REFS.
EPT	300°F	1.8×10^6	N/A	N/A	1,2,3

6. COMMENTS:

Non-metallics listed are parts of Durametallic Type HPTO Mechanical seal.

Pump is close-coupled to Motor. There are no bearings in the pump. Mechanical seal is cooled by a water-to-water seal injection cooler to ASME III; therefore, seal is not exposed to the external temperature environment. Circulation is by shaft driven pumping ring.

7. REFERENCES:

1. Durametallic Corporation Publication SD-1265
2. Durametallic Corporation Publication SD-1256
3. EPRI NP-2129 "Radiation Effects on Organic Materials in Nuclear Plants" November 1981, pg. 3-24

RESIDUAL HEAT REMOVAL PUMPS

Additional Comments

1. Radiation Qualification: Reference 3 provides test results for several formulations of ethylene propylene and ethylene propylene terpolymer. In each case, the formulations exhibited acceptable performance at radiation levels in excess of the 1.8×10^6 40 year plus one year LOCA dose for this equipment.

2. Reference 2 demonstrates the resistance of the EPT o-rings to high temperature use, as the mechanism for seal failure was demonstrated to be wear of the seal faces. The EPT o-rings remained sound throughout the testing.

RHR Pumps - Reference #1

DURAMETALLIC CORPORATION

Kalamazoo, Michigan

SD-1265
1 January 197
DSR-25

DURA SEAL® RECOMMENDATIONS FOR NUCLEAR POWER PLANTS

INTRODUCTION

In the early 1960's Durametallic recognized the growing importance of nuclear power for generating electricity. The complexity of safety considerations indigenous to this new technology, suggested that mechanical seals would take on new significance in the power industry. In keeping with the reputation for building engineered seals of unsurpassed quality, the decision was made to pursue this new and challenging market.

Since that time, Durametallic has completed a survey of the market potential, concluded a study of the effects of radiation on materials and conducted qualification tests for two major reactor designers. Our performance under test conditions simulating those anticipated during normal operation and emergency reactor cool-down has won unqualified approval of the Dura Seal for use in nuclear power plant primary, auxiliary and emergency system pumps. To substantiate this claim, we are proud to report that as of July 1, 1978, Durametallic seals have been selected for use in 119 domestic and 22 foreign plants.

The following brief review of reactor systems and the pumping services encountered in each of the systems will lead to a better understanding of the conditions imposed on mechanical seals for nuclear power plant liquid handling equipment. A description of the Dura Seals used in each service is included.

REACTOR SYSTEMS

In the Boiling Water Reactor (BWR) system, Fig. 1, water in the reactor is evaporated to steam and passed to the turbines, condensers, feed water heaters and then returned to the reactor by a feed pump. The steam from the reactor is saturated and the pressure is maintained at about 1,000 PSIG. A recirculation pump recirculates the water in the reactor to keep the metal temperature of the reactor core elements at proper values. General Electric Company is the supplier and licensor of BWR systems.

1 of 8

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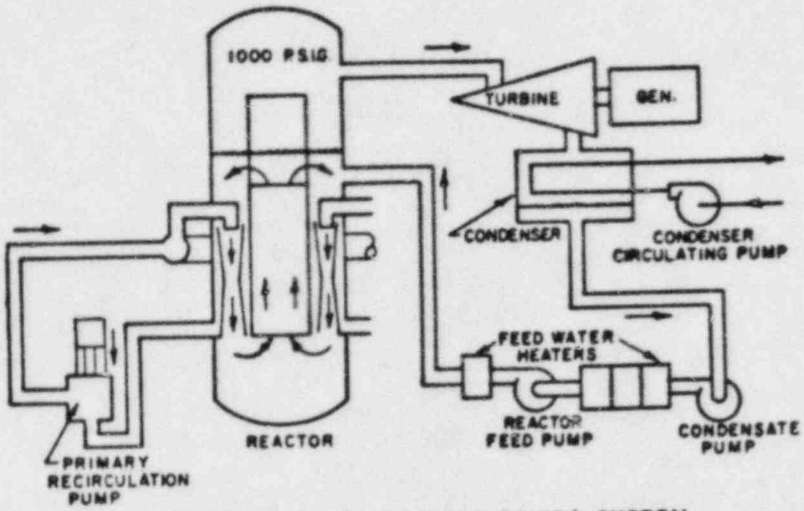

FIG. 1 BOILING WATER REACTOR (BWR) SYSTEM

In the Pressurized Water Reactor (PWR) system, Fig. 2, borated cooling water is pumped through the reactor core to remove heat and transfer it to the steam generators. Steam conditions, saturated at about 1,000 PSIG, are similar to those of the BWR, but the primary water must be at a higher temperature than the steam to make the heat transfer equipment economical and to prevent boiling in the primary loop. Pressures of 2200 PSIG, are maintained by steam pressure in a pressurizer connected to the primary coolant loop. The secondary loop water and steam do not pass through the reactor and, therefore, should not become radioactively contaminated. Babcock & Wilcox Co., Combustion Engineering, Inc., and Westinghouse Electric Corporation Manufacture and License PWR Systems.

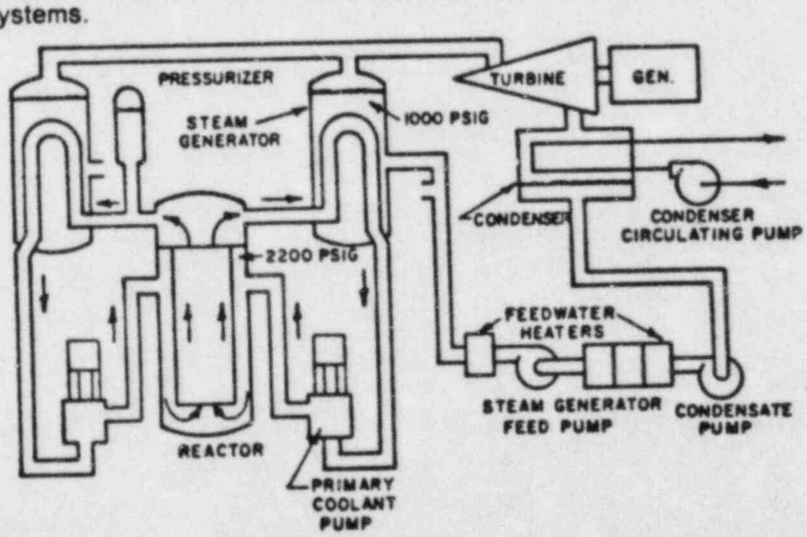

FIG. 2 PRESSURIZED WATER REACTOR (PWR) SYSTEM

The Canadian "Candu" reactor system, Fig. 3 employs natural uranium as fuel rather than enriched uranium that is used in the BWR and PWR systems. The fuel is set in tubes that form part of the primary coolant system pressure boundary. The tubes are spaced in a large vessel containing heavy water as a moderator. In this system, heat transfer is from fuel rods to the heavy water coolant and then to light water in steam generators where boiling occurs. Steam conditions are similar to the BWR and PWR systems but the primary coolant is at lower temperatures.

A fourth type of reactor, the gas cooled reactor, uses helium gas as the primary coolant through the reactor core and steam generators, relying on large compressors to circulate the helium gas.

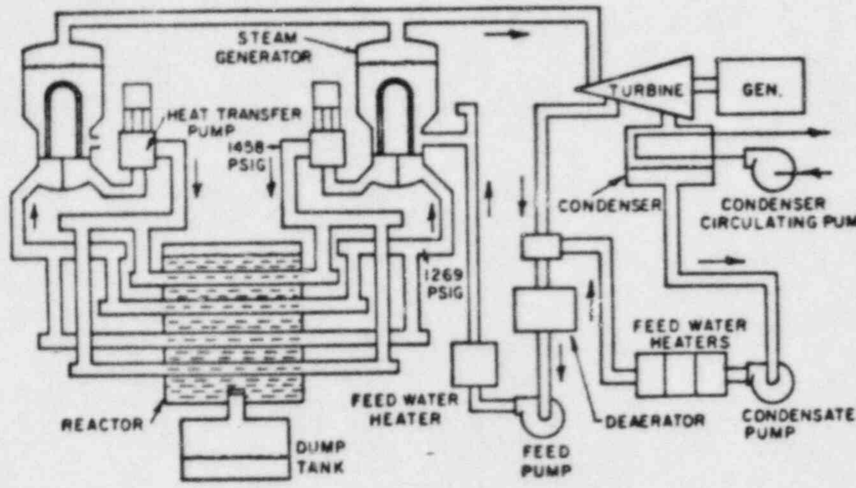

FIG. 3 HEAVY WATER "CANDU" REACTOR SYSTEM

Containment Vessel

The containment vessel is a pressure resistant concrete or metal structure completely surrounding the reactor, steam generators and coolant or recirculation pumps. Its purpose is to prevent escape of radioactivity if pressure boundaries of vessels or piping should fail. The high cost of containment vessels make their size a factor, compelling designers to position equipment carefully and include only what is absolutely necessary. Inaccessibility of the containment vessel interior during operation is another reason for locating equipment outside whenever possible and emphasizing the reliability of what must go inside.

Radioactivity hazards directly influence equipment design. Materials can deteriorate under exposure to radioactivity during the 40-year life assumed for most plants. Elastomers and gasket materials used in mechanical seals are often affected and must be carefully selected. In some cases, no suitable material will last for 40 years, thereby requiring provisions for regular replacement.

Primary Coolant/Recirculation Pumps

These large pumps circulate the cooling water through the reactor. They are the largest pumps in the plant and are normally vertical to conserve space in the containment vessel. The sealing of these pumps has required considerable development and, in general, the pump manufacturers make their own seals. Although Durametallic has not supplied mechanical seals for this service, Durametallic performed a design overview under contract with one of the major primary coolant pump manufacturers.

Feed Pumps

The steam generator feed pump in a PWR and the reactor feed pump in a BWR perform the same function as a boiler feed pump in a fossil-fuel plant; they return the condensate from the feed water heaters to the reactor or steam generators. However, rather than using conventional multistage barrel type boiler feed pumps, the feed pumps for nuclear plants are single stage pumps with double suction impellers and twin volute or diffuser type casings. The operating speeds for these pumps are as high as 6,200 RPM and the stuffing boxes are subject to 300 PSIG pressure and 374° F. temperature. Most feed pumps installed to date utilize controlled leakage throttle bushings for stuffing box sealing which require a constant flow of gland sealing water.

Durametallic is currently working in conjunction with a major manufacturer of these pumps in the development of a suitable high speed - high pressure mechanical seal design for this service.

Feed pumps in Candu reactor systems are fitted with mechanical seals because of the expense of heavy water that would be needed to flush controlled leakage bushings. Cartridge Type HPTO Dura Seals, per Fig. 4, have been supplied for this service.

Figs. 1, 2, & 3 are reprinted from Power, "Nuclear Fluid-Handling Equipment," May 1974

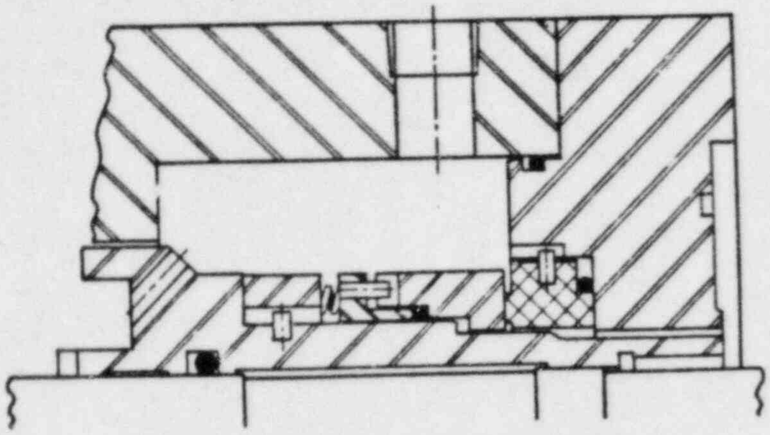

FIG. 4 CARTRIDGE TYPE "HPTO" DURA SEAL.
CANDU REACTOR FEED PUMP

Control Rod Drive Pumps (BWR)

In the BWR system, a hydraulic system is used to drive the control rods in the reactor requiring a pump to circulate the hydraulic medium. A multistage horizontal pump is used for this service with a design pressure of 2,000 PSIG. Cartridge Type PTO Dura Seals, per Fig. 5, are used. Stuffing box pressures do not exceed 300 PSIG and temperatures do not exceed 140°F.

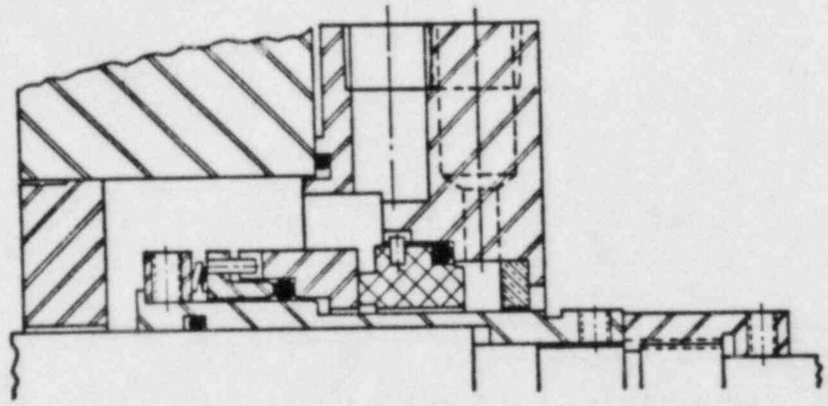

FIG. 5 CARTRIDGE TYPE "PTO" DURA SEAL.
CONTROL ROD DRIVE PUMP

SAFETY RELATED PUMPS

A key to understanding pumps in a nuclear plant is the Safety Classification as indicated in Section III of the ASME Boiler and Pressure Vessel Code. Primary coolant pumps are in Class 1 and are subject to the strictest requirements in design, manufacture and quality assurance. The plant designers' evaluation of the relation of a pump to the plant's safety determines the safety class of the pump. There are numerous safety related pumps in the nuclear power plant system, most of which fall within Class 2 with others in the lower Class 3.

Charging Pumps (PWR)

In the PWR system, a bypass flow from the primary coolant loop is passed through heat exchangers and demineralizers which treat and clean the water. A high pressure multistage barrel type charging pump, capable of overcoming full primary loop pressure, takes the treated water from a volume control tank and delivers it to the primary coolant loop, the pressurizer or to the primary coolant pump seals. The charging pumps are also used to fill the primary coolant system at startup. In some installations the charging pump is part of the Safety Injection systems and performs dual roles.

These charging pumps operate at speeds as high as 4,850 RPM with the stuffing boxes subjected to pressures up to 1,500 PSIG. Type HPTO Dura Seals as shown in Fig. 6 have been supplied for this service.

A smaller boric acid charge pump, usually a reciprocating pump, is used to maintain the boric acid concentration in the primary coolant loop. These reciprocating pumps are fitted with spring-loaded rod packing. Durametallic furnishes the spring assembly.

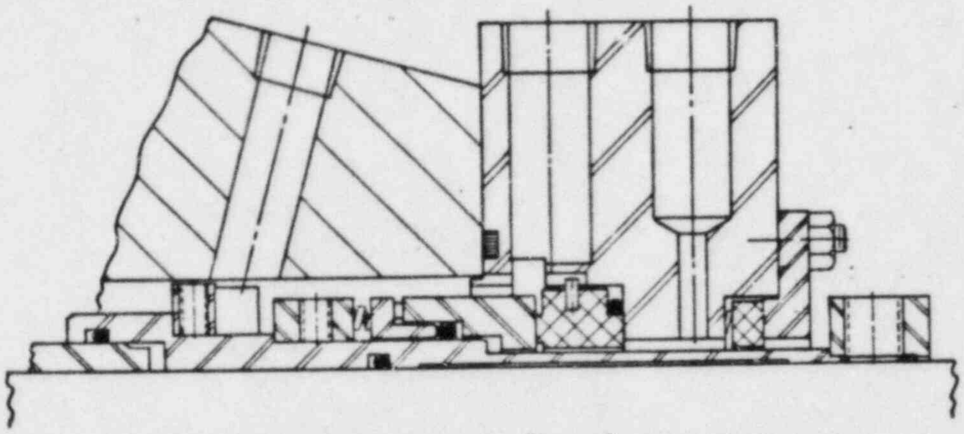

FIG. 6 CARTRIDGE TYPE "HPTO" DURA SEAL
W/ CIRCULATING RING & FLOATING THROTTLE BUSHING.
CHARGING PUMP

Clean-up Recirculation Pumps (BWR)

In the BWR system, the feed pump performs the function of a charge pump. However, water clean-up is necessary and is also done by a bypass flow from the primary coolant loop. Clean-up recirculation pumps are used to inject the cleaned demineralized water back into the primary system. In plants using high pressure demineralizers, the pump are only required to produce heads necessary to overcome system losses. These pumps are single stage, overhung impeller designs with the stuffing boxes subjected to 1050 PSIG suction pressure and utilize Type HPTO Dura Seals as shown in Fig. 7. A Dura circulating ring and an external water cooled heat exchanger is used to control the stuffing box temperature.

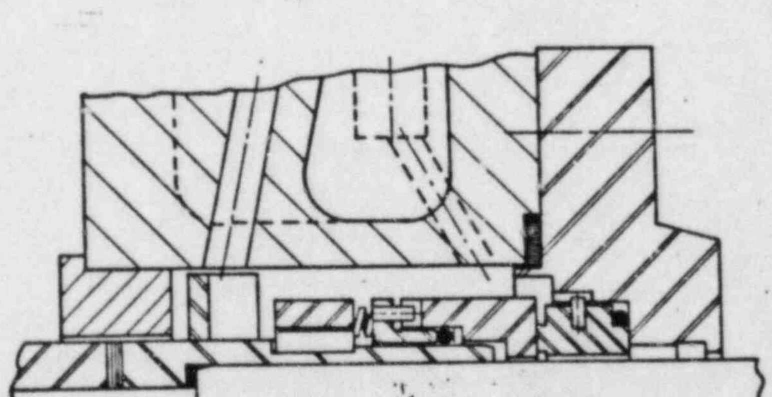

FIG. 7 TYPE "HPTO" DURA SEAL W/ CIRCULATING RING.
CLEAN-UP RECIRCULATION PUMP

5 of 8

Residual Heat Removal Pumps

Both BWR and PWR plants have residual heat removal systems which remove heat from the reactor core during shutdown and refueling. Both vertical and horizontal single stage pump designs are used operating at 1800 or 3600 RPM. Although design pressures are below 500 PSIG, Type HPTO Dura Seals with circulating ring, as shown in Fig. 8, are used to withstand the high hydrostatic test pressure imposed on the pump. A floating throttle bushing is incorporated in the gland ring to control leakage in the event of a seal failure. This auxiliary device is available with any of the seal designs shown.

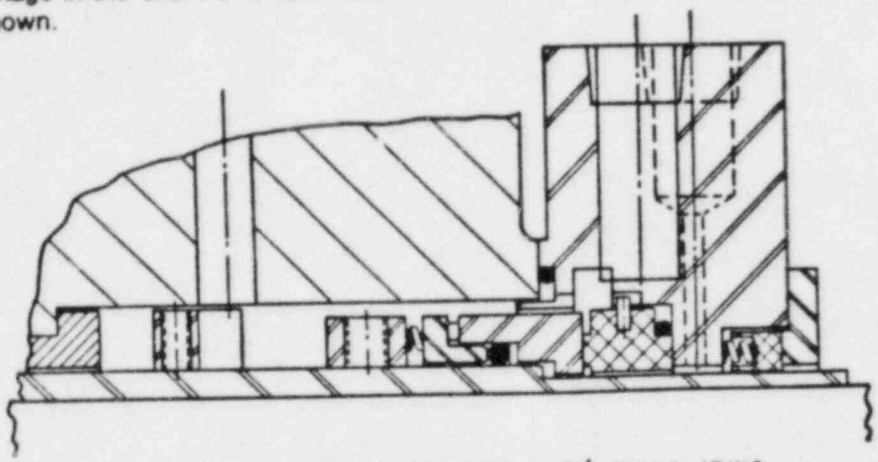

FIG. 8 TYPE "HPTO" DURA SEAL W/ CIRCULATING RING & FLOATING THROTTLE BUSHING. RESIDUAL HEAT REMOVAL PUMP

Emergency Core Spray Pumps (BWR), Safety Injection Pumps (PWR) and Standby Cooling Pumps (Candu)

Emergency systems, activated in the event of a loss-of-coolant accident, pump water to the reactor core to prevent fuel-rod cladding damage. In the BWR system, emergency core spray pumps perform this function while safety injection pumps perform similar tasks in the PWR system.

High pressure core spray and safety injection pumps must be able to overcome the pressure in the reactor. Vertical and horizontal multistage pumps operating at 1800 or 3600 RPM are used. Although high discharge pressures are required suction pressures are low, below 100 PSIG, taking suction from the suppression pool or storage tanks. Here again, although stuffing box pressures are low, Type HPTO Dura Seals per Fig. 9 are used to withstand high hydrostatic test pressures.

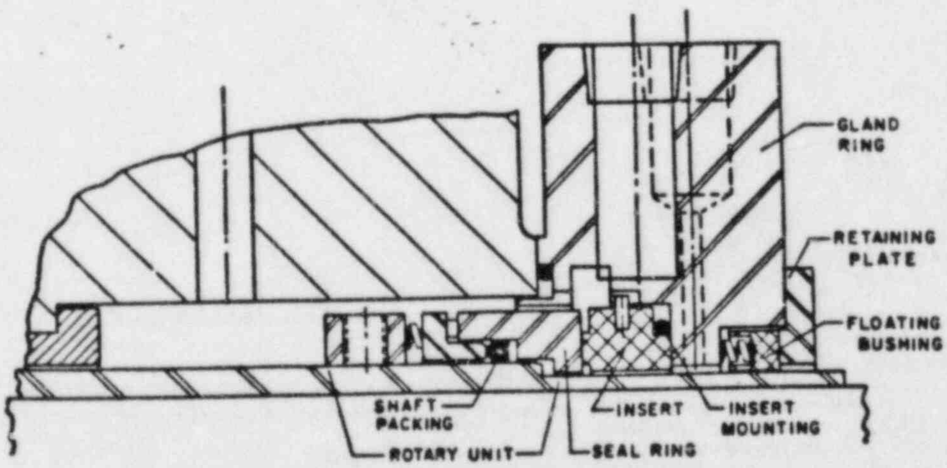

FIG. 9 TYPE "HPTO" DURA SEAL W/ FLOATING THROTTLE BUSHING.

6 of 8

Reactor Core Isolation Pumps (BWR) and Containment Spray Pumps (PWR)

A major accident would result in isolation of the reactor core from the plant condenser and from the feedwater flow. Should such isolation occur, the reactor would continue to generate steam. Reactor cc 'e isolation pumps in the BWR and containment spray pumps in the PWR deliver water to the reactor head and cores from the suppression pooi, storage tank or heat exchanger.

Reactor core isolation pumps are horizontal multistage barrel type pumps operating at turbine speeds of about 4500 RPM delivering pressures up to 1500 PSIG. Section pressures and corresponding stuffing box pressures are low, below 100 PSIG, requiring Type PTO Dura Seals, covered by Fig. 9.

Containment spray pumps are single stage vertical pumps operating at 1800 RPM. Design pressures are 550 PSIG and Type PTO Dura Seals are used as above.

Other Safety Related Pumps

All of the safety related pumps covered above are generally Class 2 pumps. There are other safety related pumps falling in the Class 3 category; such as fuel pool cooling, flash tank, reactor drain, etc., pumps which are single stage, overhung impeller, horizontal pump designs. Speeds are low, 1800 and 3600 RPM, pressures are low, 150 PSIG, and Type PTO Dura Seals per Fig. 9 are used.

Radioactive Waste System

Each nuclear power plant must have a rad-waste system to remove and concentrate gas and liquid wastes throughout the plant. The rad-waste system contains any number of holding tanks, flash tanks and an ion exchange system. Several pumps are used in the system, most of which are single stage overhung impeller horizontal ANSI B-73.1 pump designs. Both single Type RO per Fig. 10 and double Types RO per Fig. 11 or CRO unbalanced Dura Seals are used for these low pressure services.

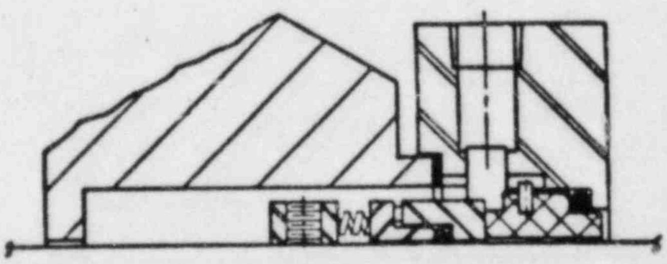

FIG. 10 INSIDE RO

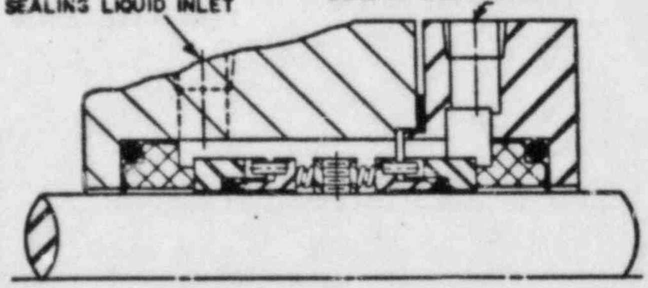

FIG. 11 DOUBLE RO ARRANGEMENT

MATERIALS OF CONSTRUCTION

Codes and standards set requirements for the design, manufacture, installation and operation of nuclear equipment. Section III of the ASME Boiler and Pressure Vessel Code governs the pressure boundaries of code-stamped fluid handling equipment. Mechanical seals are specifically excluded from the requirements of the ASME Code. However, the mechanical seal gland ring is considered a pressure boundary in most cases and is, therefore, covered by the Code. The gland ring, then, must be designed and manufactured in accordance with the Code, be of an approved material, and be covered by appropriate quality assurance.

The primary concern for radiation resistant materials in mechanical seals for nuclear services is the secondary seal elastomers. Table I covers the radiation and temperature limits of common secondary seal elastomers. Requirements for these elastomers other than radiation resistance are covered by Nuclear Regulatory Commission RDT Standard M11-1T. "Non-metallic Seal Materials."

7 of 8

TABLE I

RADIATION AND TEMPERATURE LIMITS OF SECONDARY SEAL MATERIALS

MATERIAL	RADIATION LIMITS, RADS	TEMP. LIMITS,* °F	MATERIAL	RADIATION LIMITS, RADS	TEMP. LIMITS,* °F
Neoprene	4×10^7	90	Viton	1×10^8	350
EPT	2×10^7	350	Buna "N"	1×10^8	225
Silicone	1×10^7	225	Duraflon (PTFE)	5×10^4	350
EPR	1×10^8	350	Glass Filled Duraflon	5×10^4	450

* Temperature limits shown are that for boric acid solutions.

Recommended Materials for Dura Seals (See Fig. 9 for Nomenclature)

Rotary Unit:
- Major Metal Parts: 316 Stainless Steel per ASTM A-276 or A-479
- Springs, Pins, Set Screws: 20 Stainless Steel similar to ASTM B-473

Seal Ring: Tung Car 62-6 (6% Nickel Binder)

Shaft Packing and Insert Mounting: EPT

Insert and Throttle Bushing: #5 Carbon - Graphite

Gland Ring and/or Retaining Plate: 316 Stainless Steel per ASME SA-479 (Bar), ASME SA-240 (Plate) or ASME SA-182 (Forging)

NOTE: Customer must specify acceptable material and required non-destructive testing. Durametallic stocks ASME SA-479 (Bar).

QUALITY ASSURANCE

Suppliers of nuclear equipment must provide adequate documentation that the components are suitable for their intended use and are designed and manufactured in accordance with applicable Codes and Standards. Qualification testing under actual or simulated conditions are often times necessary in order to provide documentation that the components are suitable for intended use. Durametallic performed an extensive test program, the results of which are available upon request, as SD-1256 "Qualification Testing of Dura Seals for Nuclear Power Plant Services."

Suppliers of nuclear components are also required to have an acceptable in-house Quality Assurance Program. Such a program has been in effect at Durametallic Corp., Kalamazoo, Michigan since 1965 and at Durametallic of Canada Ltd., St. Thomas, Ontario since 1976. Numerous quality assurance audits by OEM and user customers have been made resulting in complete approval. Copies of Durametallic Quality Control Manual are available upon request.

868

RHR Pumps- Reference # 2

DURAMETALLIC CORPORATION 2104 Factory Street Kalamazoo, Michigan 49001, U.S.A.

TEST REPORT ON THE QUALIFICATION TESTING OF DURA SEALS FOR NUCLEAR POWER PLANT SERVICES

SD-1256

Printed In USA

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TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

DURAMETALLIC CORPORATION 2104 Factory Street Kalamazoo, Michigan 49001, U.S.A.

INTRODUCTION

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The purpose of this report is to convey the results of our nuclear testing program to the systems designer, pump manufacturer, or engineering contractor, who will find the information useful for projecting what can be expected from the Dura Seal when it is subjected to various environments.

The report includes testing conducted on 2.5% and 5% borated water which would be typically found in Pressurized Water Reactor (PWR) services such as Residual Heat Removal pumps, Containment Spray pumps, Low Pressure and High Pressure Safety Injection pumps, etc. Borated water was chosen since this fluid imposes more severe conditions on seals than the ultra pure water used in Boiling

ter Reactor (BWR) or "Candu" Heavy Water Reactor systems. These tests were conducted without cooling at the request of reactor designers who wanted to evaluate the performance of uncooled seals for emergency core cooling system pumps. We are told that these systems would only be activated at elevated temperatures, should a break occur in the primary circuit resulting in the loss of reactor coolant. Although many nuclear designers currently incorporate provisions for cooling such emergency safeguard equipment, the seal must perform its function without cooling in the event of a simultaneous component cooling system failure. In addition, it has been suggested that some designers may actually prefer reduced seal life to the high cost of installing auxiliary cooling when there is assurance that uncooled seals will function satisfactorily throughout the duration of the emergency reactor cool-down period. It has been further suggested that total system reliability is also enhanced if cooling components susceptible to malfunction can be eliminated without adversly affecting the safety and efficiency of the system. One is not to conclude, however, that Durametallic recommends the elimination of auxiliary cooling for hot water seals. To cool or not to cool is a decision left to the system's designer after reviewing the results of our tests.

The report also includes two other test series; one on 12% borated water which is found in Charging pump services for Pressurized Water Reactors, and the other on high pressure Cleanup Recirculation pump service found in Boiling Water Reactor systems.

We trust that those readers involved in the "nuclear community" will find the contents of this report of both interest and value.

R.E. Battilana

R. E. Battilana,
Manager of Engineering

20

DURAMETALLIC CORPORATION 2104 Factory Street Kalamazoo, Michigan 49001, U.S.A.

SECTION I

THE TESTING OF DURA SEALS IN 2.5% BORATED WATER FOR NUCLEAR POWER PLANT SERVICES

Ref: Durametallic Corporation
Research Report No. 1209-A
October 20, 1976

THE TESTING OF DURA SEALS IN 2.5% BORATED WATER

This report summarizes the testing accomplished by Durametallic Corporation on Dura Seals for use in Nuclear Power Plant pumps handling 2.5% borated water. The summarized data, shown in Table I-1, represents over 4,100 hours of testing, simulating the most severe and adverse conditions that such seals might be subjected to during plant emergency conditions. All the tests that were conducted assume no external cooling was available. Only bypass flushing was used to cool and lubricate the seal faces even under the severe conditions of high temperature with little pressure above the corresponding vapor pressure. All tests were completely successful with no failures encountered during the entire test program.

This series of tests is an update of the test program conducted by Durametallic Corporation in 1969. The 1969 report is still valid in that the basic conditions under which the seals are to operate have not changed appreciably since 1969. However, seal technology has progressed and present seal designs and materials may perform better and withstand more severe conditions with less wear. This latest series of tests show the projected wear life for each of the adverse conditions tested, including the condition of 150°F product temperature and 250 PSIG seal chamber pressure which was not in the 1969 test program. Of special significance are the moderate cycle and rapid cycle tests which severely test the ability of the seal to adapt to rapid changes in temperature and pressure and to determine whether or not boric acid will immobilize or "hang-up" the seal.

CONCLUSIONS

1. Type PTO Dura Seals in the design and materials of construction tested performed totally satisfactory in distilled water containing 2.5% by weight boric acid under all conditions tested.

2. External cooling is not required.

3. Bypass flushing of the pump product from the discharge to the seal faces provides adequate cooling and lubrication.

4. The projected wear life of the seal faces when operated at various steady, stable conditions on a continuous basis were:

CONDITIONS		Projected Wear Life
Product Temp., °F	Pressure	Hours
150	V.P. + 6 ft. head	79,000
150	250 PSIG	40,400
300	V.P. + 6 ft. head	3,800
350	450 PSIG	4,770

5. Wear increases when the conditions are cycled from one to another. However, even after several product temperature and pressure cycles, seal wear was minimal and the seals could be returned to a normal condition and operate satisfactorily.

6. Seal leakage is essentially nil when the seals operate at any single condition on a continuous basis.

7. Seal leakage of a minor nature often occurs when changing from one condition to another.

8. Immobilization or seal "hang-up" from boric acid crystallization on the atmospheric side of the seal could not be made to occur from any combination of cycle changes and/or periodic minor leakage. The boric acid crystals appear to be dissolved and washed away from the seal area by any minor leakage that occured.

TEST SEAL

The seals tested were of 2" shaft size rotating at 3550 RPM and are shown schematically in Figs. I-1 and I-2. Figure I-1 is a PTO Dura Seal design which was used for most of the testing. Figure I-2 is a modified PTO design having the insert supported against the gland in a manner similar to our HPTO high pressure Dura Seal series. The purpose of testing both designs was to indicate that either design performs equally well and could be substituted if the need should arise.

The secondary seals were EPT terpolymer "O" rings in all instances. This compound is approved for use in the radiation environment anticipated for nuclear power plants where such seals are to be used. Other secondary seal materials; such as, Durafite, were not tested because an "O" ring is considered the most reliable and least expensive for this service. At the time of our first report (1969), no elastomer was considered satisfactory, hence the choice of Durafite was mandatory.

No secondary bushing seal was used with the test seals. In our prior testing it was found that such secondary seals did not adversely effect operation or hangup characteristics of the seals. It is even possible that secondary seals may reduce any tendency to hangup the seal by retaining liquid leakage longer and, thereby, tending to wash away any boric acid crystal buildup more readily. Since a design without the secondary seal may present the more severe condition for the seal, it was decided not to include it in the test arrangement.

The rotary seal ring was of solid Tung-Car f2-6 (nickel binder) and the insert of No. 5 carbon. The compression unit was of 316 stainless steel and springs pins and set screws #20 stainless steel.

The insert rubbing face design used for the final testing had a balance of 31% and face width of .175". The insert rubbing face nose length was standard at .125" for both the PTO design and HPTO design inserts. There was no anti-rotation pin used for either insert.

TEST EQUIPMENT AND FLUID

The test arrangement consisted of a heavy duty centrifugal pump circulating product to a 15 gallon accumulator tank. The top of the tank was approximate 6 feet above the seal chamber so that at the vapor pressure condition the seal actually had vapor pressure plus 6 feet of head. Figure I-3 is a schematic of the best arrangement used.

Temperature of the product was monitored by a dial thermometer in the discharge line and a thermocouple in the seal chamber as a double check.

Pressure was maintained by an external air operated pressurizing pump monitored by a calibrated pressure gage in the system.

Environmental control to the seal chamber consisted of a bypass flush from the discharge. A full 1/2" stainless steel tubing bypass line was used. The throat bushing had a .0075" radial clearance. The bypass volume was approximately 1-1/2 GPM for all tests.

The product fluid was distilled water with 2.5% by weight boric acid (4.375 PPM Boron).

TEST CONDITIONS

The specific conditions tested singly and in combination were:

Condition	Product Temperature °F	°C	Seal Chamber Pressure
1	150	66	V.P. + 6 ft. static head
2	150	66	250 PSIG
3	300	148	V.P. + 6 ft. static head
4	350	176	450 PSIG

It is believed that these conditions in various combinations represent the best and worst that might occur to a mechanical seal in a pump used for residual heat removal, containment spray injection, etc.

The tests were broken down into three categories, as follows:

1. Tests at a steady state condition (one condition only). These tests established the wear rate to be expected for each condition of temperature and pressure outlined above.

2. Tests with moderate cycling from condition 3 to 4 and then to 1, which represents a breakdown situation.

3. Tests with multiple cycling of the conditions. These tests were designed to try to foul the seal with boric acid crystals and cause a seal failure due to hangup of some type and are not representative of any set of conditions that might occur, to our knowledge.

It is firmly believed that the seal design presented can withstand any condition or combination of conditions that might occur and recover to operate normally. The entire test series was carried out with the objective of finding a way to fail the seal within the constraints of the conditions that could be encountered. As will be shown, the seal performed extremely well and recovered from adverse conditions many times over.

RESULTS

The results of testing are summarized in Table I-1 and shown graphically in Figures I-4, I-5, and I-6.

STEADY STATE CONDITION TESTS

Tests 1 through 8 of Table I-1 and Figure I-4 show the results of the steady state testing. The results of these tests reveal the expected life for the seals for a variety of potential operating conditions.

Tests 1 and 2 are a condition anticipated as a normal operating condition of 150°F and vapor pressure which may occur for long periods of time. It can be seen that at this condition the seal faces have a projected life of 79,000 hours or more than nine years. In the two tests of 238 hours duration each, used to determine the wear life, there was no measurable wear on the Tung-Car face.

Tests 3 and 4 reveal the wear of the seal if the temperature was 150°F and the pressure in the range of 250 PSIG. This condition may occur for long periods in some systems. The wear of the carbon at this condition was nominal and resulted in a projected seal life of 40,430 hours or nearly five years.

Inspection of the seal faces indicated no pitting or chipping on the carbon face and a narrow groove (.010" - .020" wide) on the Tung-Car seal ring face, adjacent to the O.D. of the contact area of the carbon wear face. This groove was 0.7 mils and 0.55 mils deep respectively and a matching ridge was observed on the carbon nose O.D. The exact cause of this grooving is not understood but it has been observed when sealing hot water and when sealing high pressure using carbon against Tung-Car. This phenomenon was observed in all tests of the series except tests 1 and 2 above where it was not evident. In the very severe test cycles of tests 13 and 14, these grooves were still of nominal depth and width. It is believed that this grooving proceeds to a point and is self-limiting and, therefore, has very little effect on the total projected wear life of the seal.

Tests 5 and 6 conducted at 300°F and vapor pressure represent the most severe conditions for wear since the liquid film between the seal faces turns to a vapor and the faces are essentially running in a vapor. The wear per hour shown on Figure I-4 was .03274 mils per hour for a projected seal life of 3,800 hours. There was no liquid leakage during these tests; however, there were white crystals of boric acid around the area of the pump and base near the seal. These crystals are the evidence of vapor leakage. It is estimated that 5 - 10 grams of crystals were in the area which would translate into 200 to 400 cc of liquid leakage for the test duration of about 72 hours.

Inspection of the carbon wear faces following these tests revealed some face pitting and a few small chips out of the I.D. edge. The damage was not extensive and the seal would have returned to normal operation without difficulty.

Inspection of the Tung-Car face revealed a narrow groove about 0.6 mils deep at the O.D. contact area of the carbon face. This groove and corresponding ridge in the carbon were about the same as that observed in Tests 3 and 4.

It was evident that the seal would perform satisfactorily under this adverse condition and that it may have a reasonably long life (3800 hours projected) even when operated at this condition continuously.

Tests 7 and 8 conducted at 350°F and 450 PSIG represent another severe condition, principally due to the high temperature. Again a condition of emergency rather than norm is portrayed. The wear per hour averaged .0262 mils per hour which translates into a seal life of 4770 hours duration. Throughout these tests there was no liquid leakage except small amounts of boric acid crystals.

Inspection of the carbon revealed face pitting and minor chips on both I.D. and O.D. The damage was not extensive and the seal appeared that it would return to normal conditions without difficulty.

The Tung-Car seal ring revealed little effect except the small groove adjacent to the O.D. of the carbon wear face similar to that noted in tests 3 and 4. A measurement of depth was not taken.

MODERATE CYCLING TESTS

Tests 9, 10, and 11 of Table I-1 and Figure I-5 show the effects of a moderate cycle from one condition to another. These tests attempt to illustrate that the seal design will perform even in an emergency operating condition such as 300°F and vapor pressure and the condition changes to 350°F and 450 PSIG and then returns to more normal condition of 150°F and vapor pressure. The 150°F and 250 PSIG condition was not used because it is not as severe as that to 150°F and vapor pressure.

Figure I-5 shows the exact cycle and time at each condition for the tests. The total wear on the carbon is also shown and the total measurable leakage at each condition is noted. It can be seen that both wear and leakage were relatively constant from test to test. Most of the leakage occurred over a short period of time, usually following or during a change from one condition to another. There was a considerable buildup of boric acid crystals around the gland and shaft where leakage is expelled but the seal was apparently not "hung-up" or hampered since it recovered to leak-free operation in each instance. Again the leakage was often in the form of crystals rather than liquid and the amount is approximate and probably low since crystals often floated into the air and were lost. The notation of "nil" for leakage denoted that the amount of boric acid crystals was very small and not readily collectable.

The wear was generally [illegible] for each test. This would indicate that changing conditions increases wear considerably as compared to a steady state condition.

The carbon insert faces appeared satisfactory after each test with only minor pitting and chipping to indicate the severe conditions encountered.

The Tung-Car seal rings revealed the groove at the O.D. of the contact area with the carbon. The groove was 1.2 mils deep and after test 10 it was 1.8 mils deep. Test 11 was not measured. The grooves remained at about .020" wide. The groove was somewhat deeper but otherwise the same as observed before.

In all instances the seals performed well and at no time indicated imminent failure. On several occasions at high temperature the seal spit and popped periodically over several hours during changes from one condition to another while the seal re-adjusted to the new condition. This may have been a reaction during the wear-in period of the faces to a new condition and would account for the minor chipping and pitting on the carbon face.

It should be noted that the same carbon was used for tests 9 and 10 which was the PTO design and for test 11 the HPTO design was used. No difference in general operation was noted.

MULTIPLE CYCLING TESTS

Tests 12 and 13 of Table I-1 and Figure I-6 show the results from multiple cycling tests. These tests were conducted principally for the purpose of illustrating the ruggedness and recovery ability of the seal design proposed and to further determine whether or not boric acid solutions in this percentage range could immobilize or hang-up the seal.

Figure I-6 shows the [illegible] history imposed on the seal. Two separate tests were conducted using a [illegible] insert of the HPTO design for each. Table I-2

shows the number of changes and conditions as well as total hours of operation in each condition for the entire test.

It can be seen that Test 12 endured 20 cycles for a total continuous time of 608 hours. After the 20th cycle the seal was leaking at 6 cc per minute but slowing when the test was terminated.

Examination of the seal revealed that the carbon face was severely pitted and several large chips had occurred on the O.D. and I.D. diameters. The cause of the leakage was believed due to face damage rather than seal immobilization. It is believed the seal would have gradually worn in so that the faces would seal off after a period of time. The Tung-Car face had a groove about 2 mils deep adjacent to the O.D. of the carbon rubbing face. Although the groove was a little deeper here than in prior tests, it was of the same general width (.020"). It is felt the extreme cycling would represent the very worst conditions for grooving that might be encountered. It is believed that about a 2-3 mil deep groove is about the worst that will be encountered and that this phenomena would not seriously effect seal life when returned to a normal condition.

Test 13 was a repeat of Test 12 with a new carbon and re-lapped Tung-Car seal ring. After 27 cycles and 905 hours, the test was terminated even though the seal was operating leak-free and satisfactorily. The test proceeded similar to test 12 in that minor leakage occurred at several times during the test, always related to a changing condition. In all cases the leakage stopped or became nil after a few hours operation.

Upon tear-down, the carbon appeared similar to that in test 12 but not as badly pitted. The Tung-Car seal ring had a groove 2.2 mils deep.

The wear on the carbon seal faces was extensive at 22.7 mils and 50 mils respectively but in consideration of the extensive cycling and conditions the faces held up well and the wear was moderate.

WEAR RATE AND PROJECTED SEAL LIFE

The projected seal life for the seal was determined based on the wear that occurred to the carbon graphite stationary element. The wear nose on the carbon is .125" long and its useful life is considered expended when this is worn away. It can be seen, however, that the seal would continue to function once the wear nose is expended since the rotary unit would then begin to wear into the main body of the carbon. The rate of wear would accelerate when the body was reached due to the wider contact area and greater heat generation. Therefore, the seal is considered worn out once the wear nose is expended.

The wear on the Tung-Car seal ring face is many times less than for the carbon and is generally disregarded for normal conditions. In the case of high temperature operation, such as 300°F and vapor pressure and 350°F and 450 PSIG, the tungsten carbide elementdoes wear but again in proportion to the highly accelerated wear of the carbon it is still a small matter and not considered in the projected life of the seal as shown in this report.

A projected seal life is not shown for the moderate cycle and rapid cycle conditions. It is believed that the combination of extreme conditions for such long periods of time would not occur but once and, therefore, a projected life would not be a realistic factor.

LEAKAGE AND IMMOBILIZATION

One of the major concerns witn seals for this service is leakage and the possibility of immobilizing or hanging up the seal. Leakage in particular was quite modest and infrequent throughout this testing. As noted before, it seemed to occur only during a change from one condition to another and even then it did not occur with each change of the same type; it was not predictable as to which change might produce moderate leakage. It could only be speculated, but it is believed that when boric acid crystals build up from vapor leakage, the seal ring tends to be held up by deposits on the sleeve adjacent to the seal faces. This restriction of the forward movement of the seal ring begins to reduce the closing force on the faces which eventually causes some liquid leakage through the faces. The liquid leakage soon washes away the boric acid, which is readily dissolved, and frees the seal ring, thereby stopping leakage.

Immobilization, which is sometimes referred to as hang-up, is related to a deposited buildup usually emanating from between the seal rubbing faces. In this case it may be occurring but, if so, it is also self-destructing by virtue of the leakage.

Upon careful inspection of the seal area after each test, it was noticed that the area adjacent to the seal on the sleeve and in front of the "O" ring shaft packing was clear and free of any boric acid. The area near the outlet to the gland was usually covered with boric acid crystals. The crystal buildup was readily washed away with cool tap water requiring little or no mechanical scrubbing for removal. The ease with which the boric acid crystals were washed away supports our premise that boric acid will not immobilize the seal in any permanent fashion.

It was believed that these tests demonstrated that the seal design will take extensive abuse and continue to seal and that boric acid crystals do not readily immobilize the seal. The number of cycles to extreme conditions and the intermittent liquid leakage during some cycles provided ample opportunity to destroy the seal faces causing extensive leakage or immobilization of the shaft packing or the movable seal ring. The seal withstood all this abuse many times over and it was concluded that the seal will withstand the severe conditions and changes and it should not be immobilized by boric acid crystals under any combination of conditions that might be encountered when sealing 2.5% borated water. In our 1969 Report it was speculated that liquid leakage dissolves and washes away boric acid crystals and these tests seemed to further strenthen this hypothesis.

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TABLE I-1

SUMMARY OF TEST RESULTS: 2.5% BORATED WATER

TEST NO.	PRODUCT CONDITIONS TEMP. °F	PRODUCT CONDITIONS PRESS. PSIG	NUMBER OF CONDITION CHANGES TEMP.	NUMBER OF CONDITION CHANGES PRESS.	TOTAL TEST TIME HOURS	LEAKAGE	TOTAL CARBON WEAR MILS	AVERAGE PROJECTED SEAL LIFE HOURS
STEADY STATE CONDITION TESTS								
1	150	V.P.	0	0	238	Nil	0.45	79600
2	150	V.P.	0	0	238	Nil	0.30	
3	150	250	0	0	351	Nil	1.05	40400
4	150	250	0	0	305	Nil	1.00	
5	300	V.P.	0	0	72	Nil	2.25	3800
6	300	V.P.	0	0	70	Nil	2.40	
7	350	450	0	0	53	Nil	1.10	4770
8	350	450	0	0	92	Nil	2.70	
MODERATE CYCLE CONDITION TESTS								
9	150/350	V.P./450	5	5	324	Nil	17.0	-
10	" "	" "	2	2	348	Fig. I-5	11.0	-
11	" "	" "	3	3	519	Nil	14.2	-
MULTIPLE CYCLE CONDITION TESTS								
12	150/350	V.P./450	20	20	608	Fig. I-6	22.7	-
13	" "	" "	27	27	905	" "	50.7	-

TABLE I-2

NUMBER OF CHANGES TO VARIOUS CONDITIONS FOR MULTIPLE CYCLE TESTS 12 AND 13

TEST NO.	TEST CONDITION	NO. OF TIMES	TOTAL HOURS AT CONDITION
12	150°F & V.P.	8	383
12	300°F & V.P.	7	119
12	350°F & 450 PSIG	5	106
	Total	20	608 hrs.
13	150°F & V.P.	8	465
13	300°F & V.P.	11	264
13	350°F & 450 PSIG	8	176
	Total	27	905 hrs.

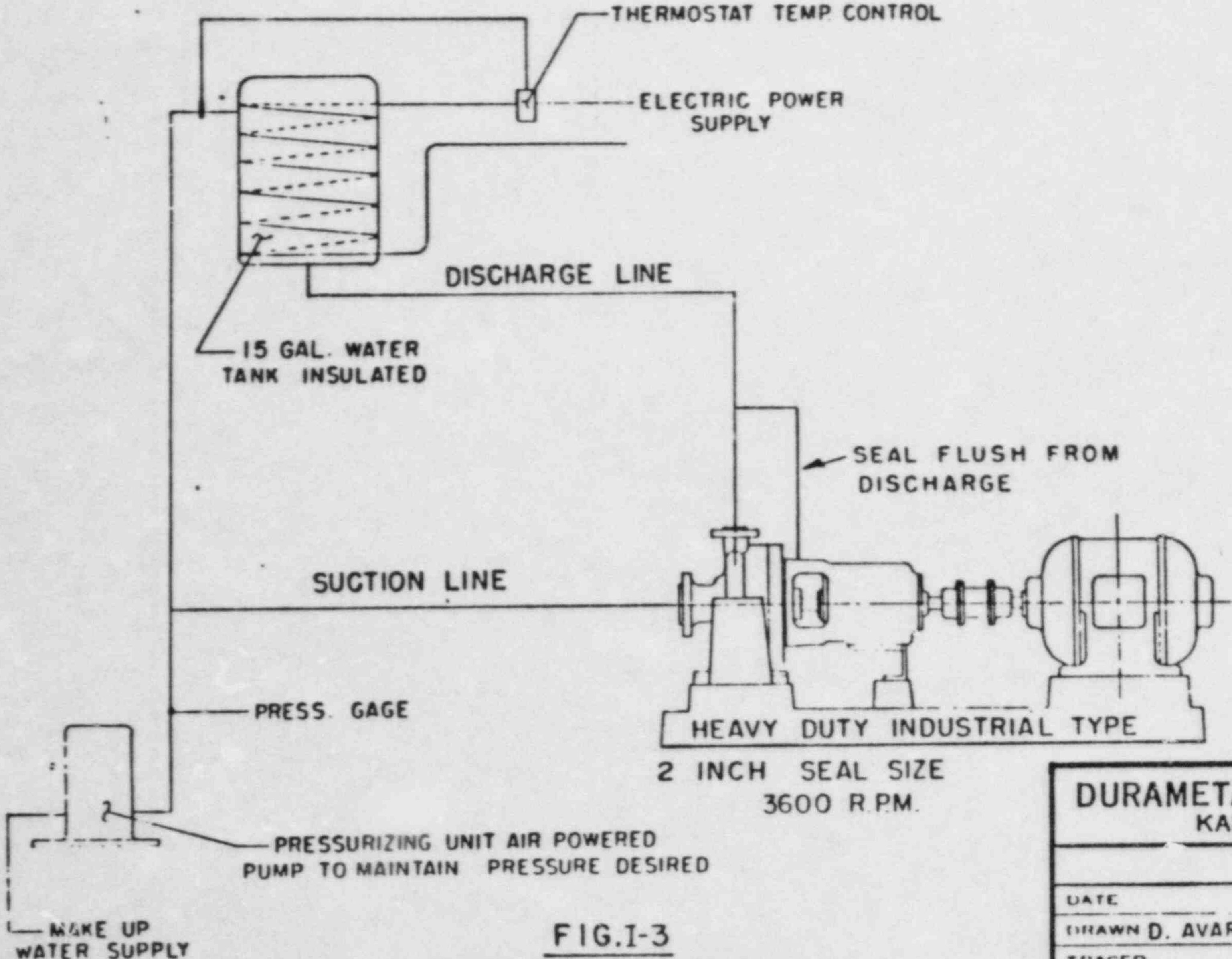


FIG.I-3

SCHEMATIC OF TEST SETUP

DURAMETALLIC CORPORATION
KALAMAZOO, MICH.

DATE	SCALE NONE
DRAWN D. AVARD	
TRACED	Dwg. No.
CHECKED	

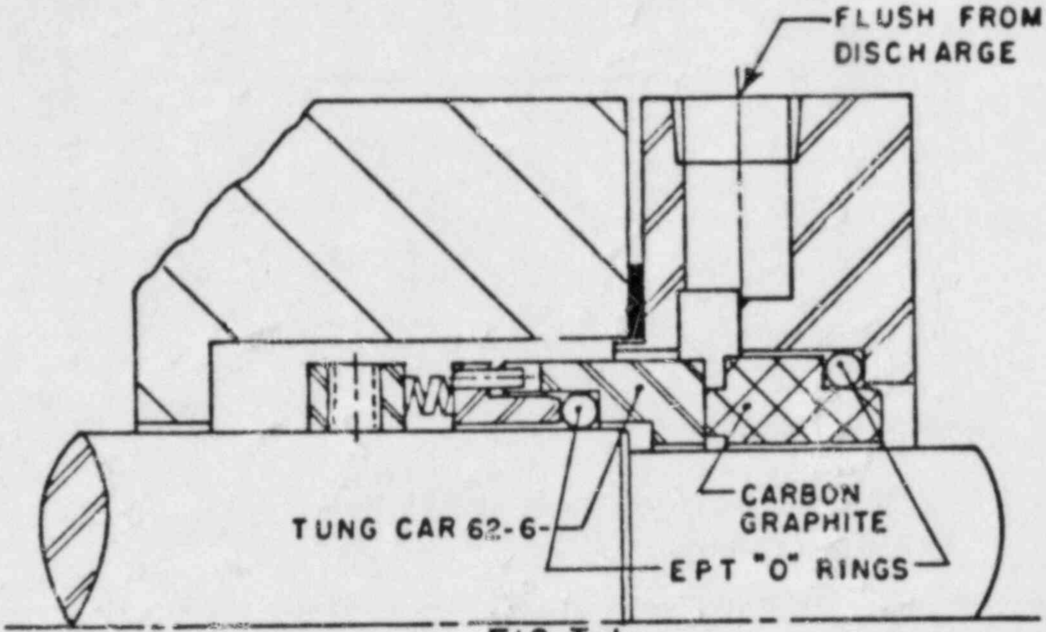


FIG I-1

TYPE "PTO" TEST SEAL WITH BYPASS FLUSH

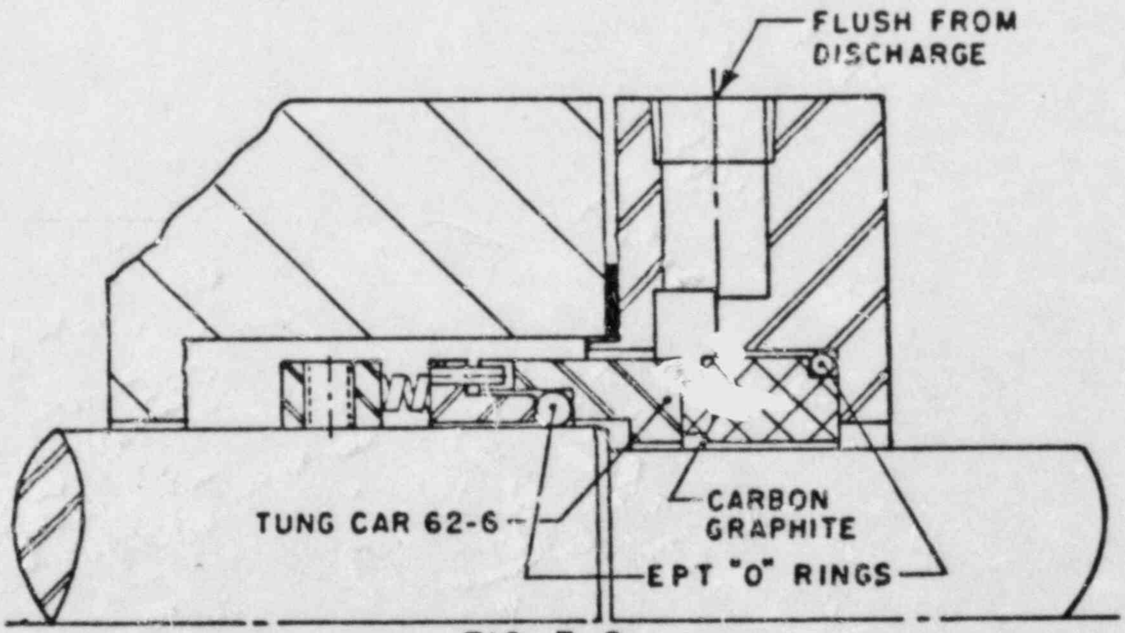


FIG. I-2

MODIFIED TYPE "HPTO" TEST SEAL WITH BYPASS FLUSH

TEST NO.	PRODUCT CONDITIONS TEMP °F	PRODUCT CONDITIONS PRESS P.SIG	TEST TIME, HOURS	TOTAL CARBON WEAR MILS.	TOTAL LEAKAGE C C
9	350 300 150	450 V.P V.P.		17.0	NIL
10	350 300 150	450 V.P V.P.		11.0	160 320 2[illegible]0
11	350 300 150	450 V.P V.P.		14.2	NIL

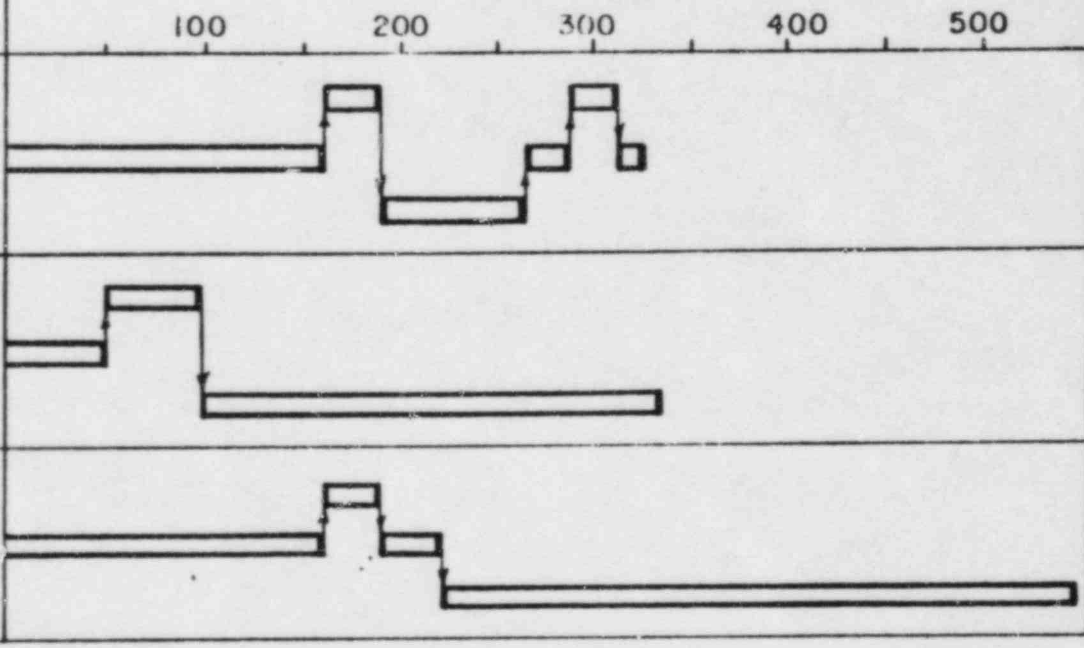
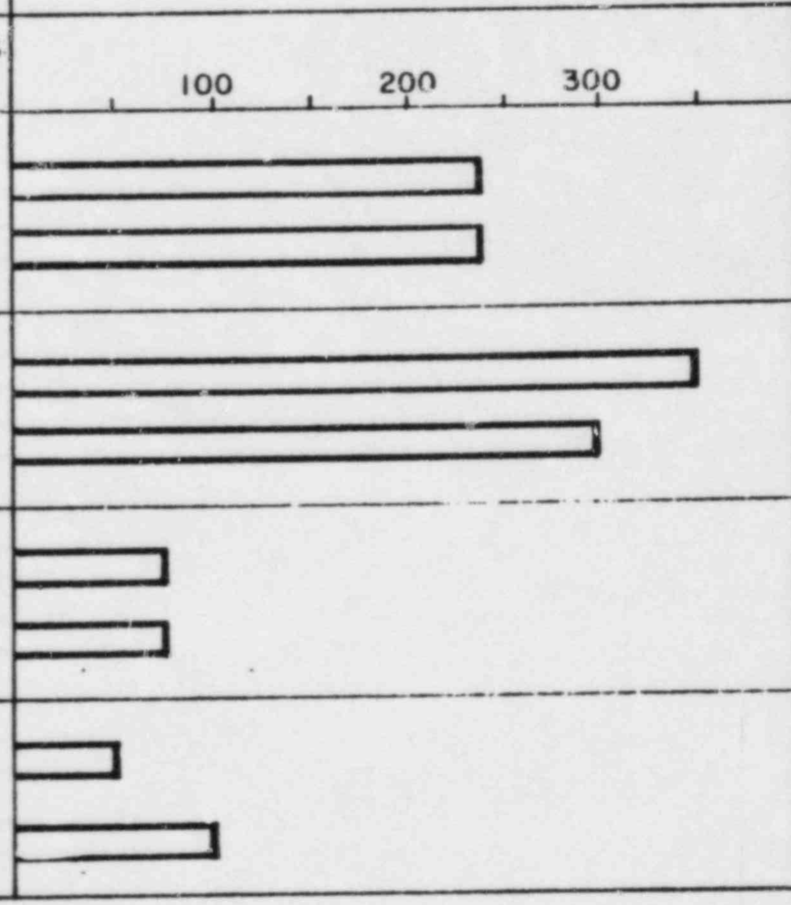


FIG. I-5 MODERATE CYCLING CONDITION TEST RESULTS



TEST NO.	PRODUCT CONDITIONS TEMP. °F	PRODUCT CONDITIONS PRESS. P.S.I.G.	TEST TIME, HOURS	TOTAL CARBON WEAR MILS	PROJECTED SEAL LIFE HOURS
1	150	V.P.		0.45	79,600
2	150	V.P.		0.30	
3	150	250		1.05	40,400
4	150	250		1.00	
5	300	V.P.		2.25	3,800
6	300	V.P.		2.40	
7	350	450		1.10	4,770
8	350	450		2.70	

FIG. I-4 STEADY STATE CONDITION TEST RESULTS

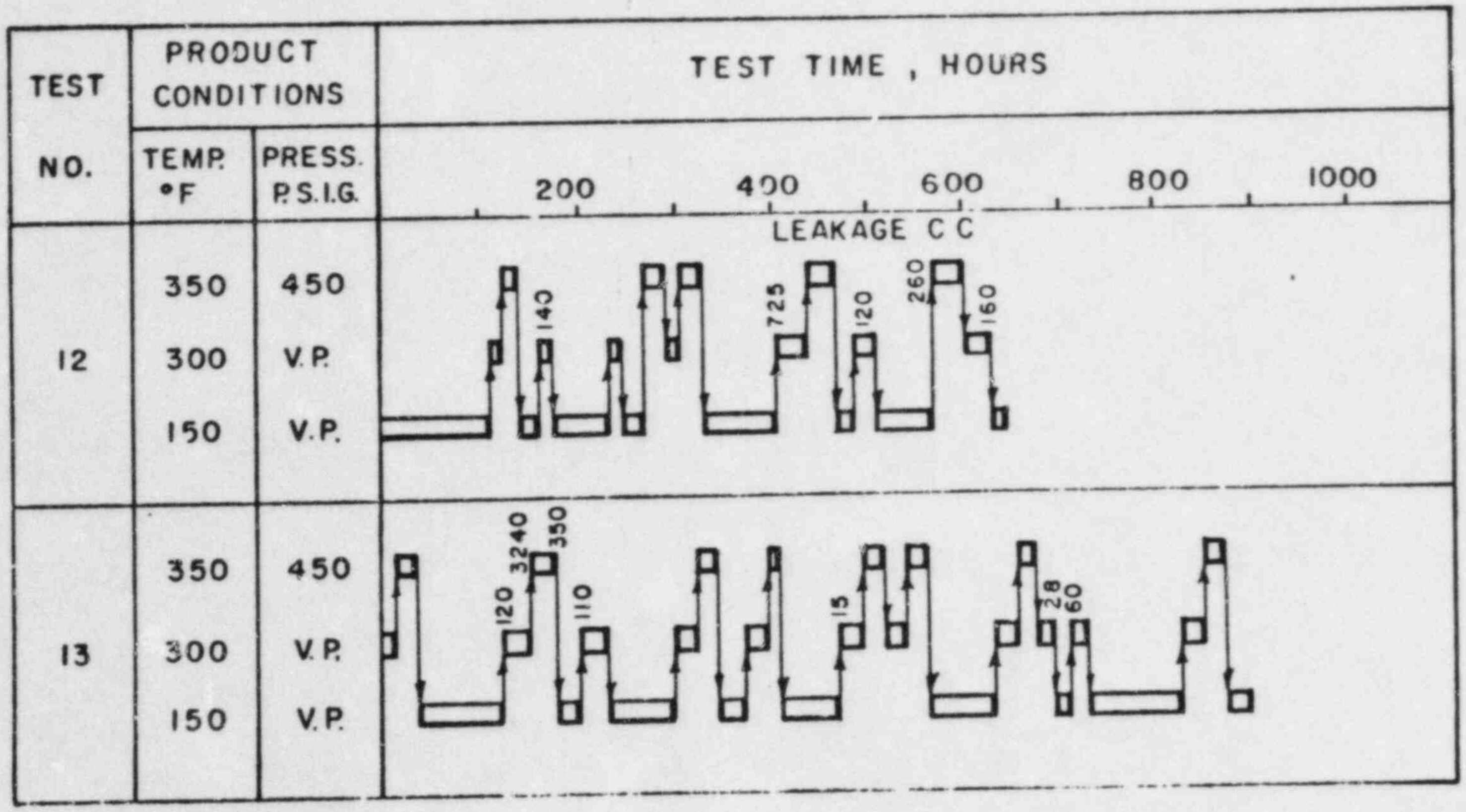


FIG. I-6 MULTIPLE CYCLING CONDITION TEST RESULTS

DURAMETALLIC CORPORATION 2104 Factory Street Kalamazoo, Michigan 49001, U.S.A.

SECTION II

THE TESTING OF DURA SEALS
IN 5% BORATED WATER
FOR NUCLEAR POWER PLANT SERVICES

Ref: Durametallic Corporation

Research Report No. 1209-B

January 16, 1978

Research Report No. 1209-C

May 9, 1978

TESTING OF DURA SEALS
IN 5% BORATED WATER

This report summarizes the testing accomplished by Durar Corporation on Dura Seals for use in Nuclear Power Plant pumps har borated water. The summarized data shown in Table II-1 represent hours of testing, simulating the most severe and adverse conditior seals might be subjected to during plant emergency conditions. A that were conducted assume no external cooling was available. Or ing was used to cool and lubricate the seal faces, even under the of high temperature with little pressure above the corresponding All tests were completely successful with no failures encountered entire test program.

This series of tests parallel the test series conducted water reported in Section I of this report. In addition, a new Carbide, was tested as previous test work indicated its potent pressure nuclear applications because of its superior abrasion high modulus of elasticity.

CONCLUSIONS

1. Type PTO Dura Seals in the design and materials of construction tested performed totally satisfactory in softened water containing 5% by weight boric acid under all conditions tested.

2. External cooling is not required.

3. Bypass flushing of the pump product from the discharge to the faces provides adequate cooling and lubrication.

4. The projected wear life of the seal faces when operated at various steady state conditions on a continuous basis were:

Condition Product Temp., °F	Pressure	Projected Wear Life, Hours
150	V.P. + 6 ft. head	91,000
150	250 PSIG	72,300
300	V.P. + 6 ft. head	4,130
350	450 PSIG	6,490

5. Wear increases when the conditions are cycled from one to another. However, even after several product temperature and pressure cycles, seal leakage was minimal and the seals could be returned to a normal condition and operate satisfactorily.

6. Seal leakage is essentially nil when the seals operate at any single condition on a continuous basis.

7. Seal leakage of a minor nature occurs when changing from one condition to another.

8. Silicon Carbide performs equally as well as Tungsten Carbide when mated against No. 5 carbon. As compared to Tungsten Carbide, under similar operating conditions, there is less wear with Silicon Carbide when mated against No. 5 carbon.

9. Immobilization or seal "hang-up" from boric acid crystals on the atmospheric side of the seal could not be made to occur from any combination of cycle changes and/or periodic minor leakage. The boric acid crystals appear to be dissolved and washed away from the seal area by any minor leakage that occurs.

TEST SEAL

The seal tested was a 2" shaft size rotating at 3550 RPM and is shown schematically in Figures II-1 and II-2. Figure II-1 is a PTO Dura Seal design which was used for most of the testing. Figure II-2 is a modified PTO design having the insert supported against the gland in a manner similar to our HPTO high pressure Dura Seal series. The purpose of testing both designs was to indicate that either design performs equally well and could be substituted if the need should arise.

An auxiliary gland, incorporating Durafite auxiliary shaft packing was used on tests 2, 3, 4, 9, and 10 as shown in Figure II-2 which is the modified HPTO seal design. It was felt that the greatest potential for hang-up would occur when using the modified HPTO arrangement since they tend to leak more than the PTO arrangement, probably due to insert face distortions that are transmitted from the gland when bolts are tightened or when temperature and pressure changes occur. Test 1 was a test of the modified HPTO design without the auxiliary gland. There was no evidence of seal hang-up with either arrangement.

No auxiliary sealing device was used with the PTO design of test seals (tests 5, 6, 7, 8, and 12). In our prior testing it was found that such auxiliary devices did not adversely effect operation or lead to hang-up of the seal. It is even possible that auxiliary devices may reduce any tendency to hang-up the seal by retaining liquid leakage longer and, thereby, tending to wash away any boric acid crystal buildup more readily. Since a design without the auxiliary device may present the more severe condition for the seal, it was chosen not to include it in some of the tests.

The rotary seal ring was of solid Tung-Car 62-6 (nickel binder) for tests 1 through 12 and Sil-Car 1 for tests 13 through 15. The insert was of No. 5 carbon. The compression unit was of 316 stainless steel and springs, pins, and set screws were #20 stainless.

The insert rubbing face design used had a balance of 31% and face width of .175". The insert rubbing face nose length was standard at .125" for both the PTO design and HPTO design inserts. There was no anti-rotation pin drive used for either insert.

TEST EQUIPMENT AND FLUID

The test arrangement consisted of a heavy duty centrifugal pump circulating product to a 15 gallon accumulator tank. The top of the tank was approximately 6 feet above the seal chamber so that at the vapor pressure condition the seal actually had vapor pressure plus 6 feet of static head. Figure I-3 in Section I is a schematic of the test arrangement used.

Temperature of the product was monitored by a dial thermometer in the discharge line and a thermocouple in the seal chamber as a double check.

Pressure was maintained by an external air operated pressurizing pump monitored by a calibrated pressure gage in the system.

Environmental [illegible] consisted of a bypass flush from the discharge [illegible] steel tubing bypass line was used. The throat bushing had a [illegible] clearance. The bypass volume was approximately 1 to 2 GPM for all tests.

The product fluid was softened water with 5 by weight boric acid (8742 PPM Boron).

TEST CONDITIONS

The specific conditions tested singly and in combination were:

Condition	Product Temperature °F	°C	Seal Chamber Pressure
1	150	66	VP + 6 ft. static head
2	200	94	250 PSIG
3	[illegible]	143	VP + 6 ft. static head
4	350	176	450 PSIG

It is believed that these conditions in various combinations represent the best and worst that might occur to a mechanical seal in a pump used for residual heat removal, containment spray, safety injection, etc.

The test were broken down into three categories, as follows:

1. Tests at a steady state condition (one condition only). These tests established the wear rate to be expected for each condition of temperature and pressure outlined above.

2. Tests with moderate cycling from condition 3 to 4 and then to 1, which represent a breakdown situation

3. A test with multiple cycling of the conditions. This test was designed to try to foul the seal with boric acid crystals and cause a seal failure due to hang-up of some type and is not representative of any set of conditions that might occur, to our knowledge.

It is firmly believed that the seal design presented can withstand any condition or combination of conditions that might occur and recover to operate normally. The number 2 and 3 test series were carried out with the objective of finding a way to fail the seal within the constraints of the conditions that could be encountered. As will be shown, the seal performed extremely well and recovered from adverse conditions many times over.

RESULTS

The results of testing are summarized in Table II-1 and shown graphically in Figures II-3, II-4, II-5, and II-6.

STEADY STATE CONDITION TESTS

Tests 1 through [illegible] II-1 and Figure II-3 show the results of the steady state testing. The results of these tests reveal the expected life for the seals for a variety of potential operating conditions.

Tests 1 and 2 are a condition anticipated as a normal operating condition of 150°F and vapor pressure which may occur for long periods of time. It can be seen that at this condition the seal faces have a projected life of 91,000 hours or more than ten years. In the two tests of over 300 hours duration each used to determine the wear life, there was no measurable liquid leakage on one test and an average of 3 cc/hour on the other. The leakage was associated with night operation when the ambient temperature dropped. Both tests used the modified HPTO insert design which is more prone to warpage from gland tightening and temperature and pressure variations.

Tests 3 and 4 reveal the wear of the seal if the temperature was 200°F and the pressure in the range of 250 PSIG. This condition may occur for long periods in some systems. The wear on the carbon at this condition was nominal and resulted in a projected seal life of 72,300 hours or nearly six years.

Inspection of the seal faces indicated no pitting or chipping on the carbon face and a narrow groove (.010" - .020" wide) on the Tung-Car face adjacent to the contact area of the carbon at the O.D. of the wear nose. This groove was 0.6 mils and 0.2 mils deep respectively and a matching ridge was observed on the carbon nose O.D. The exact cause of this grooving is not understood but it has been observed when sealing hot water and when sealing high pressure using carbon against Tung-Car. This phenomena was observed in all tests of the series. In the very severe test cycles of test 12, the groove was still of nominal depth and width. It is believed that this grooving proceeds to a point and is self-limiting and, therefore, has very little effect on the total projected wear life of the seal. For example, tests of a hot water seal after 21,000 hours of operation in 300°F water resulted in the Tung-Car groove still only 0 0017" deep.

Tests 5 and 6 conducted at 300°F and vapor pressure represent the most severe conditions for wear since the liquid film between the seal faces turns to a vapor and the faces are essentially running in a vapor. The wear per hour shown on Figure II-3 was 0.03 mils per hour for a projected seal life of 4,130 hours. There was no liquid leakage during these tests; however, there were white crystals of boric acid around the area of the pump and base near the seal. These crystals are the evidence of vapor leakage. There were very few crystals evident in the area so that leakage was very small during this test.

Inspection of the carbon wear faces following these tests revealed some face pitting and a few small chips out of the I.D. edge. The damage was not extensive and the seal would have returned to normal operation without difficulty.

Inspection of the Tung-Car face revealed a narrow groove about 0.4 mils deep at the O.D. contact area of the carbon face. This groove and corresponding ridge in the carbon were about the same as that observed in Tests 3 and 4.

It was evident that the seal would perform satisfactorily under this adverse condition and that it may have a reasonably long life even when operated at this condition continuously.

Tests 7 and 8 conducted at 350°F and 450 PSIG represent another severe condition, principally due to the high temperature. Again, a condition of emergency rather than norm is portrayed. The wear per hour averaged 0.019 mils per hour which translates into a seal life of 6,490 hours duration. Throughout these tests there was no liquid leakage except small amounts of boric acid crystals.

Inspection of the carbon wear faces revealed face pitting and minor chips on both I.D. and O.D. The damage was not extensive and the seal appeared that it would return to normal operation without difficulty.

The Tung-Car face revealed little effect except the small groove adjacent to the O.D. of the carbon wear face similar to that noted in Tests 3 and 4. The grooves were 0.3 mils and 0.1 mils deep respectively.

MODERATE CYCLING TESTS

Tests 9, 10, and 11 of Table II-1 and Figure II-4 show the effects of a moderate cycle from one condition to another. These tests attempt to illustrate that the seal design will perform when in an emergency operating condition such as 300°F and vapor pressure and the condition changes to 350°F and 450 PSIG and then returns to more normal condition of 150°F and vapor pressure.

Figure II-4 shows the exact cycle and time at each condition for the tests. The total wear on the carbon is also shown and the total measurable leakage at each condition is noted. The wear and leakage varied over a wide range in these tests. The high leakage of test 9 was due, we believe, to a poor job of tightening the gland in the original set up. Once set up, the gland was not re-adjusted to minimize leakage. This illustrates a condition that can occur when using an HPTO insert design. Test 10 used the same type of insert but the gland was adjusted more carefully to minimize leakage. Such adjustment is not difficult but does require some experience. Test 11 used the PTO flexibly mounted design insert and revealed a modest leakage. As in prior testing, much of the leakage occurred during periods of change from one condition of temperature to another. Also, the leakage at the elevated temperatures was in the form of boric acid crystals which were collected and weighed to estimate the amount of liquid leakage. A notation of nil leakage meant that there were not enough crystals to collect although some crystals were present and some floated away in the air.

There were no problems with hang-up of the seal as evidenced by the fact that the seal recovered and operated leak-free after the many upsets.

The wear variation is not readily explainable except that wide variations in wear often occur. In consideration of the large number of temperature and pressure changes, the wear is considered satisfactory. The overall average wear life of the three tests was 6584 hours or about 9 months.

The carbon insert faces appeared satisfactory after each test with only minor pitting and chipping to indicate the severe conditions encountered.

The Tung-Car faces revealed the groove at the O.D. of the contact area with the carbon. The groove was less than 1 mil deep in all three tests and almost 0.020" wide. The Tung-Car seal ring faces appeared very similar to those when 2.5% borated water was tested as reported in Section I. The major difference in seal face appearance was that the grooves in the Tung-Car faces were not as deep when using 5% borated water.

In all instances the seals performed well and at no time indicated imminent failure. On several occasions at high temperature the seal spit and popped periodically over several hours during changes from one condition to another while the seal re-adjusted to the new condition. There may have been a reaction during the wear-in period of the faces to a new condition and would account for the minor chipping and pitting on the carbon face.

A different carbon insert was used for each of the three moderate cycle tests. Tests 9 and 10 used the HPTO design insert and test 11 the PTO design ins

MULTIPLE CYCLING TESTS

Test 12 of Table II-1 and Figure II-5 shows the results from a multiple cycling test. This test was conducted principally for the purpose of illustrating the ruggedness and recovery ability of the seal design proposed and to further determine whether or not boric acid solutions in this percentage range could immobilize or hang-up the seal.

Figure II-5 shows the cycling history imposed on the seal. One test was conducted using a new carbon insert of the PTO design. Table II-2 shows the number of changes and conditions as well as total hours of operation in each condition for the entire test.

It can be seen that test 12 endured 25 cycles for a total continuous time of 655 hours. After the 25th cycle, the seal recovered to operate leak-free at 150°F and vapor pressure.

Examination of the seal revealed that the carbon face was only moderately pitted and that moderate chipping had occurred on the O.D. The Tung-Car face had a groove about 0.8 mils deep by 0.020" wide adjacent to the O.D. of the carbon rubbing face. It is felt the extreme cycling would represent the very worst condition for grooving that might be encountered. It is believed that about a 2-mil deep groove is the worst that will be encountered and that this phenomenon would not seriously effect seal life when returned to a normal condition.

The results of tests 13, 14, and 15 are shown graphically in Figure II-6. These results are comparable to the multiple cycling tests of Figure II-5. The tests on the Sil-Car 1 were not of as long duration but consisted of more time of operation at the V.P. and 300°F condition, which is quite severe from a wear and face damage standpoint. Considering this factor, the carbon wear running against Sil-Car 1 is considerably less than with Tung-Car 62-6. The Tung-Car vs No. 5 carbon in test 12 wore the carbon 28.4 mils whereas test 13 with Sil-Car 1 vs No. 5 carbon wore the carbon only 13.2 mils.

It was concluded that Sil-Car 1 causes less wear on the carbon counterface than that which would occur if Tung-Car were used.

Another factor noted with Tung-Car was that the Tung-Car face was grooved in the area adjacent to the O.D. of the carbon rubbing face. With Tung-Car in test 12, the groove was .0008" deep x .020" wide. In the case of Sil-Car in test 13, the same groove appeared but it was only .0002" deep and about .020" wide. It appears that both materials are grooved but Sil-Car 1 grooves only about 25% as deep as when Tung-Car was used.

It was concluded that both Tung-Car and Sil-Car 1 are grooved by No. 5 carbon when operating in 5% borated water but that Sil-Car 1 is more resistant to this grooving phenomenon.

WEAR RATE AND PROJECTED SEAL LIFE

The projected seal life for the seal was determined based on the wear that occurred to the carbon graphite stationary element. The wear nose on the carbon is 125 mils (.125") long and its useful life is considered expended when this is worn away. It can be seen, however, that the seal would continue to

function once the wear nose is expended since the rotary unit would then begin to wear into the main body of the carbon. The rate of wear would accelerate when the body was reached due to the wider contact area and greater heat generation. Therefore, the seal is considered worn out once the wear nose is expended.

The wear on the tungsten carbide rotary face is many times less than for the carbon and is generally disregarded for normal conditions. In the case of high temperature operation, such as 300°F and vapor pressure and 350°F and 450 PSIG, the tungsten carbide element does wear but again in proportion to the highly accelerated wear of the carbon it is still a small amount and not considered in the projected life of the seal as shown in this report. The wear is generally in the form of a narrow groove, less than 2 mils deep x 10-30 mils wide, at the O.D. of the wear nose track.

A projected seal life is not shown for the moderate cycle and multiple cycle conditions. It is believed that the combination of extreme conditions for such long periods of time would not occur but once and, therefore, a projected life would not be a realistic factor.

LEAKAGE AND IMMOBILIZATION

One of the major concerns with seals for this service is leakage and the possibility of immobilizing or hanging up the seal. Leakage in particular was quite modest and infrequent throughout this testing. As noted before, it seemed to occur only during a change from one condition to another and even then it did not occur with each change of the same type; it was not predictable as to which change might produce moderate leakage. It could only be speculated, but it is believed that when boric acid crystals build up from vapor leakage, the seal ring tends to be held up by deposits on the sleeve adjacent to the seal faces. This restriction of the forward movement of the seal ring begins to reduce the closing force on the faces which eventually causes some liquid leakage through the faces. The liquid leakage soon washes away the boric acid, which is readily dissolved, and frees the seal ring, thereby stopping leakage.

Immobilization, which is sometimes referred to as hang-up, is related to solids emanating from seal face leakage, accumulating on the shaft at the atmospheric side of the shaft packing. In this case it may be occurring but, if so, it is also self-destructing by virtue of the leakage.

Upon careful inspection of the seal area after each test, it was noticed that the area adjacent to the seal on the sleeve and in front of the "O" ring shaft packing was clear and free of any boric acid. The area near the outlet to the gland was usually covered with boric acid crystals. The crystal buildup was readily washed away with cool tap water requiring little or no mechanical scrubbing for removal. The ease with which the boric acid crystals were washed away supports the premise that boric acid will not immobilize the seal in any permanent fashion.

It was believed that multiple cycle testing demonstrated that the seal design will take extensive abuse and continue to seal and that boric acid crystals do not readily immobilize the seal. The number of cycles to extreme conditions and the intermittent liquid leakage during some cycles provided ample opportunity to destroy the seal faces causing extensive leakage or immobilization of the movable seal ring. The seal withstood all this abuse many times over and it was concluded that the seal will withstand the severe conditions and changes and it should not be immobilized by boric acid crystals under any combination of conditions that

might be encountered when sealing 5% borated water. In our 1969 report it was speculated that liquid leakage dissolves and washes away boric acid crystals and these tests seemed to further strengthen this hypothesis. It was evident that as long as the seal leakage is dissolvable in water, the seal should not become immobilized and leak from upset conditions similar to those tested herein.

TABLE II-1

SUMMARY OF TEST RESULTS: 5 BORATED WATER

TEST NO.	PRODUCT CONDITIONS TEMP. °F	PRODUCT CONDITIONS PRESS. PSIG	NUMBER OF CONDITION CHANGES TEMP.	NUMBER OF CONDITION CHANGES PRESS.	TOTAL TEST TIME HOURS	LEAKAGE CC/HR.	TOTAL CARBON WEAR MILS	AVERAGE PROJECTED SEAL LIFE HOURS
STEADY STATE CONDITION TESTS								
1	150	V.P.	0	0	303	Nil	0.60	91,000
2	150	V.P.	0	0	333	3	0.35	
3	200	250	0	0	329	1	0.70	72,300
4	200	250	0	0	309	4	0.45	
5	300	V.P.	0	0	161	Nil	10.0	4,130
6	300	V.P.	0	0	135	Nil	2.7	
7	350	450	0	0	95	Nil	2.4	6,490
8	350	450	0	0	90	Nil	1.4	
MODERATE CYCLE CONDITION TESTS								
9	150/350	V.P./450	10	10	571	26	11.6	-
10	" "	" "	9	9	450	Nil	4.8	-
11	" "	" "	11	11	824	1.5	15.1	
MULTIPLE CYCLE CONDITION TESTS								
12	150/350	V.P./450	25	25	655	Fig. II-5	28.4	-
MULTIPLE CYCLE CONDITION TESTS: SILICON CARBIDE VS NO. 5 CARBON								
13	150/350	V.P./450	13	13	486	Nil	13.2	-
14	" "	" "	3	3	191	Nil	5.8	-
15	" "	" "	12	12	313	Fig. II-6	4.4	-

TABLE II-2

NUMBER OF CHANGES TO VARIOUS CONDITIONS FOR MULTIPLE CYCLE TEST NO. 12

TEST NO.	TEST CONDITION	NO. OF TIMES	TOTAL HOURS AT CONDITION
12	150°F & V.P.	9	459
12	300°F & V.P.	6	114
12	350°F & 450 PSIG	10	82
	Total	25	655

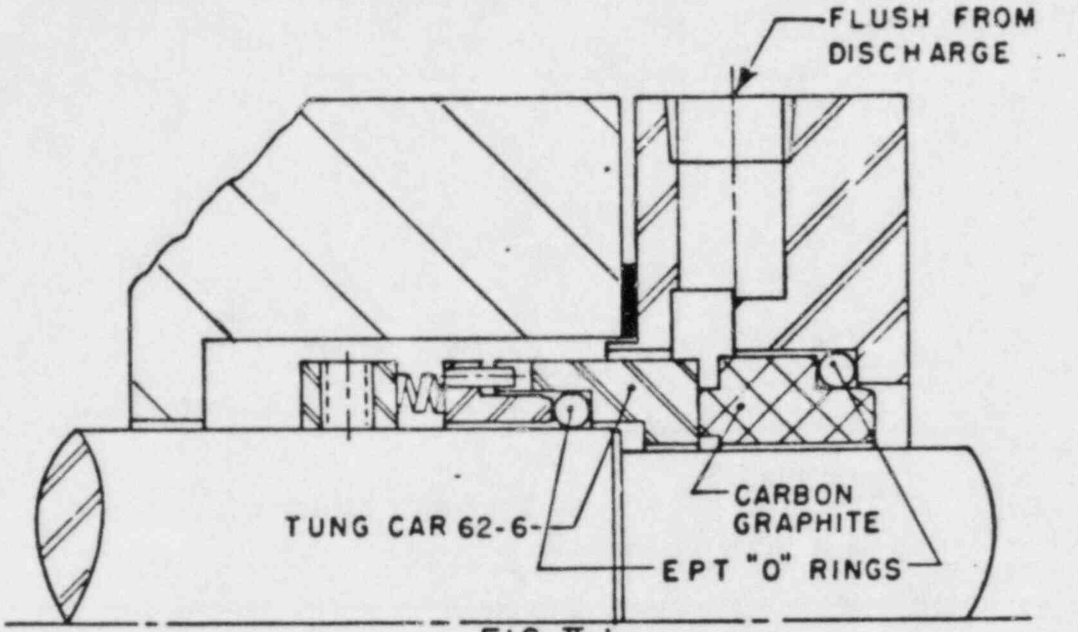


FIG II-1

TYPE "PTO" TEST SEAL WITH BYPASS FLUSH

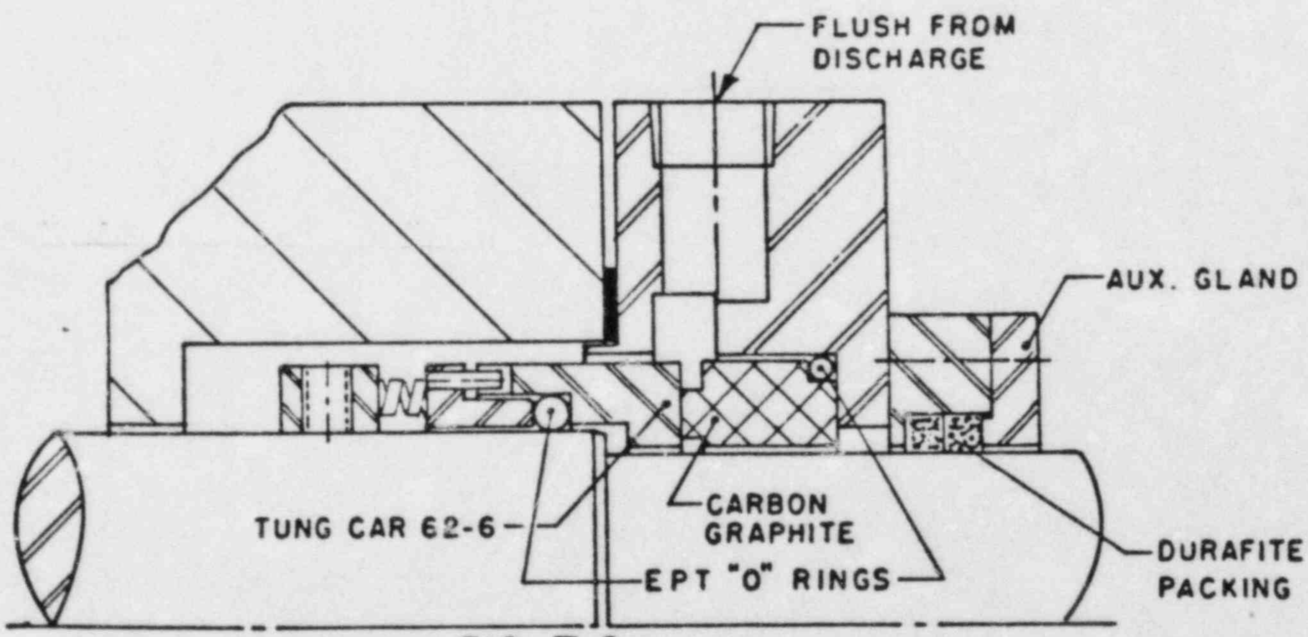


FIG. II-2

MODIFIED TYPE "HPTO" TEST SEAL WITH BYPASS FLUSH

TEST NO.	PRODUCT CONDITIONS TEMP. °F	PRODUCT CONDITIONS PRESS. P.S.I.G.	TEST TIME, HOURS	TOTAL CARBON WEAR MILS	PROJECTED SEAL LIFE HOURS
1	150	V.P.		0.60	91,000
2	150	V.P.		0.35	
3	200	250		0.70	72,300
4	200	250		0.45	
5	300	V.P.		10.0	4,130
6	300	V.P.		2.7	
7	350	450		2.4	6,490
8	350	450		1.4	

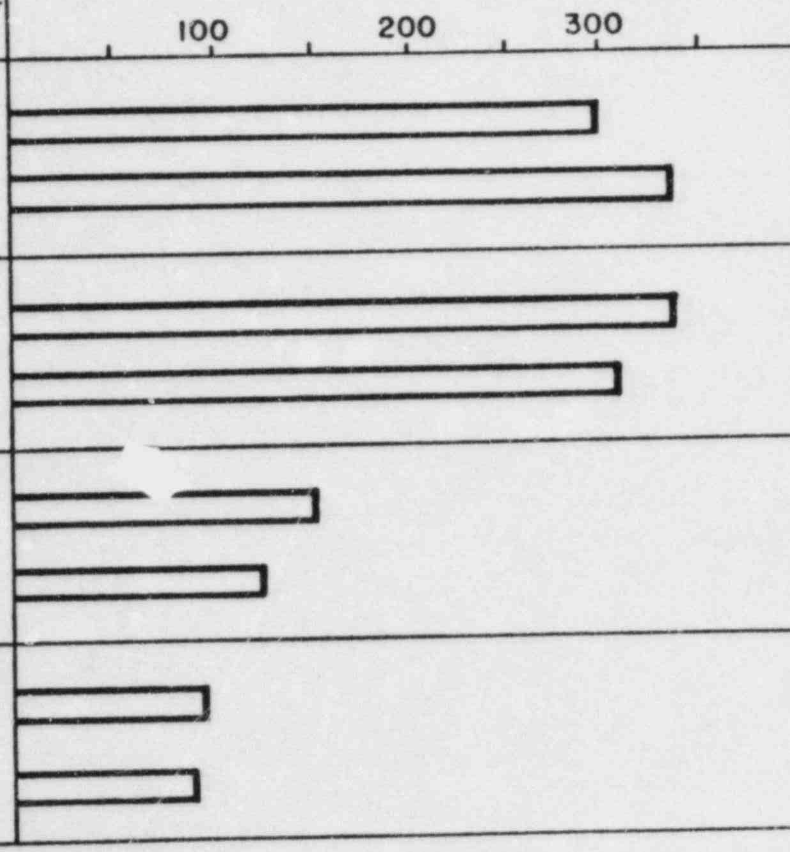


FIG. II-3 STEADY STATE CONDITION TEST RESULTS

50

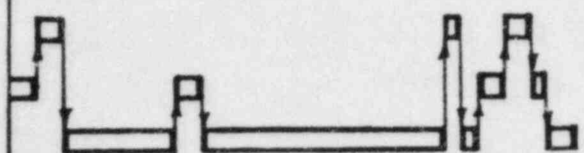
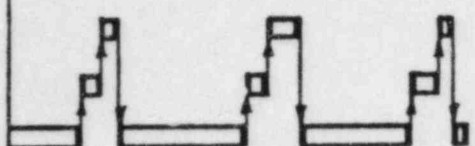
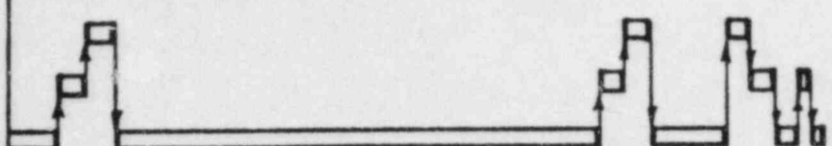
TEST NO.	PRODUCT CONDITIONS TEMP. °F	PRESS. P.S.I.G.	TEST TIME, HOURS (100, 300, 500, 700)	TOTAL CARBON WEAR MILS	TOTAL LEAKAGE C C
9	350	450		11.6	11,130
	300	V. P.			220
	150	V. P.			3,675
10	350	450		4.8	NIL
	300	V. P.			
	150	V. P.			
11	350	450		15.1	80
	300	V. P.			1240
	150	V. P.			

FIG. II - 4 MODERATE CYCLING CONDITION TEST RESULTS

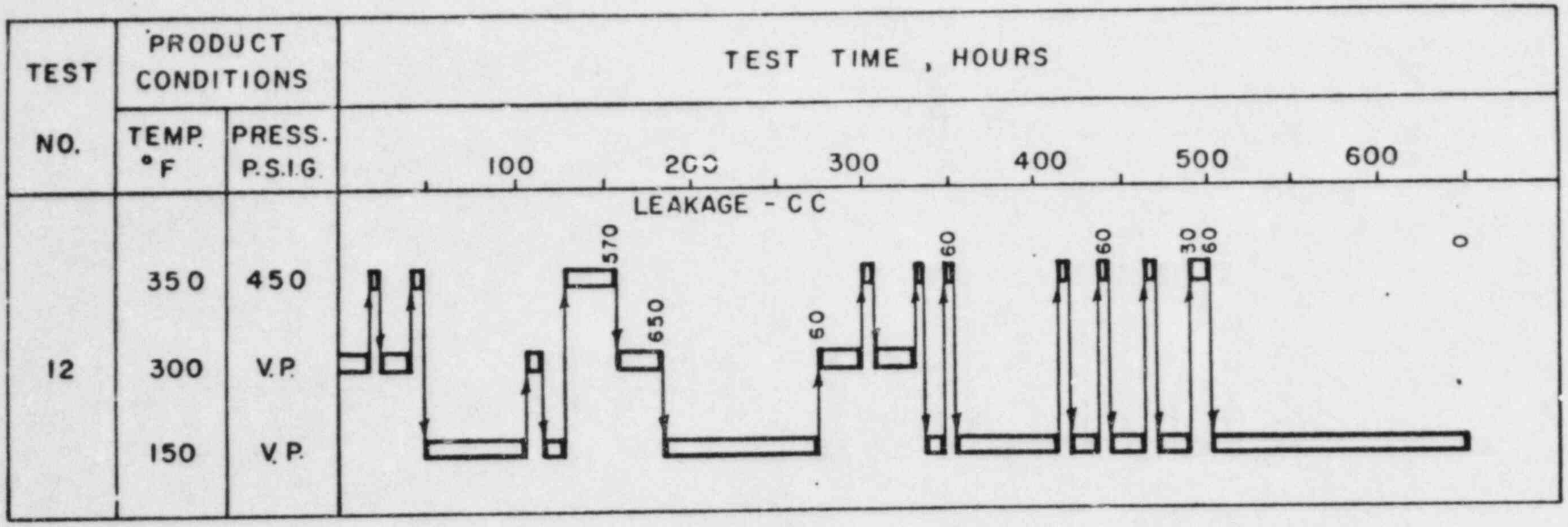


FIG. II 5 MULTIPLE CYCLING CONDITION TEST RESULT

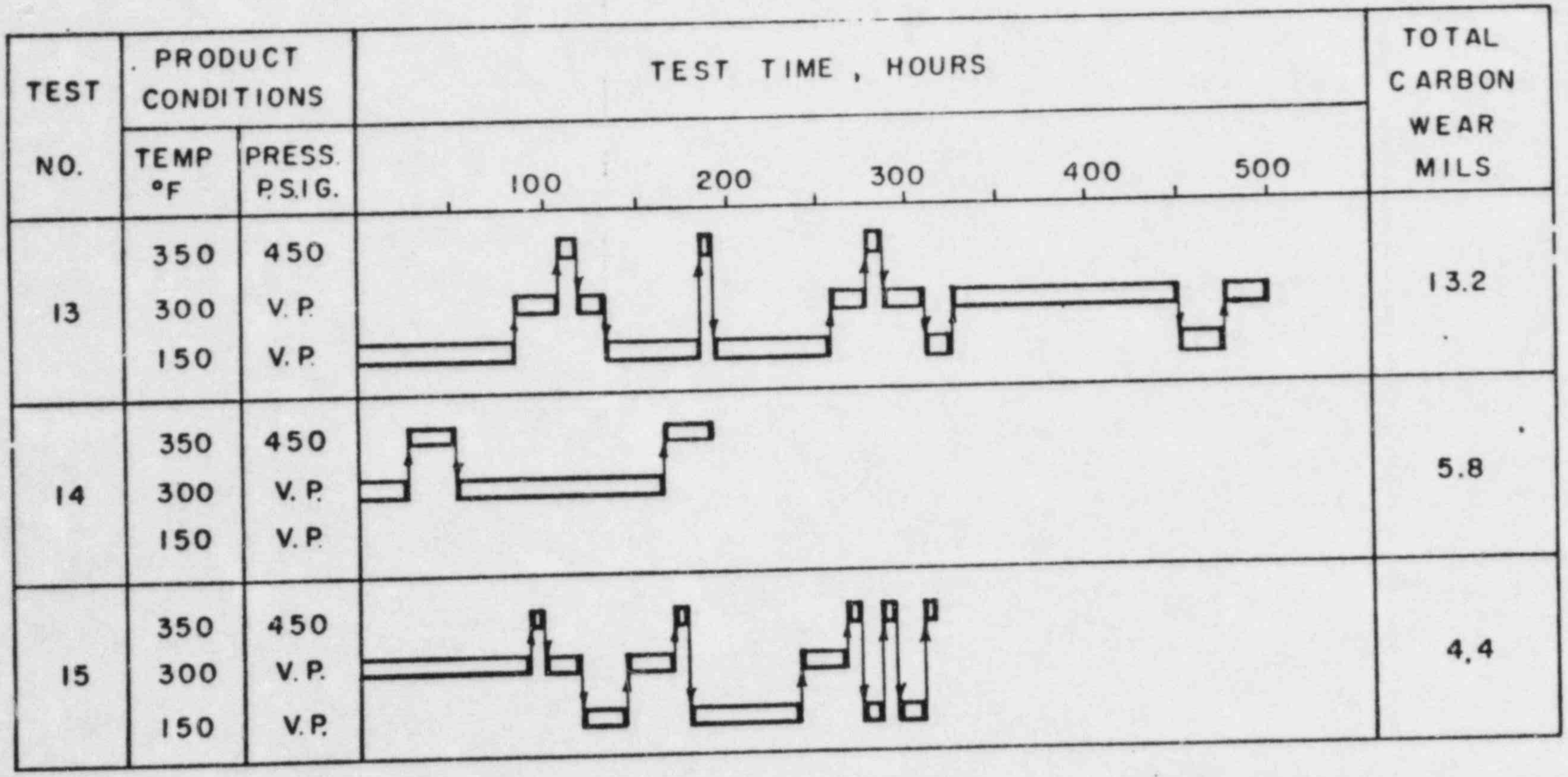


FIG. II-6 CYCLING TEST RESULTS SIL-CAR I VS NO. 5 CARBON

DURAMETALLIC CORPORATION 2104 Factory Street Kalamazoo, Michigan 49001, U.S.A.

SECTION III

THE TESTING OF DURA SEALS IN 12% BORATED WATER FOR NUCLEAR POWER PLANT SERVICES

Ref: Durametallic Corporation
Research Report No. 1200-B
June 4, 1975

TESTING OF DURA SEALS IN 12% BORATED WATER

This report summarizes the testing accomplished by Durametallic Corporation on Dura Seals for use in Nuclear Power Plant pumps handling up to 12% borated water. The summarized data, shown in Table III-1 represents over 3,250 hours of testing.

The purpose of Test Series A was to determine the seal life of a Type RO Unbalanced Dura Seal in a dead-ended stuffing box operating in 12% by weight boric acid. Three combinations of seal face materials were operated on long term tests to determine the projected seal life of each.

The purpose of Test Series B was to define the operating limits of a Type RO Unbalanced Dura Seal in a dead-ended stuffing box operating in boric acid. It was intended to perform a short series of tests to quickly confirm that this seal design would operate satisfactorily in boric acid concentrations up to 12% by weight and determine the maximum allowable boric acid concentration for each set of face materials.

All the tests that were conducted assume that no external flushing or cooling was available.

CONCLUSIONS

1. Type RO Dura Seals using Tungsten Carbide vs No. 5 Carbon seal faces operating in a dead-ended stuffing box performs satisfactorily in a boric acid solution up to and including 5% by weight boric acid.

2. Type RO Dura Seals using Tungsten Carbide vs Tungsten Carbide seal faces operating in a dead-ended stuffing box performs satisfactorily in a boric acid solution up to and including 12% by weight boric acid.

3. External cooling is not required up to product temperatures of 180°F. The wear rate increases rapidly at temperatures above 180°F.

4. Seal leakage is essentially nil.

5. Wear rates were moderate and overall seal performance was very good indicating that these seals would provide good seal performance and long seal life.

6. Bronze vs Tungsten Carbide is not satisfactory for sealing 12% by weight boric acid.

TEST SEALS

The seals used in Test Series A were 1-3/4" Tupe RO Unbalanced Dura Seals operating at 3500 and 1750 RPM. The rotating seal ring material for all tests was Tung-Car 62-6(nickel binder). The stationary insert was a clamp style insert, shown schematically in Figure III-1. Three insert materials were tested; No. 5 carbon, Tung-Car 62-6 and Bronze. Each insert had a standard rubbing face nose length of .125". The compression unit was of 316 stainless steel with #20 stainless springs, pins, and set screws. The "O" ring shaft packing was EPT.

The seals for Test Series B were 2" Type RO Unbalanced Dura Seals operating at 3500 RPM and are shown schematically in Figure III-2. The rotating seal ring material for all tests was Tung-Car 62-6 (nickel binder). The stationary insert materials tested were No. 5 Carbon and Tung-Car 62-6. The compression unit was of 316 stainless steel with #20 stainless springs, pins and set screws. All "O" ring secondary seals were EPT. The insert rubbing face nose length was standard at .125" and no anti-rotation pin drive was used.

A fixed bushing with a radial clearance between the shaft O.D. and the bushing I.D. was installed on the pump product side of the seal to reduce self-flushing and to provide a dead-ended seal chamber.

TEST EQUIPMENT AND FLUID

The seals in Test Series A were tested in a single stage, end suction horizontal process pump. The pump speed was 3500 and 1750 RPM. The pump recirculated the fluid through a 12 gallon tank via a 3/4" discharge line and 1-1/2" suction line. The stuffing box temperature and pressure was measured through taps to the stuffing box.

The product fluid was demineralized water containing 12% by weight (20,981 ppm Boron) boric acid. No cooling or bypass flushing was used.

The test arrangement for Test Series B consisted of a simulated stuffing box attached to a mounting plate as shown in Figure III-3. The shaft was supported by a bearing housing.

Pressure was maintained by external air pressurizing the top of an accumulator tank holding the product fluid and monitored by a calibrated pressure gage.

Temperature was controlled by the use of a Dura thermocooler (evaporation type heat exchanger) with circulation induced by a circulating ring attached to the shaft. Temperature was monitored by dial thermometers.

Temperature control of the boric acid solution was the major problem encountered. The test facility was modified many times so that this parameter could be reasonably controlled. Even so, without automatic temperature controls, constant temperatures could not be maintained. It was attempted to keep the product temperature between 155°F and 180°F.

The product fluid was softened water containing 5% by weight (8,742 ppm Boron) 6% by weight (10,490 ppm Boron) and 12% by weight (20,981 ppm Boron) boric acid.

TEST CONDITIONS

Test Series A was conducted at pressures varying from 10-20 PSIG on the stuffing box. Tests were run for a nominal of 30 days with frequent stops and starts to simulate on-off conditions. Stops were occasionally prolonged to permit the boric acid to settle out in order to determine if start-up problems would occur.

Test Series B was conducted at pressures varying from 20-50 PSIG. Pressure normally has an effect on the wear rate but at these low pressures the difference in wear rate was not sifnificant. This is indicated by comparing Test Series 4 - 6. Tests 4 and 5 were run at 50 PSIG and Test 6 at 20 PSIG, all other conditions being identical. The wear results on this set of tests is very consistent, in spite of the differences in pressure.

RESULTS

The results of testing are summarized in Table III-1.

The carbon insert of Series A Test No. 1 operating at 3500 RPM wore rather rapidly and resulted in 19.7 mils wear in 28 days of operation. Assuming the seal wear nose to be worn out after .100" wear on the carbon, the projected life of this seal would be only 142 days. The seal performed well otherwise and did not leak noticeably or show signs of clogging or wear of other parts.

The same carbon insert was tried at 1750 RPM, Test No. 2, and performed well. As expected, the wear at the lower RPM was less and a projected life of 322 days was indicated. Performance otherwise was quite satisfactory.

A solid Tung-Car 62-6 insert replaced the carbon in Test No. 3 and performance was excellent. The wear after 33 days of testing was hardly measurable on the tungsten carbide faces. The life expectancy was, therefore, extremely long suggesting that perhaps some other pump components may wear out before the seal. There was no indication of wear or damage to any other parts of the seal upon completion of the test.

Since tungsten carbide is an expensive material, Test No. 4 was tried using a bronze stationary insert. The bronze wore heavily and sufficient leakage occurred to warrant termination of the test after only three days time.

Tests 1 - 6 of Test Series B were conducted using Tung-Car 62-6 and No. 5 Carbon as face materials. No modifications were made to the standard type RO seal design. Tests 1 - 3 were conducted in a 5% boric acid solution. Moderate wear was experienced and overall seal performance was very good. Tests 4 - 6 were conducted in 6% boric acid. The wear rates in these tests were high, indicating short seal life. Tests 1 - 6 indicate that No. 5 Carbon against Tungsten Carbide performs well in boric acid solutions up to and including 5%.

Test 7 was run in 6% boric acid using a Tung-Car 62-6 insert and seal ring. No wear was measured for this test. The same face materials were then used for Tests 8, 9, and 10 sealing 12% boric acid. Again no wear was measured for these tests. These tests ran very satisfactorily and indicate that this face material combination would provide good seal performance and long seal life in boric acid solutions up to and including 12%.

During Tests 11 and 12, product temperatures ran higher than desired. The average product and box temperaturee during these tests was 200°F. Wear rates during these two tests were very high, indicating flashing across the seal faces This problem was not experienced at slightly lower temperatures General test results indicate that temperatures up to 180°F can be tolerated without seriously effecting the seal life.

During all tests, leakage was nil.

TABLE III-1

SUMMARY OF TEST RESULTS

TEST SERIES	TEST NO.	PRODUCT CONDITIONS % BORIC ACID	TEMP. °F	PRESS. PSIG	SPEED RPM	TOTAL TEST TIME HOURS	SEAL FACE MATERIALS ROTATING	STATIONARY	AVERAGE CARBON WEAR MILS/DAY	AVERAGE PROJECTED SEAL LIFE HOURS
A	1	12	160	10	3500	672	Tung-Car 62-6	No.5 Carbon	.70	3,408
"	2	12	140	15	1750	720	"	"	.31	7,728
"	3	12	172	20	3500	792	"	Tung-Car 62-6	0.003	24,000 +
"	4	12	167	15	3500	72*	"	Bronze	- -	- -
B	1	5	145	20	3500	96	Tung-Car 62-6	No.5 Carbon	.18	13,333
"	2	5	160	20	"	96	"	"	.18	13,333
"	3	5	170	20	"	48	"	"	.20	12,000
"	4	6	180	50	"	72	"	"	.80	3,000
"	5	6	180	50	"	192	"	"	.60	4,000
"	6	6	155	20	"	24	"	"	.80	3,000
"	7	6	145	20	"	148	"	Tung-Car 62-6	0	24,000 +
"	8	12	150	40	"	24	"	"	0	24,000 +
"	9	12	180	40	"	72	"	"	0	24,000 +
"	10	12	160	35	"	72	"	"	.56	4,285
"	11	6	200	20	"	144	"	"	2.80	857
"	12	12	200	45	"	8	"	"		

* Test stopped after 72 hours of operation due to excessive leakage of 80 drops per minute and increasing.

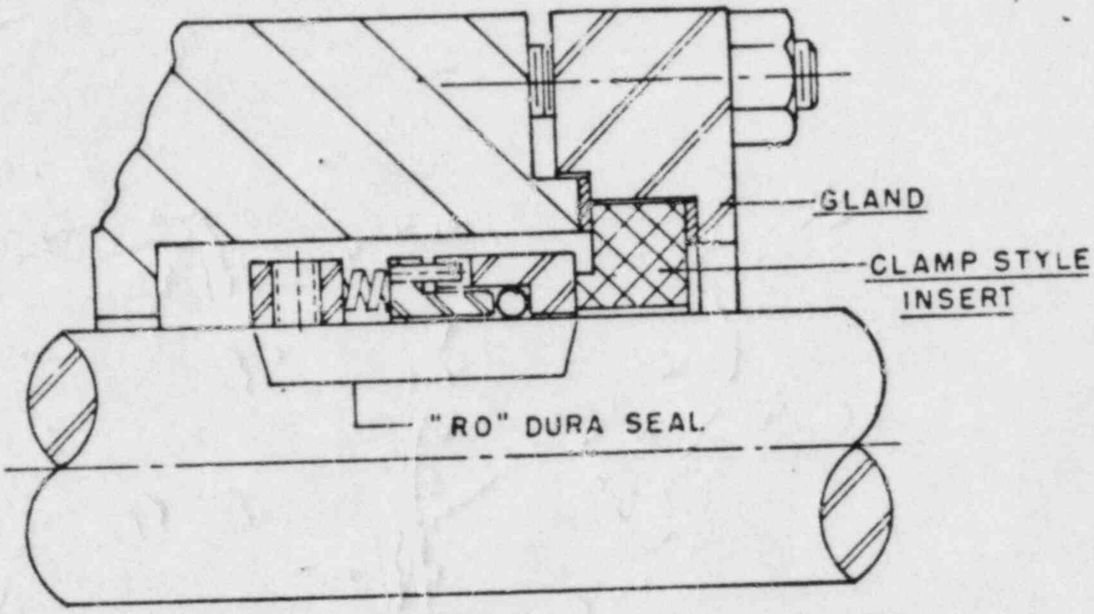


FIG. III - 1

TYPE "RO" TEST SEAL ARRANGEMENT

TEST SERIES "A"

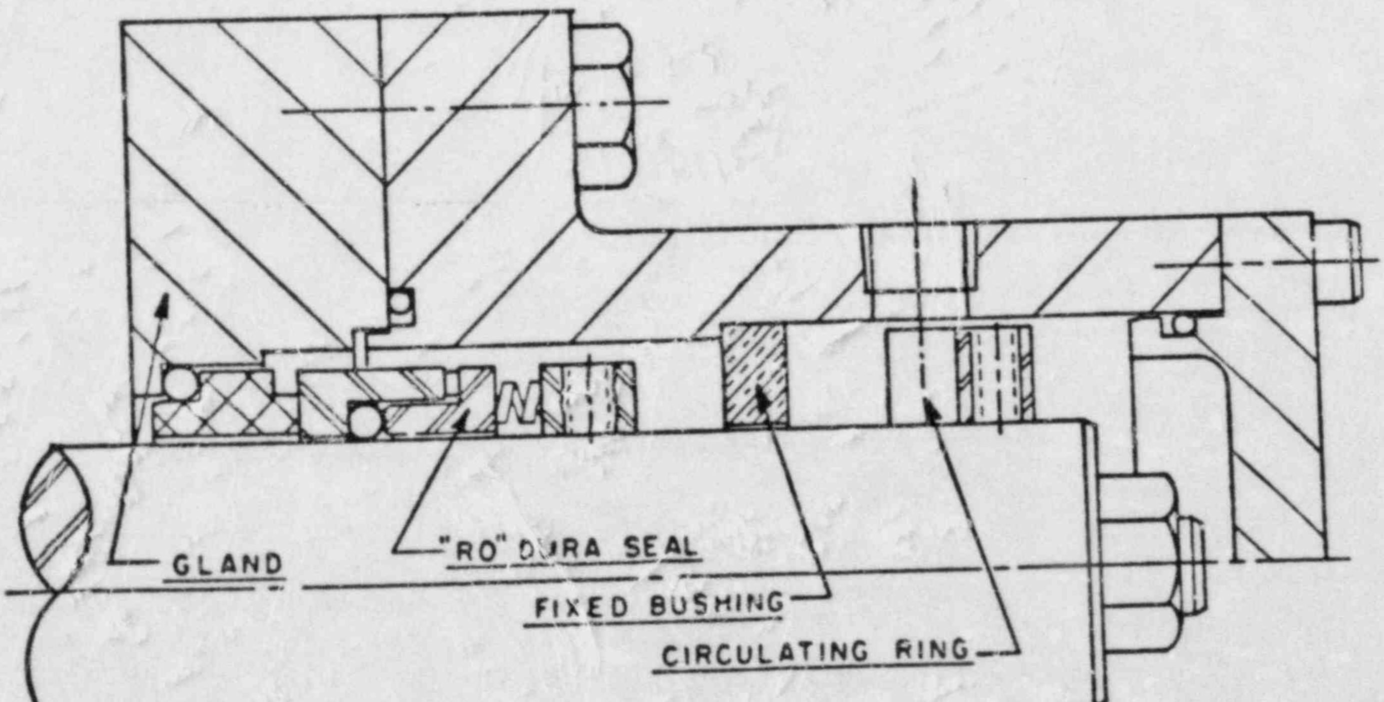


FIG. III - 2

TYPE "RO" TEST SEAL ARRANGEMENT

TEST SERIES "B"

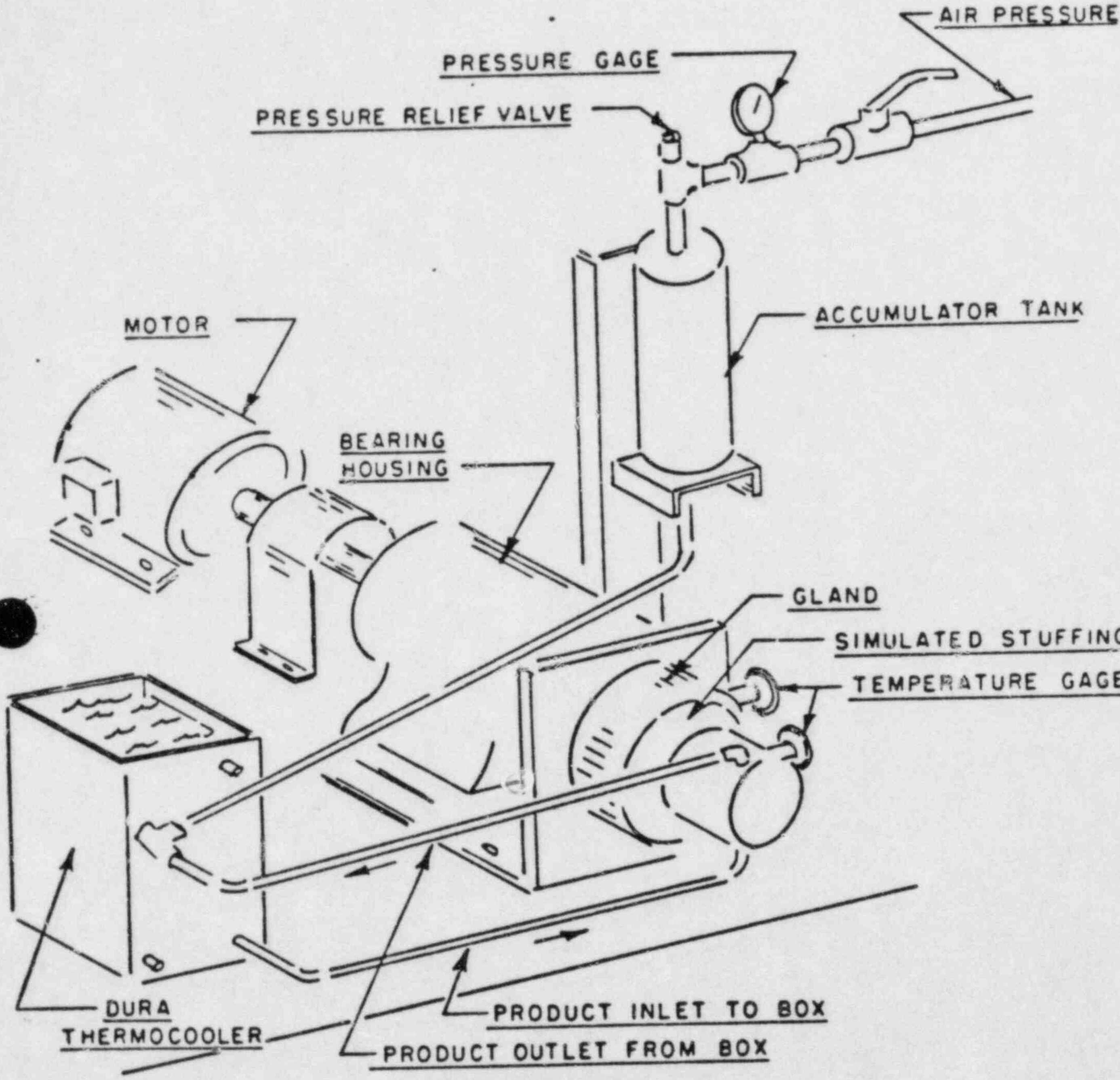


FIG. III-3
TEST EQUIPMENT

DURAMETALLIC CORPORATION 2104 Factory Street Kalamazoo, Michigan 49001. U.S.A.

SECTION IV

THE TESTING OF TYPE HPTO HIGH PRESSURE DURA SEALS FOR BOILING WATER REACTOR (BWR) "CLEANUP RECIRCULATION" PUMP SERVICE

Ref: Durametallic Corporation
Service Report No. SR-78-228
May 1, 1978

THE TESTING OF TYPE HPTO HIGH PRESSURE DURA SEALS FOR BOILING WATER REACTOR (BWR) "CLEANUP RECIRCULATION" PUMP SERVICE

This report summarizes the testing accomplished by Durametallic Corporation on Type HPTO High Pressure Dura Seals for use in "Cleanup Recirculation" pumps used in the Boiling Water Reactor nuclear power plant system. The summarized data, shown in Table IV-1 and Figures IV-1 and IV-2 represent several weeks of testing with the final design subjected to both pressure and temperature cycles.

The acceptance criteria used was a maximum allowable seal leakage rate of 360 cc/24 hours in the cold condition for the first 48 hours and 180 cc/24 hours at the design temperature or beyond 48 hours of seal running time.

CONCLUSIONS

1. Type HPTO Dura Seals with a flexibly mounted insert design performed satisfactorily under all conditions tested.

2. Type HPTO Dura Seals with a rigid insert mounting design leaked excessively as a result of gland deflection caused by gland nut tightening procedures.

3. A seal balance of 37% should be used for maximum seal life under the conditions tested. Seal balance will vary depending upon operating conditions and should be selected for each individual case.

4. Seal leakage for the first 48 hours of operation may average up to 15 cc/hour (360 cc/day) for the conditions tested.

5. After a 48 hour run-in period, seal leakage should not exceed 7.5 cc/hour (180 cc/day) for the conditions tested.

6. Seal leakage rates will vary depending upon seal design and operating conditions. Estimated leakage rates can be calculated for each individual case.

TEST SEAL

The seals tested were 2-1/8" Type HPTO Dura Seals rotating at 3600 RPM and are shown schematically in Figures IV-1 and IV-2. Figure IV-1 shows a rigidly mounted insert design wherein the stationary insert backs up to the gland ring shoulder when subjected to high seal cavity pressures. Figure IV-2 depicts a flexibly mounted stationary insert design wherein the insert is completely isolated from the gland ring.

The rotary seal ring and insert were of solid Tung-Car 62-6 (nickel binder). The compression unit and gland ring were of 316 stainless steel. Pins and set screws were of #20 stainless steel and the springs were of XM-19 stainless steel. The secondary sealing "O" rings, hold rings and back-up rings were EPT terpolymer. A 316 stainless steel circulating ring was used to circulate the seal cavity fluid through a heat exchanger to maintain seal cavity temperature.

The insert rubbing face designs used had balances of 32% and 37% with standard .062" nose lengths. There were no anti-rotation pins used on any inserts.

TEST EQUIPMENT AND FLUID

The test arrangement consisted of a commercial high pressure centrifugal pump circulating product to a 15 gallon accumulator tank as shown in Figure IV-3.

Temperature of the product was monitored by temperature gages located near the suction nozzle and discharge nozzle. The temperature values taken were an average of the two temperature gages.

Pressure was maintained by an external air operated pressurizing pump monitored by a pressure gage location near the suction nozzle.

The product fluid was softened water.

Environmental control to the seal cavity consisted of a circulating ring mounted on the shaft forward of the seal which circulated the seal cavity fluid through a water cooled heat exchanger. The process fluid outlet from the heat exchanger was returned to the seal cavity through a drilled passage in the seal cavity housing leading directly to the seal faces.

TEST CONDITIONS

Fluid:	Softened Water
Temperature:	535°F maximum
Operating Pressure:	1040 PSIG
Hydrostatic Pressure:	1725 PSIG
Speed:	3600 RPM

TEST PROCEDURE

1. Vent all air when filling the system with water.

2. Hydrostatically apply pressure of 1725 PSIG and hold for 30 minutes. Measure the amount of leakage for the 30 minute period.

3. Apply pressure of 200 PSIG and start the pump. Measure leakage for 10 minutes.

4. Repeat 3 above for the following pressures (PSIG) in the following order: 400, 600, 800, 1000, 800, 600, 400, 200, 400, 600, 800, 1000.

5. Maintain pressure at 1000 PSIG and increase temperature to 535°F. Maintain pressure and temperature for one hour and measure leakage for this one hour period.

6. Close pump suction and discharge valves to isolate the pump from the system. Allow the pump to cool 30°F lower than the system temperature.

7. Reopen the pump suction and discharge valves.

8. Decrease the system temperature to 160°F or less and measure leakage collected in 10 minutes.

9. Repeat 5, 6, 7 and 8 three times for a total of four startups and shutdowns.

RESULTS

The results of testing are summarized in Table IV-1 and shown graphically in Figures IV-4 and IV-5.

Test No. 1 was run with the rigid insert mounting design as shown in Figure IV-1. The insert balance was 37% and a spiral wound metal gland ring gasket was used. This first set of tests quickly revealed that seal leakage was inconsistent from one test to the next with leakage rates ranging from 2 to 500 cc/hour. It was found that seal leakage was dependent upon the gland nut tightening procedure, torque values and whether the gland ring spiral wound gasket was new or used. It was also found that seal leakage could be changed significantly by loosening or tightening the gland nuts while the pump was operating.

Test No. 2 was run under the same conditions outlined above with the insert balance reduced to 32%. Results similar to those above were observed with the initial leakage rates at 1000 PSIG pressure ranging from 40 to 120 cc/hour.

Test No. 3 was conducted with an EPT elastomer "O" ring gland gasket in place of the spiral wound metal gasket, requiring only 15 ft-lbs of torque to seal at the gasket. Although the initial leakage rates were reduced to 24 to 30 cc/hour, leakage remained unpredictable.

As a result of these three series of tests, the insert design was revised to a flexibly mounted insert wherein the insert is completely isolated from the gland ring as shown in Figure IV-2. This change provides an insert design which would be uneffected by gland ring distortion. Tests 4 and 5 were

conducted to evaluate seal performance with the flexibly mounted insert and seal balances of 32% and 37%.

Test No. 4 was conducted with a 37% seal balance. Dynamically at 1000 PSIG, these seals leaked 2-20 cc/hour at startup. After a run-in period of 48 hours, leakage dropped to near zero.

Test No. 5 was conducted to determine if the initial leakage rate and run-in time could be reduced without sacrificing seal life. The seal balance for these tests was lowered to 32% to increase the unit loading on the seal faces. Initial seal leakage ranged from 6-12 cc/hour. After a run-in period of 48 hours, seal leakage was near zero. Examination of the seal faces also revealed some slight heat checking not seen in Test No. 4.

It was concluded from test series 4 and 5 that flexibly mounting the insert reduced the leakage rate to 2-20 cc/hour initially and to near zero after a run-in period of 48 hours. It was also concluded that even though a lower balance would slightly reduce initial leakage, it was not significant.

Examination of the seal parts from test series 4 and 5 showed that initial leakage was being caused by convexing of the seal faces. Even though this causes more initial seal leakage, the additional fluid between the faces during run-in reduces the amount of wear and damage sometimes associated with seal run-in. This is, therefore, considered beneficial to overall good seal life.

Once satisfactory seal performance was established, a test procedure for seal acceptance was written as outlined. The pump was hydrostatically tested for 1/2 hour at 1725 PSIG. Seal leakage was measured at 13 cc/hour.

The pressure cycle testing consisted of cycling the pump from 200 PSIG to 1000 PSIG, back to 200 PSIG and finally up to 1000 PSIG again. This was done in 200 PSIG increments with each pressure increment being held for 10 minutes.

When the pump was first started at 200 PSIG, a leakage rate of 12 cc/hour was observed. After this, the leakage settled down, ranging from 0 - 6 cc/hour as shown in Figures IV-4.

The temperature cycle tests consisted of heating the pump to 535°F, holding that temperature for one hour, performing a 30°F minimum temperature shock on the pump, then cooling to below 160°F. At this point the leakage was measured. This cycle was run four times at a pressure of 1000 PSIG. During the first two cycles the pump remained running during the cool-down portion of the cycle. During the last two cycles, the pump was shut off during cool-down and the leakage was measured with the pump off.

The temperature cycles and results are shown in Figure IV-5.

The leakage rate at the end of cycles 1 and 2 was 6 cc/hour. The leakage rate at the end of cycle 3 was 3 cc/hour, while no leakage was measured at the end of the fourth cycle.

At the end of cycle four, the pump was started and run ten minutes to see if the seal would begin leaking dynamically; no leakage was observed.

The acceptance criteria for this test series was based on the seal leakage rates. Under 48 hours running time or when the pump was in a cold condition, a leakage rate of 360 cc/day (15 cc/hour) was allowed. After 48 hours running time or when the pump was hot, the leakage could not exceed 180 cc/day (7.5 cc/hour).

At no time during the acceptance test series were these leakage rates exceeded.

TABLE IV-1

DYNAMIC TEST RESULTS AT 1000 PSIG AND ROOM TEMPERATURE

TEST NO.	INSERT DESIGN	GLAND GASKET	GLAND NUT TORQUE, FT-LBS.	INSERT BALANCE,%	NO. OF TESTS	LEAKAGE RATE, CC/HR.
1	Rigid	Spiral Wound	40 - 175	37	12	2 - 500
2	Rigid	Spiral Wound	200	32	5	40 - 120
3	Rigid	"O" Ring	15	37	2	24 - 30
4	Flexible	Spiral Wound	200	37	1	16
5	Flexible	Spiral Wound	200	32	3	2 - 12

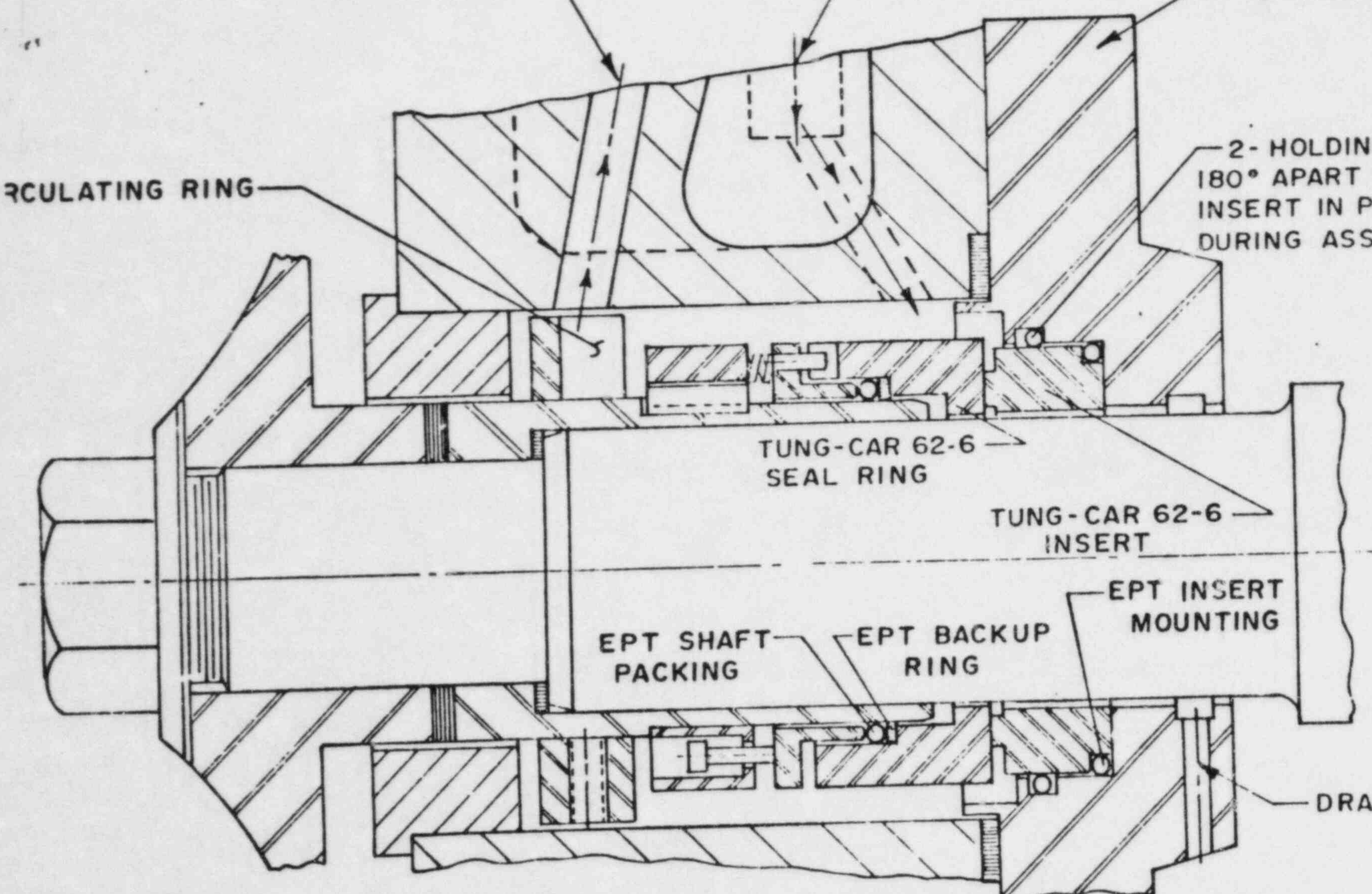


FIG. IV -1

TYPE "HPTO" DURA SEAL WITH RIGID INSERT MOUNTING DESIGN

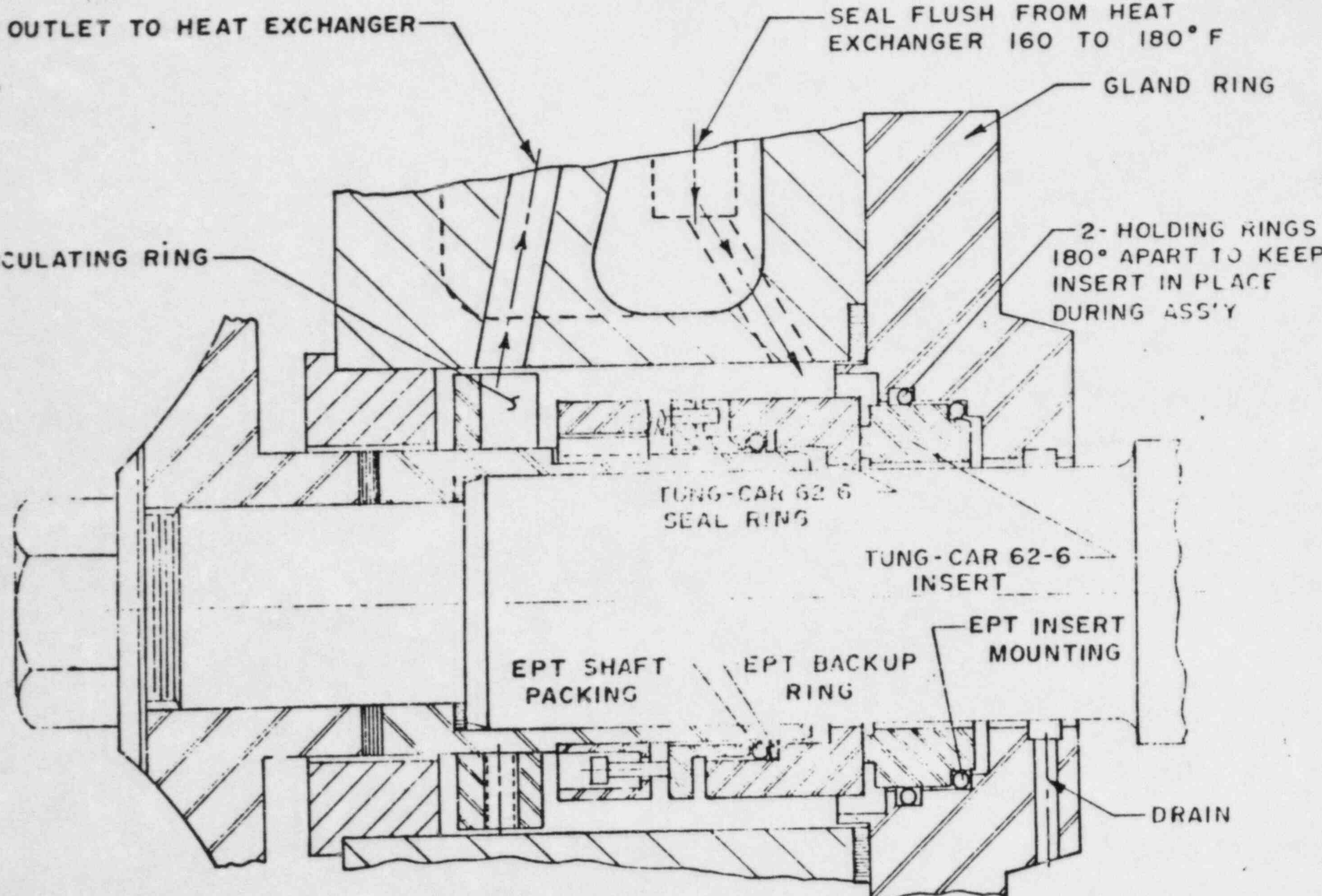


FIG. IV - 2

TYPE "HPTO" DURA SEAL WITH FLEXIBLY MOUNTED INSERT DESIGN

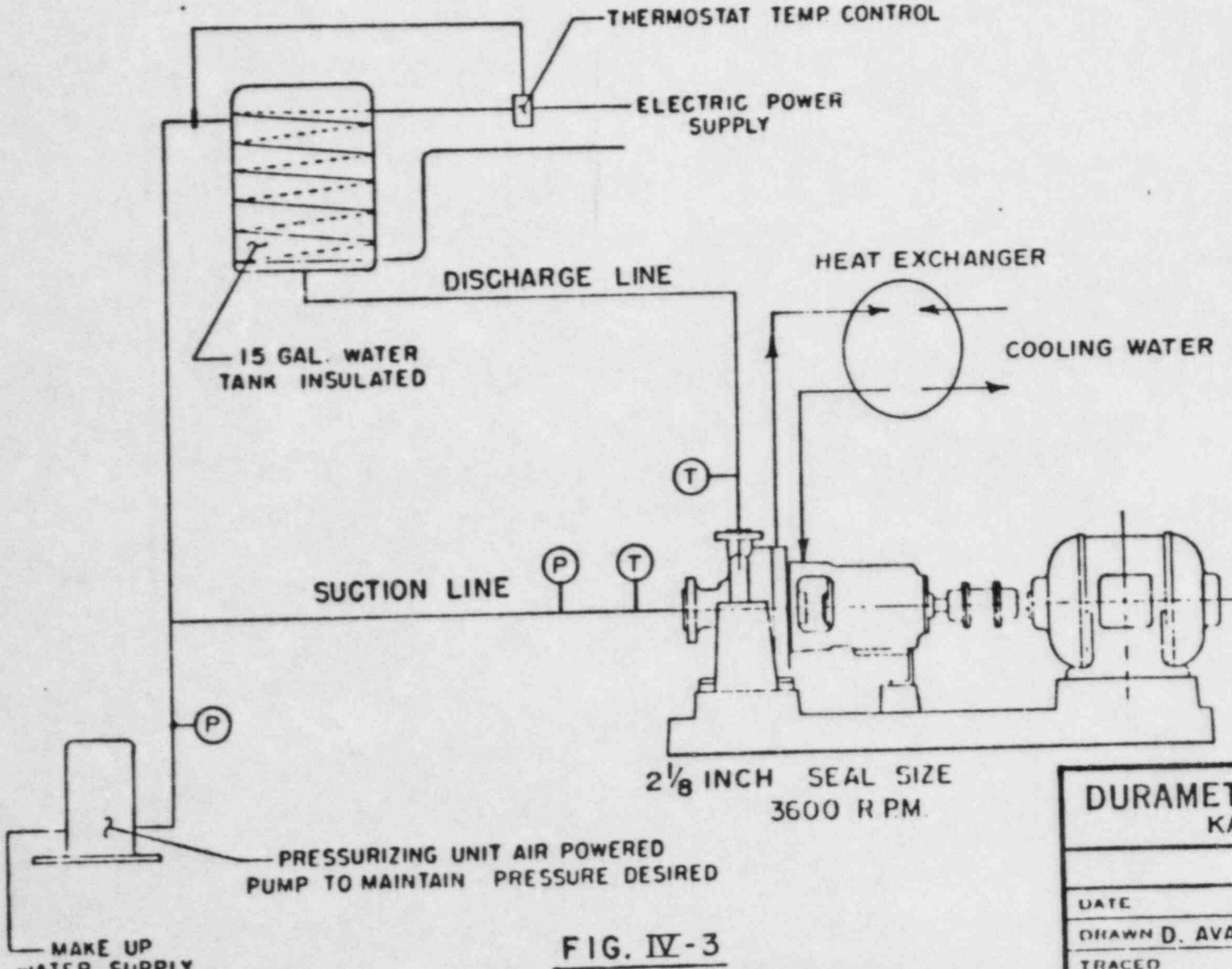


FIG. IV-3

SCHEMATIC OF TEST SETUP

DURAMETALLIC CORPORATION KALAMAZOO, MICH.	
DATE	SCALE NONE
DRAWN D. AVARD	
TRACED	Dwg. No.
CHECKED	

FIGURE IV - 4

PRESSURE CYCLE TEST RESULTS

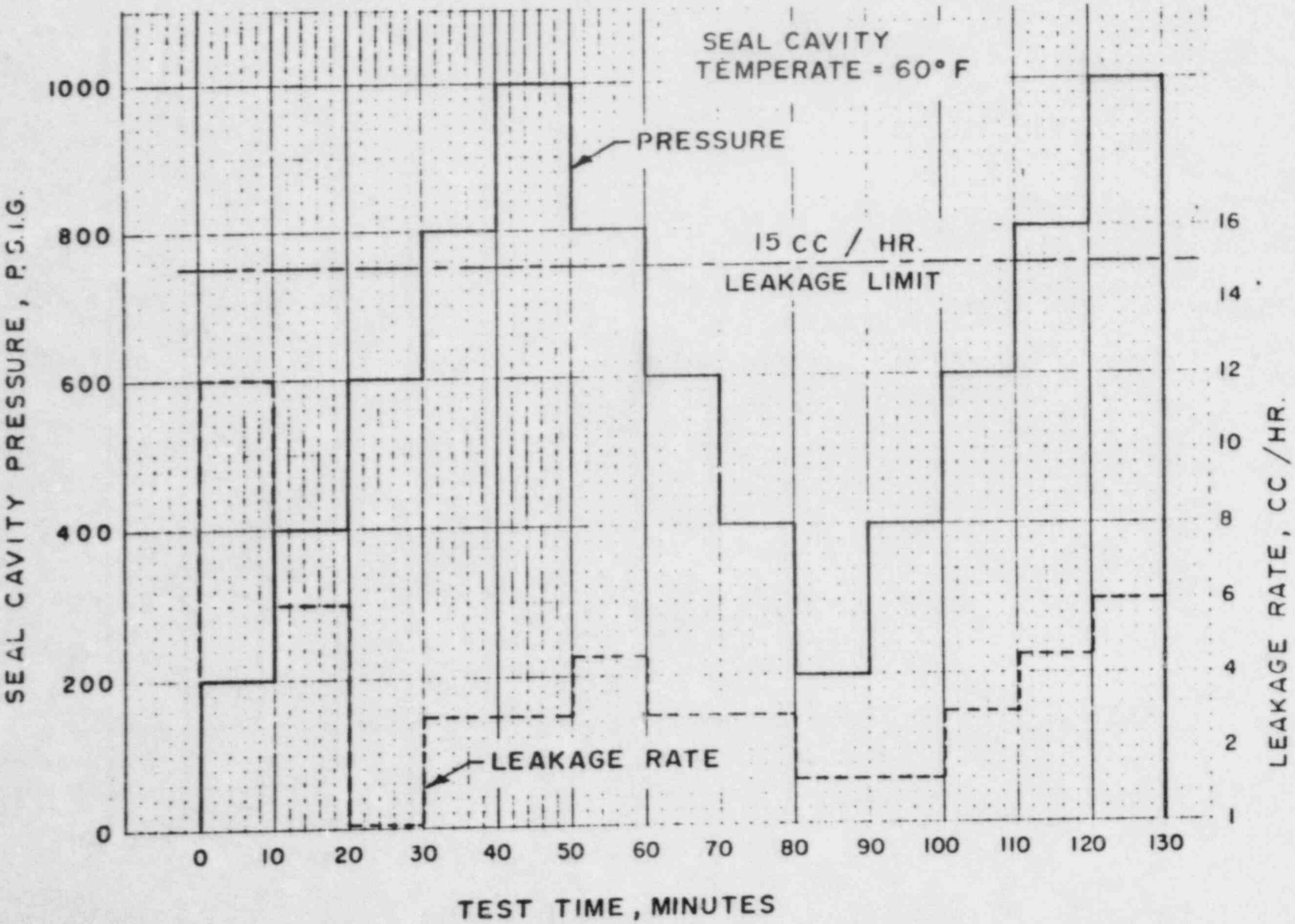
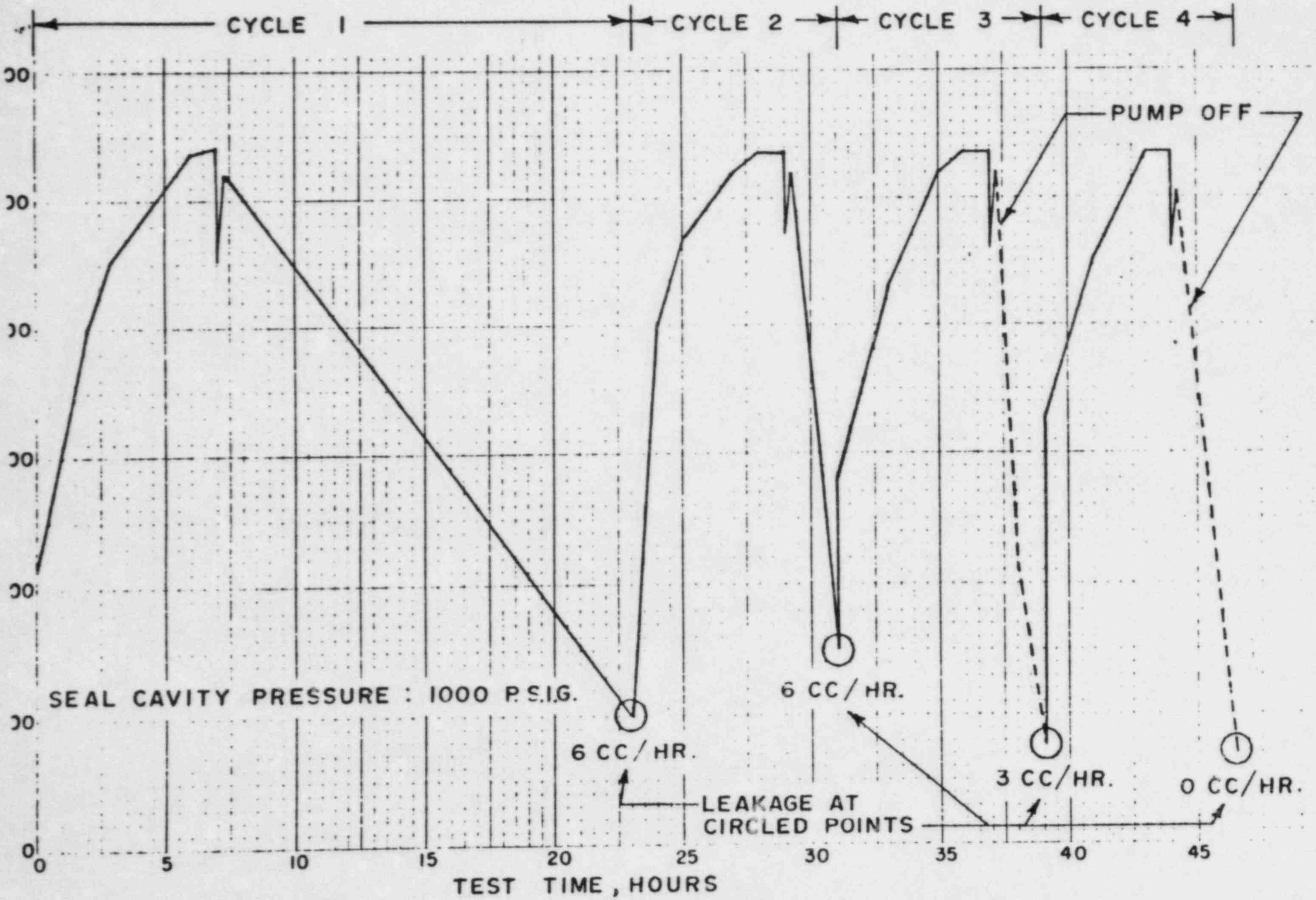


FIGURE IV-5

TEMPERATURE CYCLE TEST RESULTS



RHR Pumps - Reference # 3

Ethylene-Propylene/threshold - 1×10^6 rads/compression set

Although some experimental formulations showed poor radiation resistance, a number of commercial materials appear to be comparable to crosslinked polyethylene. As with other polyolefins, radiation resistance will depend on the effectiveness of antioxidant systems (especially at elevated temperatures). Reference 28 reports dose rate effects with greater degradation at low dose rates when the total dose exceeded about 2×10^7 rads for one ethylene-propylene cable insulation. Reference 8 details effects of radiation on cable insulation and jacket materials, including EPDM-based and EPM-based insulations (both mineral filled). No changes in oxidation resistance were found following total dose up to 10^8 rads (dose rate was 5×10^5 rads/hour). Elongation of the EPDM insulation was not significantly changed after 5×10^6 rads, but was reduced to 48% of the initial value after 5×10^7 rads and 37% after 1×10^8 rads. The EPM insulation retained 81% of its unirradiated value after 5×10^6 rads, 41% after 5×10^7 rads, and 26% following 1×10^8 rads. Reference 39 also reports very good radiation resistance of EP rubber (EPDM base) and that cables using special chloroprene jackets and EP insulation passed IEEE-383 tests.

EPDM retained 79% and EPM retained 90% of the original tensile strength after 10^8 rads. Changes in permanent electrical properties were relatively unimportant. Reference 35 reports similar results for ethylene propylene cable insulations, but reports that a fire-retardant additive appeared to cause instability of electrical properties in an EPDM-based material at exposures above 10^7 rads. Reference 55 reports minor reductions in mechanical properties of EP-F234 after 5×10^4 rads, but less than 25% decrease in those properties at 10^6 rads. A 50% decrease in elongation was noted after 2×10^7 rads and in tensile strength after 2×10^8 rads. The 5×10^4 rad value is not cited above, since it is not generally applicable and does not represent significant change to the material.

Barbarin[6] recommended an EP compound (Parker-Hannifin E740-75) as exhibiting the best known combination of radiation, fluid, and temperature tolerance. He warned that variations in compounding can cause wide difference in properties. One EP compound showed 28.6% increase in compression set after 10^7 rads and would be acceptable as a dynamic seal, while one (Parker-Hannifin E515-80) exhibited 46.6% increase in that property under the same test conditions. He recommended that no dynamic seals be used after radiation doses greater than 10^7 rads due to excessive compression set. Reference 61 indicates a 10^7 rad "allowable" dose for EP as for polyethylenes.

CATAWBA NUCLEAR STATION
ENVIRONMENTAL QUALIFICATION OF SAFETY-RELATED MECHANICAL EQUIPMENT

1. EQUIPMENT IDENTIFICATION: Pressurizer Power Operated Relief Valves

2. MANUFACTURER: Control Components International

3. MODEL OR ID NUMBER(S): C2G0-X2-X3BW-X4BW-41AH43

   Tags: 1-2NC32B, 34A, 36B

4. ACCIDENT ENVIRONMENT:

   PEAK TEMPERATURE: 330°F DURATION AT PEAK: 10 minutes

   RAD: 1.1×10^8

   EXPOSED TO CONTAINMENT VESSEL CHEMICAL SPRAY ENVIRONMENT (BORIC ACID & SODIUM HYDROXIDE SOLUTION): Yes

5. QUALIFIED ENVIRONMENT:

MAT'L	TEMP	RAD	ACCEPTABLE FOR SPRAY	REPLACEMENT INTERVAL	REFS.
See Comments and Reference 1				N/A	1

6. COMMENTS: Integrity of non-metallic materials not required for equipment to perform its current safety function.

7. REFERENCES:

1. Accident Environmental Analysis Report . . . Covering 1500# Class 1 Nuclear Pressurizer Power Operated Relief Valves, February 4, 1981 (CNM-1205.10-0171)

Reference #1

Pressurizer PORV

DIV	STATUS	INIT.	DATE
MECH	A AP	REH DRD	
MECH	NC AA	JML MGO	
ELECT	NC NC NC A	CWW AEC JDT 7M	

DOCUMENT CONTROL DATE
MAR 5 1981
DUKE POWER COMPANY
DESIGN ENGINEERING

APPROVED
DUKE POWER CO.
DATE: MAY 15 1981
S. K. BLACKLEY, JR.
CHIEF ENGINEER
By: MECHANICAL DIVISION

QA CONDITION 1

ACCIDENT ENVIRONMENTAL ANALYSIS REPORT

FOR

DUKE POWER COMPANY, CATAWBA NUCLEAR STATION

UNITS 1 and 2

MILL POWER SUPPLY COMPANY ORDER NUMBER A-63027

DUKE POWER SPECIFICATION NUMBER CNS-1205.10-1 and ADDENDUM #9

CONTROL COMPONENTS INTERNATIONAL WORK ORDER NUMBER 18789-1 & 2

COVERING

1500# CLASS I

NUCLEAR PRESSURIZER POWER OPERATED RELIEF VALVES

DRAWING NUMBER 921101010

PREPARED BY: David Koo DATE 2-4-81

REVIEWED BY: [signature] DATE 2/4/81

APPROVED BY: [signature] DATE 2/4/81

CNM 1205.10-0171

TABLE OF CONTENTS

I. ABSTRACT

The analysis contained in this report is to ~~justify~~ verify that the design of the valve-actuator assembly will fail close during the accident environmental condition given in IEEE 382-72, Table 1, Table 2, and Figure 1. The effect of the degradation of non-metallic materials due to radiation and temperature exposure and effect of safe shutdown earthquake on the actuator failure mode were studied separately. It is concluded that the valve-actuator assembly will fail close when being subjected to the accident environmental condition, provided proper exhaust at the bottom of the actuator is maintained.

... concluded that under the accident ...mental condition the valve-actuator ...ly will fail to the closed position ...ed proper exhaust at the bottom of ...tuator is maintained) upon the ... control air.

II. BACKGROUND AND INTRODUCTION

Duke Specification CNS-1205.10-1, paragraph 8.1.16, states that the pressurizer power operated relief valves and operators shall be designed to fail closed, while being subjected to the accident environmental conditions given in IEEE 382-72, Table 1, Table 2, and Figure 1 concurrent with a safe shutdown earthquake (SSE). The analysis contained in this report to justify the design is based on information obtained from other manufacturers and tests performed at Control Components International. It is not the intention of this report to prove the structural integrity of the valve-actuator assembly under the given accident environmental conditions.

III. VALVE AND ACUTATOR MATERIAL SPECIFICATION

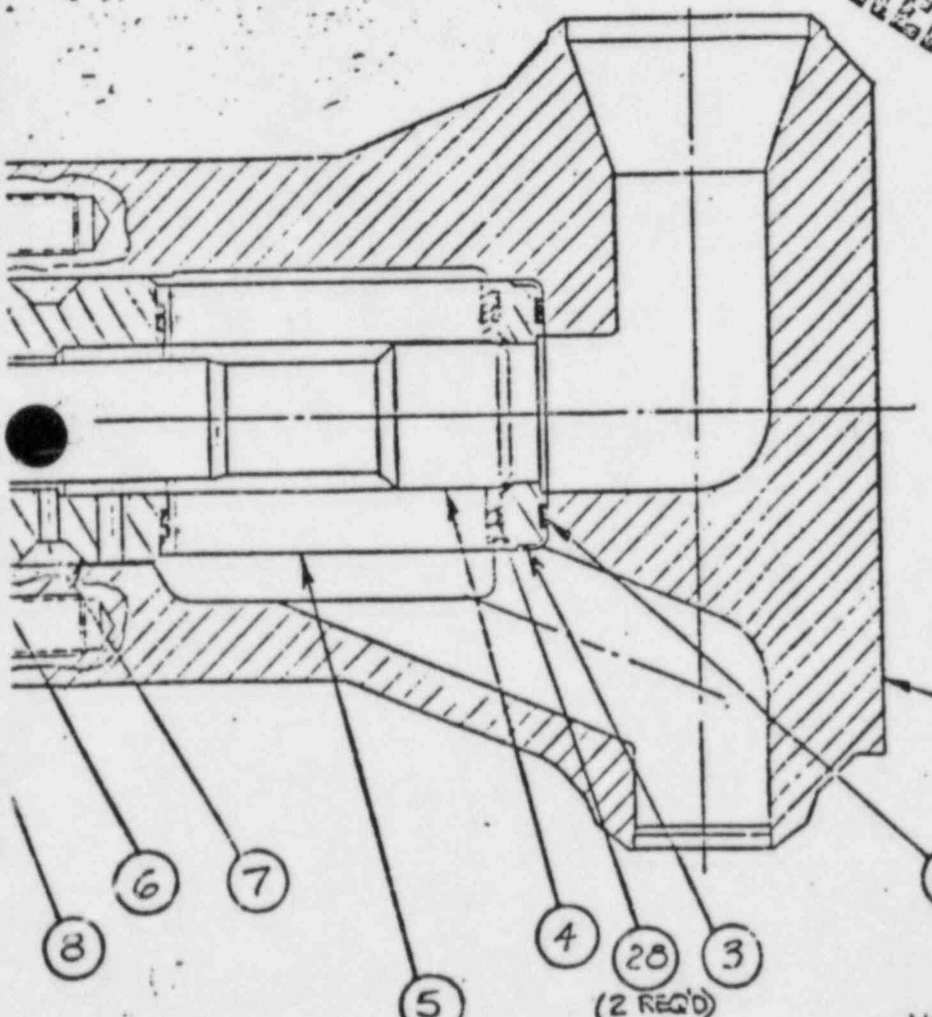
The actuator consists of a 4130 steel cylinder, carbon steel springs, 300 series stainless steel end caps, piston and stem, four ethylene propylene o-rings, two Halar piston seals, and Halar rod seal. (See Figure 2 and Bill of Material.) The valve body, the bonnet, and the seat ring are made of ASTM A182 GR316. The disk stack is made of 410 stainless and the plug is ASME SA637 GR688-2 material. (For specific material of each component, please refer to Figure 1, and Bill of Material.) The stem packing material is GTN-70, and the gaskets are made of SS 347 and asbestos, low chloride.

5.127

FIGURE 1

REVISIONS				
ECO NO	LTR	DESCRIPTION	DATE	APPROVED
0773	L	REVISE SEAT RING MAT'L		

REFERENCE ONLY



C.C.I. DISTRIBUTION UNCONTROLLED

NUCLEAR
SPECIAL HANDLING REQUIRED

NUCLEAR SAFETY RELATED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ±2°

MATERIAL (SEE BILL OF MAT'L)

FINISH

HEAT TREAT

USED ON

CONTRACT NO

PREP | CHK | DSGN | PROJ | APVD

13789-1

CONTROL COMPONENTS INC.
A SUBSIDIARY OF BABCOCK & WILCOX
IRVINE CALIFORNIA

BODY ASSY
3X4 GLOBE, 1534#, 2.5 PLUG

SIZE	CODE IDENT NO	DWG NO
C	19552	921201009

SCALE | SHEET OF

☐ STANDARD
☒ SPECIAL

SPEC

ASSEMBLY NUMBER: 921201009

BILL OF MATERIAL

CONTROL COMPONENTS, INC.

STEAM

5-14-76

PAGE 1 OF 4

W. O./CONTRACT NUMBER: 18787

REV. 2

LATEST ASS'Y START DATE

ASS'Y PULL

ASS'Y START

RELEASE STATUS

ISSUE | NUMBER | DATE

ASSEMBLY NAME: BODY ASSY, 3X4 GLB, 1534#, 2.5 PLUG

ITEM	ITEM DESCRIPTION	PART NUMBER	QUANTITY EA	QUANTITY TOTAL	ISSUE	SOURCE: P.O. # S.O. #	DATE DUE MONTH	DATE DUE DAY	LOCATION	STOCK AREA	MATERIAL LIST – ITEM REFER. NUMBER
	BODY ASSY	921201009									
1	BODY	320101236	1								
	(ASME SA182-GR-316)										
2	GASKET FLEXITALLIC	324501061	1								
	(ASB & 347, LOW CHLORIDE)										
3	RING, SEAT	320301161	1								
	SA240GR316/SA-182F316										
4	PLUG	320601125	1								
	(ASME SA637-GR-688-2										
5	DISK STACK ASSY	923701343	1								
	(410 CRES)										
6	GASKET, FLEXITALLIC	324501066	1								
	(ASB & 347, LOW CHLORIDE)										
7	BONNET	321401616	1								
	ASME-SA182-F316 OR ASME-SA479-316										
8	FLANGE, BONNET	321501038	1								
	(ASME SA182-GR-316)										

SEE BODY ASSY DWG REV. BLK FOR CHGS.

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DUKE POWER COMPANY
DESIGN ENGINEERING

CNM 1205-10-0171

BILL OF MATERIAL
CONTROL COMPONENTS, INC.

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☒ SPECIAL

STEAM 5-14-76

W.O./CONTRACT NUMBER: 18789-

ASSEMBLY NUMBER: 921201009

LATEST ASS'Y START DATE
ASS'Y PULL
ASS'Y START

REV. 2

RELEASE STATUS: ISSUE / NUMBER / DATE

ASSEMBLY NAME: BODY ASSY, 3X4 GLB, 1534#, 2.5 PLUG

ITEM	ITEM DESCRIPTION	PART NUMBER	QUANTITY EA	QUANTITY TOTAL	ISSUE	SOURCE: P.O. # / S.O. #	DATE DUE MONTH	DATE DUE DAY	LOCATION	STOCK AREA	MATERIAL LIST – ITEM REFER. NUMBER
9	STUD 1-8 x 5 3/4	323707019	9								
	(ASME · SA 193-B7)										
10	WASHER, LOCK, 1" HVY	251130042	9								
	(STEEL)										
11	NUT, HEX, 1"-8UNC HVY	250440116	9								
	(ASME-SA-194-GR 7)										
12	PACKING	120809002	9								
	(GRAFOIL GTN-70)										
13	EXTENSION, LEAK-OFF	323101309	1								
	(ASME SA 479-316)										
14	FLANGE, RETAINER	324401047	1								
	(ASTM A240-316)										
15	RING, RETAINER	324201044	1								
	(18-8 CRES)										
16	FOLLOWER, PACKING	322401073	1								
	(316 CRES)										
17	FLANGE, PACKING	322501013	1								
	(ASTM-A479-316										

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SPECIAL HANDLING
REQUIRED

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DUKE POWER COMPANY
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SEE BODY ASSY DWG. REV. BLK. FOR CHGS.

90 of 227

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CONTROL COMPONENTS, INC.

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ASSEMBLY NUMBER: 921201009

STEAM

5-14-76

W.O./CONTRACT NUMBER: 18789-.

LATEST ASS'Y START DATE | ASS'Y PULL | ASS'Y START

REV. L

RELEASE STATUS — ISSUE | NUMBER | DATE

ASSEMBLY NAME: BODY ASSY, 3X4 GLB, 1534#, 2.5 FLG

ITEM	ITEM DESCRIPTION	PART NUMBER	QUANTITY EA	QUANTITY TOTAL	ISSUE	SOURCE: P.O. # S.O. #	DATE DUE MONTH	DATE DUE DAY	LOCATION	LOCATION STOCK AREA	MATERIAL LIST – ITEM REFER. NUMBER
18	STUD, ALL THD, (3/4-10X6)	323723015	2								
	(ASTM-A193-B7)										
19	NUT, HEX 3/4-10	250440088	6								
	(ASTM-A194-2H)										
20	SCREW, HEX HD (1/2-13 X 3)	250310035	4								
	(18-8 CRES)										
21	NUT, HEX (1/2-13)	250440035	4								
	(18-8 CRES)										
22	CONNECTOR, STEM	322701005	2								
	(18-8 CRES)										
23	SCREW, HEX HD (3/8-16X1½)	250310043	6								
	(18-8 CRES)										
24	WASHER, LOCK, 3/8	251130033	6								
	(18-8 CRES)										
25	RING, LANTERN	323301017									
	(17-4 PH CRES)										
26	YOKE M/F 330201019	333601003	1								
	(ASTM A351-CF8)										

SEE BODY ASSY DWG. REV BLK FOR CHGS.

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PAGE 4 OF

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W. O./CONTRACT NUMBER: 18739

ASSEMBLY NUMBER: 921201009

LATEST ASS'Y START DATE — ASS'Y PULL — ASS'Y START

REV. L

RELEASE STATUS — ISSUE — NUMBER — DATE

ASSEMBLY NAME: BODY ASSY, 3X4 GLB, 1534#, 2.5 PLUG

ITEM	ITEM DESCRIPTION	PART NUMBER	QUANTITY EA	QUANTITY TOTAL	ISSUE	SOURCE: P.O.# S.O.#	DATE DUE MONTH	DATE DUE DAY	LOCATION	STOCK AREA	MATERIAL LIST – ITEM REFER. NUMBER
27	SPACER, PACKING	320401407	1								
	400 SERIES S.S.										
28	GASKET, FLEXITALLIC	324501065	2								
	(ASB & 347, LOW CHLORIDE)										

NUCLEAR
SPECIAL HANDLING
REQUIRED

DOCUMENT
CONTROL DATE
MAR 5 1981
DUKE POWER COMPANY
DESIGN ENGINEERING

CNM 1205 10-0171

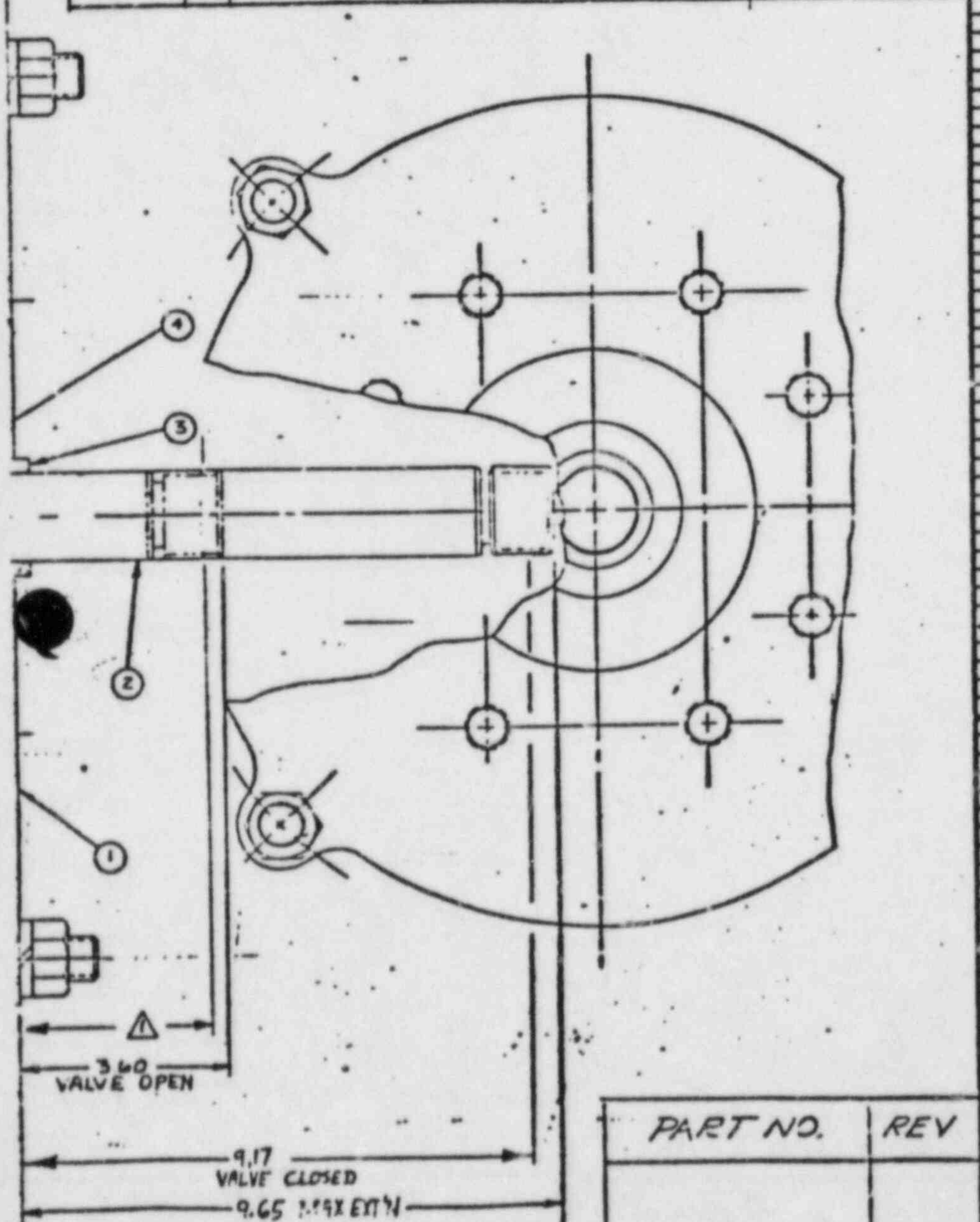
SEE BODY ASSY DWG REV BLK. FOR CHGS.

10 of 27

FIGURE 2

REVISIONS

ECO NO	LTR	DESCRIPTION	DATE	APPROVED
92464	—	RELEASED	[illegible]	CGS
3317	A	REVISED ITEMS ③ ② & ①	[illegible]	CGS
0477	B	ADDED ITEM "20, UNIT WT. WAS 298, ADDED C.G. TWO PLCS NOTE 5 SPRING LOAD WAS EXT 1176, RET 2700 REV'D NOTES 1, 2	3/3/70	CGS



PART NO.	REV

CONTRACT NO

CONTROL COMPONENTS INC.
A SUBSIDIARY OF BABCOCK & WILCOX
IRVINE CALIFORNIA

ACTUATOR ASSY
145 in², 5.57 STROKE

PREP	[illegible]	[illegible]
	[illegible]	[illegible]
PROJ		
APVD	CGS	[illegible]

SIZE	CODE IDENT NO	DWG NO
C	19562	930100099

SCALE NONE UNIT WT 309.5 lbs SHEET 1 OF 1

DOCUMENT CONTROL DATE
MAR 5 1981
DUKE POWER COMPANY
DESIGN ENGINEERING

CNM 1205-10-0171

11 of 27

APPLICATION		REVISIONS				
NEXT ASSY	USED ON	E.C.O. NO.	LTR	DESCRIPTION	DATE	APPROVAL
		92464	–	RELEASED	7/11/79	CGS
		92728	A	ITEM 11 WAS 3005..; #15 WAS 25044003B.	8/17/79	CGS
		93008	B	ITEM 8 P/N WAS 251120003	9.6.79	CGS
		93291	C	#13 WAS 255590539 .HALAL, SEAL	10/11/79	CGS
		93764	D	#13 WAS 655590002	11/12/79	CGS
		0478	E	ADDED ITEM #20	3/3/80	CGS

CNM 1205·10-0171

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCE ON ANGLES ± 2°
DECIMALS (.000) ± .010
(.00) ± .03
(.0) ± .1

	SIGNATURES	DATE
DR BY	[illegible]	7-11-79
CHK BY	[illegible]	7-12-79
APPD BY	CGS	7/13/79

CCI CONTROL COMPONENTS INC
IRVINE CA
A SUBSIDIARY OF BABCOCK & WILCOX

ACTUATOR ASSY
145 IN²
5.57 STROKE B/M 12.82

SIZE	CODE IDENT NO.	DOCUMENT NO.
A	19562	930101099

SCALE NONE SHEET 1 OF 1

BILL OF MATERIAL
Control Components International

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PAGE 1 OF

W.O. CONTRACT NUMBER: 18789-1-2

DM 7-12-79

ASSEMBLY NUMBER: 930101099

LATEST ASSY START DATE: ASSY PULL / ASSY START

REV.: E

RELEASE STATUS: ISSUE / NUMBER / DATE

ASSEMBLY NAME: ACTUATOR ASSY 14.5 IN² 5.5.7 STROKE

ITEM	ITEM DESCRIPTION	PART NUMBER	QUANTITY EA	QUANTITY TOTAL	ISSUE	SOURCE: P.O. # S.O. #	DATE DUE MONTH	DATE DUE DAY	LOCATION	STOCK AREA	MATERIAL LIST - ITEM REFER. NUMBER
	ACTUATOR ASSY	930101099									
1	CAP, END, LOWER M/F 323501004 300 SERIES SS	330301071	1								
2	STEM, 1.50 Ø 300 SERIES SS	330501088	1								
3	BUSHING, STEM BRONZE 660	333701027	1								
4	SEAL, ROD HALAL	255590539	1								
5	PISTON 300 SERIES SS	330401078	1								
6	SEAL, PISTON HALAL ?	255590540	2								
7	CAP, END, UPPER M/F 323501004 300 SERIES SS	330301072	1								
8	WASHER, FLAT CARBON STEEL	133301001	1								

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90

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PAGE 2 OF

ASSEMBLY NUMBER: 930101099

ASSEMBLY NAME: ACTUATOR ASSY 145 IN² 5.5.7 STROKE

7-12-79

REV: E

ITEM	ITEM DESCRIPTION	PART NUMBER	QUANTITY EA	QUANTITY TOTAL	ISSUE	SOURCE: P.O.# S.O.#	DATE DUE MONTH	DATE DUE DAY	LOCATION	STOCK AREA	MATERIAL LIST ITEM REFER. NUMBER
9	NUT, HEX JAM 300 SERIES SS 1⅛-12UNF	250440245	1								
10	STUD 3/4-10X24.62 300 SERIES SS	333101017	4								
11	CYLINDER 4130	330101017	1								
12	SPRING CARBON STEEL	330701032	1								
13	O RING ETHYLENE PROPYLENE EDM	255520513	2								
14	WASHER, LOCK, SPRING 300 SERIES SS	251130032	8								
15	NUT HEX 3/4-10UNC A194-2H /CAD PLT	250440088	8		1						
16	LABEL WARNING 300 SERIES SS	132701001	1								
17	SCREW DRIVE 300 SERIES SS	250040004	8								

CNM 1205-10-0171

BILL OF MATERIAL
Control Components International

PAGE 3 OF [illegible]

☐ STANDARD
☒ SPECIAL

DM 7-12-79

ASSEMBLY NUMBER: 930101099

REV. E

ASSEMBLY NAME: ACTUATOR ASSY 145 IN² - 5.57 STROKE

ITEM	ITEM DESCRIPTION	PART NUMBER	QUANTITY EA	QUANTITY TOTAL	ISSUE	SOURCE: P.O. # S.O. #	DATE DUE MONTH	DATE DUE DAY	LOCATION	STOCK AREA	MATERIAL LIST - ITEM REFER. NUMBER
18	LABEL NAMEPLATE	132701002	1								
	300 SERIES SS										
19	O-RING	255520372	1								
	ETHYLENE PROPYLENE										
20	SPRING	130701001	1								
	C'STL										

CNM 1205-10-0171

DOCUMENT CONTROL DATE
MAR 5 1981

15 of 27

CNM 1205-10-0171

IV. ANALYSIS

A. ANALYSIS OF RADIATION AND TEMPERATURE IMPACT ON NON-METALLIC COMPONENTS

Metallic components, grafoil packings, and asbestos flexitallic gaskets in the valve and actuator assembly are considered basicly immune to radiation exposure. The components that may undergo deterioration when exposed to the radiation dosage and temperature given in IEEE 382-72, Table 1, Table 2, and Figure 1, are the o-rings and seals within the actuator.

As mentioned in the previous section, there are four ethylene propylene o-rings, two Halar piston seals, and one Halar rod seal inside the actuator. The following is a brief report extracted from vendor's literature on radiation and temperature impact on these materials:

Ethylene Propylene

Compression tests are conducted in a nuclear environment with a radiation dosage of 10^8 RAD with various grades of ethylene propylene (see Table 1 of Appendix). The o-rings used in the actuator are the standard grade which is E515-80. The results shows a slight increase in hardness and some decrease in the tensile strength. But there is a significant decrease in the elongation in percent at break and tear strength. The compression set test shows a 96.2% compression set of the original deflection after 93 days under 25% deflection.

Halar

"The radiation-sensitized grade Halar 502 resin was developed to permit efficient cross-linking at low dosages, typically 10 megarads, compared with as much as 30 megarads for the unsensitized grades. In addition to cross-linking more efficiently, radiation-sensitized Halar resin has improved radiation resistance, i.e., it has better retention of properties on exposure to high dosages (100-1,000 megarads of radiation)."*

*Quote from "Radiation Cross-Linking of Halar Fluoropolymer" by Allied Chemical, See Appendix II.

A. Halar - continued

In Table I of Appendix II the material is subjected to a maximum of 25 megarads of electron-bean irradiation at 73°F and 392°F. As shown, the strength of the material decreases significantly as the test temperature increases. Table II shows the effect on the material when exposed to Cobalt-60 irradiation at the same dosage and temperature. The same results are seen.

B. EFFECT OF DEGRADATION OF MATERIAL ON ACTUATOR FAILURE MODE

As seen in the analysis, both the ethylene propylene o-rings and Halar seals and o-rings will undergo certain amounts of degradation when exposed to the radiation dosage and temperature requirements given in IEEE 382-72, Table 1, Table 2, and Figure 1. Due to the compression set of the materials, tney are no longer able to maintain the sealing ability. Nevertheless, upon air failure, the valve and its operator will be driven to fail close by the spring preload force in the actuator despite the failure of seals, provided proper exhaust of the bottom of the actuator is maintained.

Note: The exhausting devices are not within the CCI scope of supply.

C. EFFECT OF SAFE SHUTDOWN EARTHQUAKE ON ACTUATOR FAILURE MODE

An actuator speed test with applied side load was performed on a pressurizer power operated relief valve in June 1980. During the test, a side load of 3,000 pounds is applied to the bottom end cap of the stainless steel actuator. The valve opened in 2.0 seconds, closed in 1.1 seconds, and failed close in 1.8 seconds (see Appendix III, paragraph 2.3). This test demonstrates the ability of the valve to fail close under the simulated seismic condition. Reference seismic analysis

17127

V. CONCLUSION

The pressurizer power operated relief valves and operators will fail close while bieng subjected to the accident environmental conditions given in IEEE 382-72, Table 1, Table 2, and Figure 1 concurrent with a safe shutdown earthquake.

VI. REFERENCES

1. Duke Specification CNS-1205.10-1, Addendum #9.

2. IEEE 382-72.

3. Parker Seals General Bulletin #23, March 1978.

4. "Radiation Cross-Linking of Halar Fluoropolymer" by Allied Chemical, Specialty Chemical Division, 1975.

5. Combined Seismic Analysis for Duke McGuire and Catawba, Revision F. by B. Petrick, September 1980.

CNM 1205.10-0171

19 of 27

Selecting elastomeric seals for nuclear service

Compression set tests have proved more reliable than tensile tests in the selection of elastomer compounds for use as seals in a nuclear environment

CNM 1205·10-017 1

By ROBERT BARBARIN, Parker Hannifin Corp./Seal Group

In the early 1960s, the primary test used in selecting elastomers for reactor seals was a tensile test conducted on unstressed slabs of the compounds after they had been subjected to irradiation. These standard tests had the unfortunate ability to make compounds look very appealing to the nuclear engineer while completely failing the primary requirements of seal engineers. Today, a test has been developed which promises to satisfy the demands of both engineers. This is a test to determine the compression set of seals which are simultaneously squeezed (as they would be when installed) and irradiated (as they may be when in service) over prolonged periods. The new data provide criteria by which compounds may be selected for long life, normally requiring replacement only during conservatively scheduled five-year reactor overhauls.

Typical applications for elastomeric seals in and around nuclear reactors include the static seals in pressurized conduits containing radioactive fluids, and the dynamic seals in structural hydraulic snubbers.

Compression set

Compression set may be defined as the percent by which a seal fails to return to its original dimension after compression, expressed as a percent of its deflection. This loss of dimensional memory is due to changes in the elastomer's arrangement and density of molecular cross-links. As the change in cross-linking progresses, the seal will gradually take on the shape of the confining groove and relax the force that it exerts on the confining surfaces.

Since this normally occurs before tensile property changes, the tensile tests are frequently omitted as contemporary criteria for nuclear seal compound selection.

Of the three major types of radiation from nuclear fission, only gamma rays are normally considered a hazard to elastomer seals that are completely enclosed in conventional metal grooves. Alpha and beta rays are effectively stopped by thin metal barriers. Gamma rays, however, easily penetrate the typical elastomeric seal glands and cause cumulative changes in the compounds (see Table 1).

All elastomers tested to date have shown excessive compression set at 10^8 rads, yet a number of compounds showed acceptable compression set at 10^7 rads of gamma radiation dosage.

Therefore, no elastomer known today should be considered for

Table 1. Effects of gamma radiation on the principal properties of elastomeric compounds most often considered for seals in and around nuclear reactors. Compression set tests were conducted at room temperature and 25% deflection, for the number of days noted, while under radiation from cobalt strips in air.

Generic or Base Polymer (Compound No.)	Radiation Dosage in Rads	Hardness in Pts on Shore "A" Scale (Pts Change)	Tensile Strength in Psi @ Break (% Change)	Elongation in % @ Break (% Change)	Modulus in Psi @ 100% Stretch (% Change)	Tear Strength in lb/in. (% Change)	Compression Set Test: Days Deflected	Compression Set Test: CS in % of Original Deflection
Silicone (S455-70)	Original	69	807	117	668	63	93	7.6
	10^7	72 (+3)	733 (-9)	89 (-24)	—	63 (0)	93	31.4
	10^8	85 (+16)	—	—	—	—	93	90.5
Silicone (S604-70)	Original	66	1010	149	695	70	93	3.8
	10^7	69 (+3)	1020 (+1)	129 (-13)	833 (+25)	62 (-11)	93	20.0
	10^8	85 (+19)	939 (-7)	31 (-79)	—	29 (-59)	93	92.4
Ethylene Propylene (E515-80)	Original	78	1450	213	689	164	93	16.2
	10^7	78 (0)	1220 (-16)	176 (-17)	740 (+7)	148 (-10)	93	46.6
	10^8	84 (+6)	1030 (-29)	79 (-63)	—	71 (-57)	93	96.2
Ethylene Propylene (E740-70)	Original	70	2080	233	554	174	93	6.7
	10^7	73 (+3)	2140 (+3)	194 (-17)	808 (+46)	163 (-6)	93	28.6
	10^8	79 (+9)	1700 (-18)	96 (-59)	—	70 (-60)	93	90.5
Fluorocarbon (V747-75)	Original	75	1510	190	634	128	93	14.7
	10^7	76 (+1)	1580 (+5)	130 (-32)	1120 (+77)	87 (-32)	93	66.7
	10^8	88 (+15)	1180 (-22)	29 (-85)	—	82 (-36)	93	93.3
Polyurethane (P642-70)	Original	66	3560	582	342	306	56	17.1
	10^7	67 (+1)	3570 (0)	491 (-16)	444 (+30)	374 (+22)	56	55.2
	10^8	66 (0)	1420 (-60)	201 (-65)	—	146 (-52)	56	91.4
Fluoro-silicone (L677-70)	Original	68	1050	180	520	72	128	13.3
	10^7	72 (+4)	668 (-36)	97 (-46)	—	—	128	67.6
	10^8	84 (+16)	—	—	—	—	128	97.1

20 of

applications where 10^7 rads dosage will be exceeded between scheduled overhauls.

Table 1 documents several compounds frequently considered for nuclear seals, showing their original properties and those same properties after exposure to 10^7 rads. At this dosage, two silicones, two nitriles and one ethylene propylene compound exhibit acceptable compression set. A second ethylene propylene compound, as well as polyurethane, polyacrylate, fluorocarbon, and fluorosilicone, would not be recommended because they all tested out at marginal or excessive compression set. The results for polyurethane are particularly revealing; the tensile, tear and modulus tests were either unchanged or actually improved by 10^7 rads, but the compression set rose from approximately 17% to over 55%.

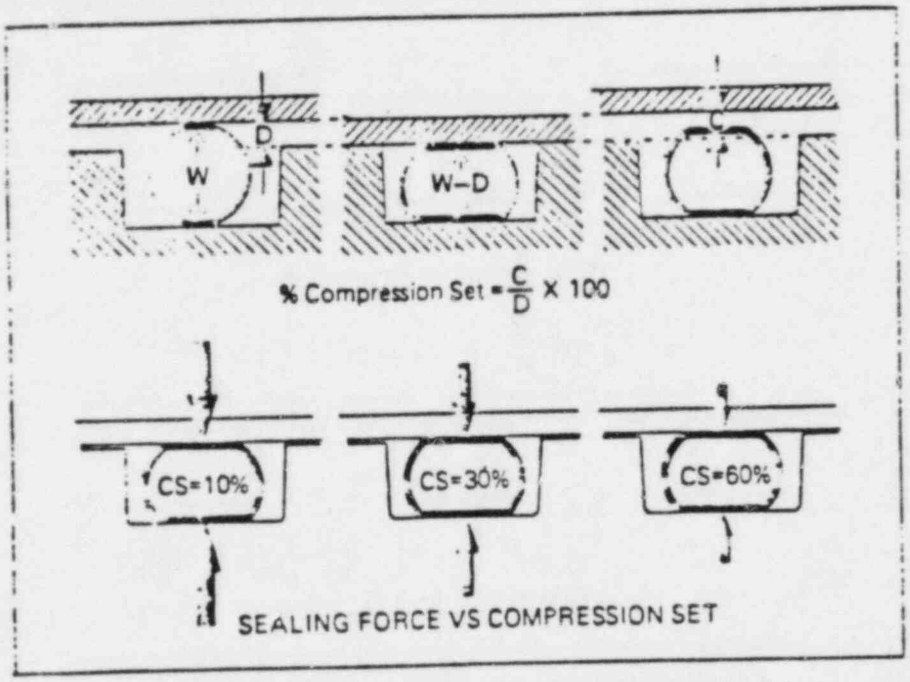

Figure 1. Compression set (the percentage of initial deflection which is unrecovered when a seal is released) directly affects the force that a compression seal can maintain on its sealing lines. This factor, which is increased by radiation, is a prime criterion for the selection of seals for reactors.

Temperaiures and fluids

Service temperatures and/or fluids often degrade an elastomer faster and more severely than gamma radiation. This is illustrated clearly by comparisons between Tables 1 and 2. While Table 1 shows the effects of gamma radiation without fluid or temperature influences, Table 2 shows the effects of fluids and temperatures frequently encountered in nuclear reactor environments but without the gamma radiation. It is interesting to note that the polyurethane degradation documented in Table 2 was the result of temperature, but that it would doubtless have been attributed to radiation if it had occurred in a reactor.

The combined effects of radiation, temperature and fluid are seldom a simple addition of their individual effects, but are synergistic. However, knowledge of all three characteristics for each compound will help in the selection of the best compounds for testing.

Table 2. Effects of fluid immersion in principal reactor fluids on polyurethane and ethylene propylene elastomers considered for seals in and around nuclear reactors. Note severe effects of temperature excursions on properties of polyurethane compounds compared to the properties of most ethylene propylenes.

Generic or Base Polymer (Compound No.)	Immersion Test Fluid immersed 3 hrs @ 340F + 3 hrs @ 320F + 18 hrs @ 250F	Hardness in Pts on Shore "A" Scale (Pts Change)	Tensile Strength in Psi @ Break (% Change)	Elongation in % @ Break (% Change)	Modulus in Psi @ 100% Stretch (% Change)	Volume Change in %	Compression Set in % of Original Deflection
Polyurethane (P4611)	Original properties	95	7240	470	1590		
	GE SF 96 Silicone (200 c/s)	89 (-6)	4250 (-41)	537 (+14)	1370 (-14)	-0.8	119.2
	GE SF1154 Silicone	89 (-6)	3650 (-50)	550 (+17)	1400 (-12)	-0.3	cancelled
	Water	89 (-6)	4680 (-35)	576 (+23)	1180 (-26)	+2.3	96.5
Polyurethane (P642-70)	Original properties	66	3780	699	350		
	GE SF 96 Silicone (200 c/s)	Deteriorated				-1.7	cancelled
	GE SF1154 Silicone	Deteriorated				-2.2	cancelled
	Water	Deteriorated					
Ethylene Propylene (E740-75)	Original properties	73	2390	177	991		
	GE SF 96 Silicone (200 c/s)	73 (0)	28[illegible] (+17)	207 (+17)	865 (-13)	-1.5	19.9
	GE SF1154 Silicone	70 (-3)	2660 (+11)	198 (+12)	800 (-19)	+3.0	17.8
	Water	74 (+1)	2600 (+9)	182 (+3)	873 (-12)	0.0	14.4
Ethylene Propylene (E652-90)	Original properties	88	2330	146	1230		
	GE SF 96 Silicone (200 c/s)	91 (+3)	2330 (0)	146 (0)	1500 (+22)	-2.5	44.9
	GE SF1154 Silicone	89 (+1)	2430 (+4)	143 (-2)	1490 (+21)	+0.4	cancelled
	Water	90 (+2)	2450 (+5)	145 (-1)	1430 (+16)	-1.0	42.0
Ethylene Propylene (E529-65)	Original properties	61	1450	273	279		
	GE SF 96 Silicone (200 c/s)	61 (0)	1680 (+16)	317 (+16)	296 (+6)	-4.5	29.6
	GE SF1154 Silicone	60 (-1)	1520 (+5)	279 (+2)	290 (+4)	-2.1	28.4
	Water	61 (0)	1590 (+10)	298 (+9)	276 (-1)	-0.1	29.8
Ethylene Propylene (E692-75)	Original properties	74	1610	239	563		
	GE SF 96 Silicone (200 c/s)	72 (-2)	1350 (-16)	209 (-13)	578 (+3)	-3.4	25.4
	GE SF1154 Silicone	72 (-2)	1620 (+1)	219 (-8)	549 (-2)	+0.8	30.5
	Water	73 (-1)	1100 (-32)	171 (-28)	545 (-3)	+0.2	16.7

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APPENDIX II

HALAR

RADIATION CROSS-LINKING OF HALAR® FLUOROPOLYMER

Section Contents

CNM 1205·10-0171

Allied Chemical

Tomorrow's Plastics Today

Specialty Chemicals Division
P.O. Box 1087R
Morristown, N.J. 07960

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CNM 1205·10-0171

RADIATION CROSS-LINKING OF HALAR® FLUOROPOLYMER

When exposed to ionizing radiation, HALAR® fluoropolymer cross-links and, thereby, becomes infinitely high in molecular weight. The formation of a cross-linked network accounts for the unique properties of irradiated HALAR fluoropolymer and is the reason it can be classified as a "radiation-resistant" polymer.

Radiation-Sensitized HALAR Resin

The radiation-sensitized grade HALAR 502 resin was developed to permit efficient cross-linking at low dosages, typically 10 megarads, compared with as much as 30 megarads for the unsensitized grades. In addition to cross-linking more efficiently, radiation-sensitized HALAR resin has improved radiation resistance, i.e., it has better retention of properties on exposure to high dosages (100 - 1000 megarads) of radiation. Radiation-sensitized grades of HALAR resin also contain proprietary additives that minimize the evolution of acidic gases and inhibit oxidative chain scission reactions. These grades are recommended if postcross-linking is to be performed or if HALAR resin parts are to be used in applications where radiation resistance or high temperature resistance is required.

Effect of Radiation on Tensile Properties

Tables R-I and R-II show the effect of radiation on the tensile properties of HALAR resin at 23°C and 200°C. The most dramatic effect of radiation is to increase the breaking elongation and work to break of HALAR resin at elevated (> 150°C) temperatures. A cobalt 60 dosage of 10 megarads, for example, increases HALAR resin's breaking elongation at 200°C from 25% to 410%. The work to break of irradiated HALAR resin is increased at five megarads by a factor of 50. The increased work to break of irradiated HALAR resin accounts for its enhanced toughness and better cut-through resistance at elevated temperatures. The properties of HALAR resin at ambient temperature are not significantly affected by low dosages (5 megarads) of radiation. Higher dosages cause a progressive decrease in breaking elongation.

Effect of Radiation on Thermal Stress Cracking

Radiation cross-linking of HALAR fluoropolymer greatly increases its resistance to thermal stress cracking. A dosage of 10 megarads renders HALAR resin strips completely resistant to thermal stress cracking at 200°C in mandrel wrap tests (Fed. Spec. L-P-390C, Part H). Unirradiated HALAR resin cracks within two hours at 200°C in this wrap test because of the very high stress levels imparted to the specimen.

Radiation Resistance

Radiation resistance refers to retention of properties on exposure to large dosages of ionizing radiation.

HALAR resin ranks among the most radiation resistant of polymers. Radiation-sensitized grades of HALAR resin maintain useful properties even after exposure to 200 megarads of cobalt 60 irradiation. The overall radiation resistance of HALAR resin compares favorably with ultra high-molecular-weight polyethylene and is much superior to PTFE and FEP polymers. PTFE and FEP are adversely effected by changes as low as 2 megarads.

The comparative radiation resistance of HALAR fluoropolymer, PTFE, and FEP is illustrated in Table R-III. Cobalt 60 dosages of greater than 25 megarads cause PTFE and FEP to become weak and fragile. Exposure to a dosage greater than 50 megarads reduces the strength of PTFE and FEP to a level too low to be measured by standard Instron techniques. HALAR fluoropolymer, on the other hand, maintains useful properties even after exposure to dosages of 200 megarads.

CUSTOM IRRADIATION OF HALAR FLUOROPOLYMER

Industrial irradiation is normally accomplished by exposing a material to cobalt 60 or to high-energy electrons. A cobalt 60 source emits gamma rays which are capable of penetrating thick sections of matter. When exposed to cobalt 60, most, but not all, organic polymers undergo cross-linking reactions. Cobalt 60 cross-linking is a relatively slow process which requires hours of exposure to achieve high cross-link densities. Irradiation by high-energy electrons is accomplished by exposing a material to the rays emitted by an electron beam machine. High-energy electrons have low penetrating power and are only effective in cross-linking thin-wall (> 1/8 in.) items such as wire, tubing, sheet, etc. In contrast to cobalt 60 irradiation, electron-beam irradiation is a rapid process which can be completed in a matter of seconds. For materials that can be rapidly cross-linked, electron beams may be used in line with processing equipment such as wire-coaters or tubing extruders.

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There are a number of facilities throughout the country which do custom irradiation. Both electron-beam and cobalt-60 facilities exist. In general, the costs for custom irradiation depend on the density of the product, total dosage, and the volume of the package.

Isomedix, Parsippany, New Jersey, is a typical facility equipped for cobalt-60 irradiation. The company maintains two 150,000 curie cobalt-60 sources which are located in a heavily shielded room. Product to be irradiated is placed on one of several turntables in the shielded room. The source, which is kept beneath a pool of water, is brought to a point near the product and held there for a preset time. The product is rotated to give a high degree of radiation uniformity. Dosage depends primarily on the time the product is exposed to the source. Distance from the source is the variable that determines dose rate. Cartons up to 18 in. x 18 in. on the bottom or drums may be stacked as high as 56 in. on each of six turntables. Even larger items can be accommodated with some sacrifice in radiation efficiency.

Typical 1973 prices quoted by Isomedix for custom irradiation are $1 per cubic foot per megarad, for volumes in excess of 50 cubic feet.

Isomedix can irradiate wire and cable on spools of various sizes. The 1973 price is $15 per reel for a 5 megarad exposure. For a 4,000 foot reel, this corresponds to $3.75 per thousand feet, and for an 11,000 foot reel to $1.36 per thousand feet. Specific prices are dependent on quantities involved.

Radiation Dynamics, Westbury, New York, is a typical custom irradiator equipped for high-energy-electron irradiation. The company maintains two Dynamitron 1500 KV, 10 MA beam scanners which are positioned over 2-ft. wide conveyor belts in a room shielded by several feet of concrete. The 1973 price of irradiation is $100 an hour or $550 a day. Their conveyor system can handle 800 ft^2/hour at 5 megarads. The maximum size object that can be accommodated measures 24 in. x 48 in. In general, objects with wall thicknesses of up to .01 in. can be irradiated by electron beams. Objects with thicker walls should be irradiated by cobalt 60.

Radiation Dynamics is equipped to irradiate wire and cable having outside diameters of up to 100 mils. At a dosage of 5 megarads, the 1973 price is $3.00 per thousand feet.

CNM 1205·10-0171

TABLE R–I

EFFECT OF ELECTRON–BEAM IRRADIATION

ON THE TENSILE PROPERTIES OF HALAR FLUOROPOLYMER GRADE 502

Temp. °C	DOSAGE (megarads)	Yield stress psi	Break stress psi	Yield elong. %	Break elong. %	Modulus psi	Work to break psi
23°C (73°F)	0	4650	8100	4.5	225	2.0×10^5	11,000
	2	4700	8050	4.5	220	2.0×10^5	10,800
	5	4600	7700	4.0	210	2.0×10^5	10,300
	10	4550	7500	5.0	215	2.0×10^5	9,400
	25	5450	8100	4.5	175	2.5×10^5	7,100
200°C (392°F)	0	265	215	10	25	2.8×10^3	35
	2	295	235	35	145	2.3×10^3	310
	5	335	435	30	430	3.5×10^3	1,150
	10	295	575	35	520	2.7×10^3	1,350
	25	370	770	35	355	3.4×10^3	[illegible]

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TABLE R–II

EFFECT OF COBALT–60 IRRADIATION

ON THE TENSILE PROPERTIES OF HALAR FLUOROPOLYMER GRADE 502

Temp. °C	Dosage (megarads)	Yield stress psi	Break stress psi	Yield elong. %	Break elong. %	Modulus psi	Work to break psi
23°C (73°F)	0	4250	7750	4.5	235	1.8×10^5	9800
	2	4500	7650	4.5	215	1.7×10^5	9600
	5	4650	7550	4.0	200	1.8×10^5	9400
	10	4520	6850	4.5	170	1.7×10^5	8800
	25	4470	4600	4.5	105	1.7×10^5	6200
200°C (392°F)	0	265	220	10	25	3.4×10^3	35
	2	310	250	30	275	3.5×10^3	720
	5	315	630	30	490	3.7×10^3	2000
	10	325	710	35	410	3.7×10^3	2100
	25	310	580	35	390	3.6×10^3	1550

TABLE R–III

COMPARATIVE RADIATION RESISTANCE

OF FLUOROPOLYMERS

Cobalt-60 dosage (megarads)	Tensile breaking stress (psi) elongation at break (%) HALAR FLUOROPOLYMER	PTFE	FEP
0	7000/210	3000/300	3000/290
50	4600/105	900/<5	1500/<5
100	4200/65	•	•
500	4000/20	•	•
1000	2800/10	•	•

• Too low to be measured.

APPENDIX III

G-4

Control Components, Inc. INFORMATION

a subsidiary of Babcock & Wilcox

To: D. W. Smeller

From: M. Coleman

Cust.: Duke Power

Subj.: Actuator Speed Tests with Applied Side Load

File No. or Ref. 18789-1

Date 6/6/80

1.0 SCOPE

To set up and operate valve/actuator assembly per TP-532.

2.0 SUMMARY OF TEST RESULTS

2.1 With the valve body pressurized to 2500 PSI, per customer's request, stroking time without any side load was:

Time to Open	Time to Close
.71 seconds	.91 seconds
.61 seconds	.92 seconds
.71 seconds	.90 seconds

2.2 With valve body pressurized to 2500 PSI and a side load of 2130 lbs. force applied to lower actuator end cap, stroking speed was:

Time to Open	Time to Close
.75 seconds	.91 seconds
.74 seconds	.94 seconds
.74 seconds	.90 seconds

2.3 Valve/actuator performance with 3000 lbs force applied to the lower actuator end cap was: 2.0 seconds to open, 1.1 seconds to close, and 1.8 seconds to fail close from the full open position. This extreme side load condition is not required per TP-532, however it was performed by CCI's Research and Development group to illustrate the performance and structural integrity of the valve/actuator assembly. The stroke times mentioned above were taken with a hand held stop watch. The stroke times mentioned in paragraph 2.1 and 2.2 were taken by electronic stop clocks actuated by switches at the top and bottom of the actuator shaft's stroking range.

2.4 The valve/actuator assembly did move to the full close position with loss of electrical power and with 1,000 PSIG remaining in the valve body.

Actuator Speed Tests with Applied Side Load - 6/6/80

3.0 PERFORMANCE REQUIREMENT

3.1 With 80 PSIG air supply to the actuator and a side load of 2204 lbs force applied to the lower actuator end cap, the valve stroking speed shall be 2.0 seconds or less to open and 2.0 seconds or less to close.

3.2 This valve/actuator assembly is a fail closed device and should move from the full open position to the full close position with the loss of electrical power and with a valve body pressure > 500 PSIG.

M. Coleman

M. COLEMAN

MC/js