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THE Marquardt COMPANY VAN NUYS, CALIFORNIA

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TEST REPORT - EVALUATION OF DU PONT LRU 488 AS A SEAT SEAL MATERIAL IN THE MARQUARDT R4D ENGINE VALVE

TMC Program 7208-3

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1.0 INTRODUCTION

Under contract to the Jet Propulsion Laboratory (Reference P. O. GK-541658-01, Items 3 and 4), The Marquardt Company conducted the evaluation test program described herein, to assess the suitability of DuPont LRU 488 molded elastomeric teflon as a seat seal material for the R4D valve. Molded seat seals, in accordance with a TMC configuration, were supplied by J.P.L. and assembled into R4D valve seat assemblies. The seat assemblies were installed into R4D valves and subjected to a test program intended to evaluate leakage characteristics as a function of cycle life and temperature.

2.0 SUMMARY

During the period 19 December 1970 through 26 January 1971, The Marquardt Company conducted an evaluation test program on molded elastomeric seat seals of DuPont LRU 488. Six molded seals were supplied by JPL and two were assembled into two Marquardt R4D valve seats. Seal surface profiles were traced with a Bendix Proficorder to document the sealing surface interface prior to valve build-up. TMC P/N 228683 S/N 027 and 028 valves were assembled. The seat of the S/N 028 valve exhibited satisfactory seal surface attributes while that of the S/N 027 valve appeared eccentric to the seat centerline. Subsequent acceptance testing resulted in excessive leakage of the S/N 027 valve and satisfactory test results with the S/N 028 valve.

The S/N 027 valve seat was reworked to replace the seal and insert but a similar eccentric seal face profile and excessive leakage resulted. Machining of the seat to attempt to compensate for the eccentric seal resulted in a seal profile which appeared to be capable of maintaining contact with the valve armature in the closed position, but subsequent leak checking resulted in excessive leakage. Further rework to recover this valve seat as a valid test unit was abandoned.

The S/N 028 valve was subjected to a cycle and temperature test with valve leakage monitored at specified increments of cycling. After completion of 7500 cycles at ambient temperature and 2500 cycles at 160°F, a leak rate of 6-7 scc/min of GN_2 at 100 psig was measured. Subsequent disassembly of the valve disclosed significant loss of the seal material and testing was terminated.

* JPL compound identification number

Though the test goal of 25, 000 valve cycles with leakage of less than 1 scc/hr of GN_2 was not achieved, the test results indicate that the DuPont LRU 488 material is a suitable valve seat seal material but seal designs are not interchangeable with virgin TFE seals. Test unit failure results from flow-stream-impingement-motivated seal extrusion and subsequent seal shearing by the valve closing action. The elastomeric teflon seal design must preclude flow stream impingement which results in deformation of the seal such that subsequent valve action shears the material.

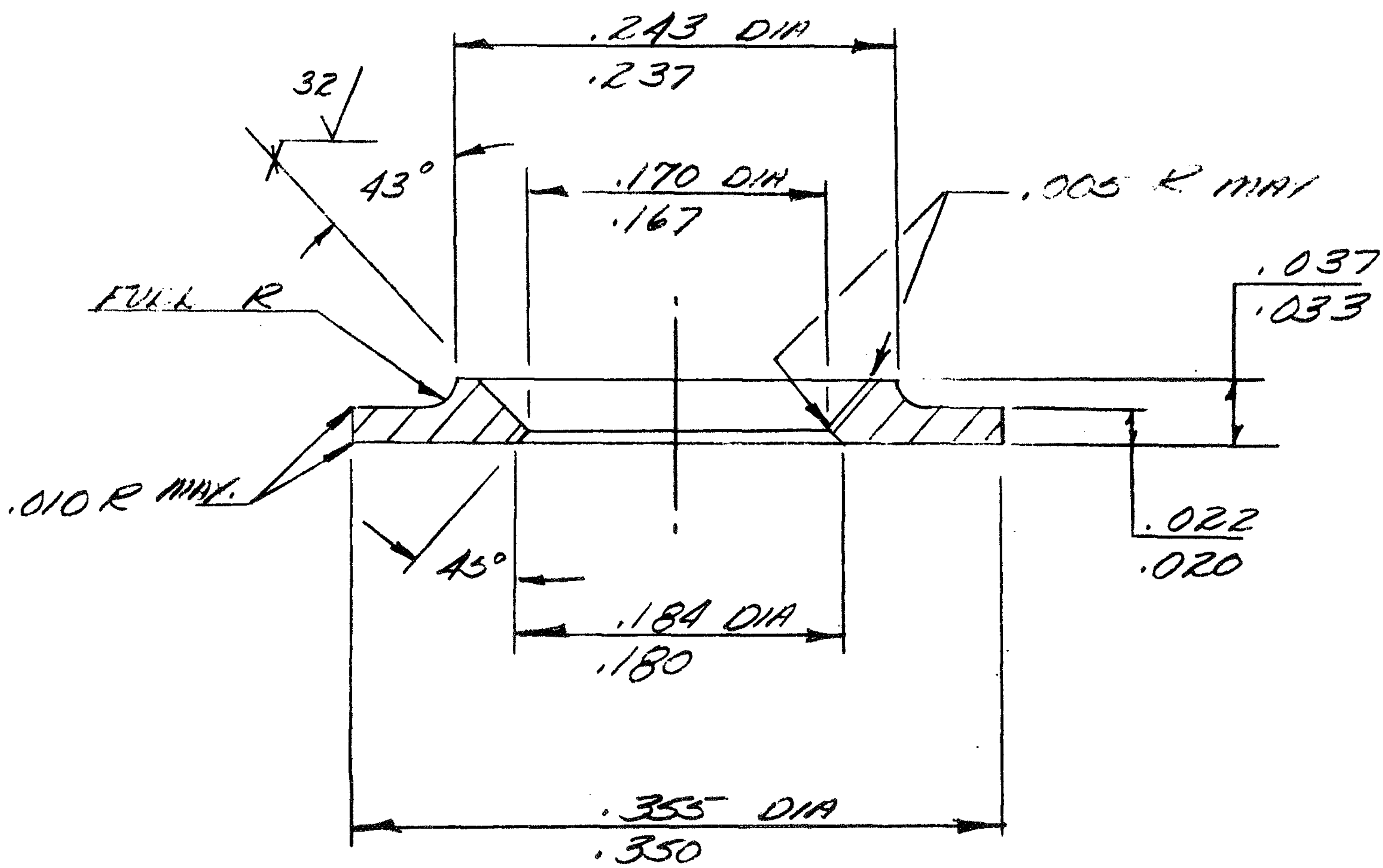
3.0 DISCUSSION

Seat seals of DuPont LRU 488 were molded by JPL in accordance with a TMC-supplied sketch (Figure 1). The configuration of this seal was to provide a seal interface identical with the TFE seal of the Marquardt R4D valve seat assembly (P/N 228683). To substantiate molding accuracy and document critical fit dimensions of the respective seals with the mating parts, seal O.D., I.D. and critical thickness were measured and recorded (Table I). The undersize O.D. dimension indicated material shrinkage which could be compensated for by minor modification of the mold. Seal thickness was slightly oversize but the magnitude appeared to be inconsequential. Under microscopic examination (to 40X) the seal profile was uniform and flash free, with the exception of the outside diameter. A significant quantity of foreign material inclusions were apparent within the seal material (metallic particles and black stringers) but none broke through the surfaces, or appeared to jeopardize the capability of the seal to function.

The seat assemblies, from S/N 027 and 208 P/N 228683 valves, were removed and machined to remove the inserts and TFE seals in preparation for reassembly with the new seal material. Inserts in accordance with Figure 2 were fabricated. After cleaning all detail parts, seat assembly was accomplished using special tooling and fixtures normally employed in the manufacture of R4D valve seats. Since the normal seat assembly procedure is to assemble the seal into the insert, cool this assembly to less than -200°F, then press it into the seat which is at ambient temperature, this procedure was used to assemble seat S/N 1012 (valve S/N 027). The resultant assembly evidenced cracking of the seal material due to the brittle nature of the material at the cold temperature. The insert and seal were removed and all subsequent seat assemblies were accomplished at ambient temperature.

Following the assembly of seat S/N 042 (valve S/N 028), an RTV mold was made of the sealing surface and a profile of the surface traced on a comparitor (Figure 3). To document an accurate profile trace, the seal profile was traced on a Bendix Proficorder (Figure 4). All traces evidenced excellent sealing capabilities (adequate seal "proud"), and the seat was installed in the valve assembly.

After reworking seat S/N 1012, reassembly was accomplished at ambient temperature. The RTV mold profile (Figure 5) and Proficorder trace (Figure 6) confirmed the observed eccentric seal condition observed visually. A preliminary leak check of the seat, assembled into the S/N 027 valve resulted in seat leakage in excess of 100 scc/min. at inlet pressures



SEAT SEAL

Figure 1

SHEET

SEAL

DATE 12/19/70

SEE BELOW

INSPECTOR Jess Rabun

ACTUAL DIMENSIONS

	S/N 001	S/N 002	S/N 003	S/N 004	S/N 005	S/N 006
1. .170/.167 ID	.169	.169	.169	.169	.169	.169
2. .355/.350 OD.	.345		.346		.343	.346
3. .022/.020 DIM	.024	.024	.025	.024	.024	.026

NOTE: NOT ABLE TO CHECK ITEM #2 .355/.350 WITH FLASH. DIMENSIONS SHOWN WERE MADE AT TIME OF SEAT ASSEMBLY AFTER REMOVING FLASH

TABLE I

ENGINEERING EXPERIMENTAL ORDER NO. **T 19062**

TMC A 1064

PART NAME: INSERT			ISSUE DATE: 1-4-70
A.M.R. NO. (IF APPLICABLE)	DUE DATE: 1-5-70	ORIGINATED BY: R. Lynch	MFG. CHARGE NO.: 7208-3-1501
DELIVER TO: R. Lynch	PROJECT ENGINEER: R. Lynch H031	SHOP SUPERVISOR (SIGN WHEN COMPLETED)	

FAB 4 OF AM 355 VAC. MELT BAR
OR ENG. APPROVED ALTERNATE

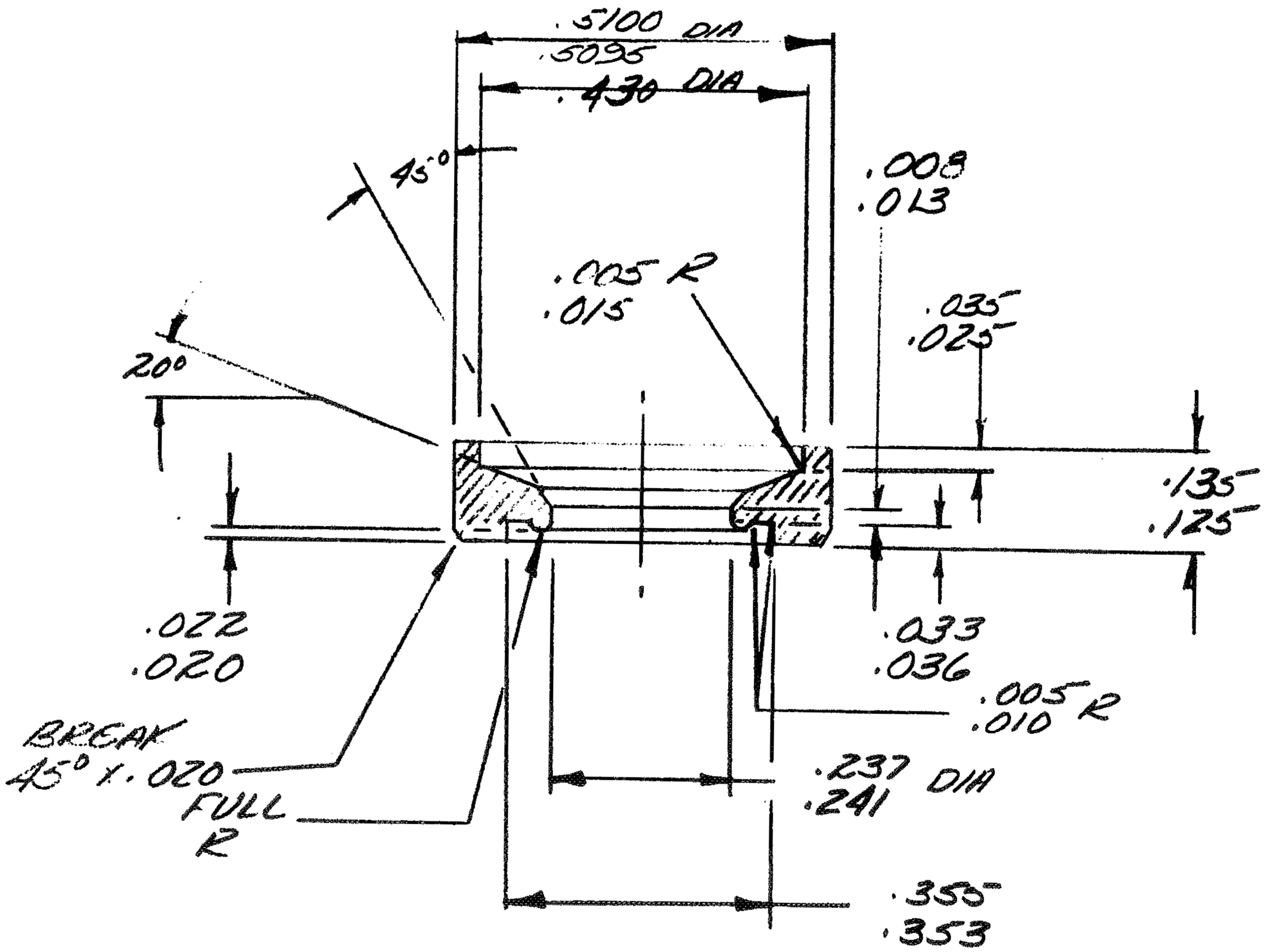


Figure 2

SEAT S/N 042
SEALING SURFACE PROFILE
50 X SIZE

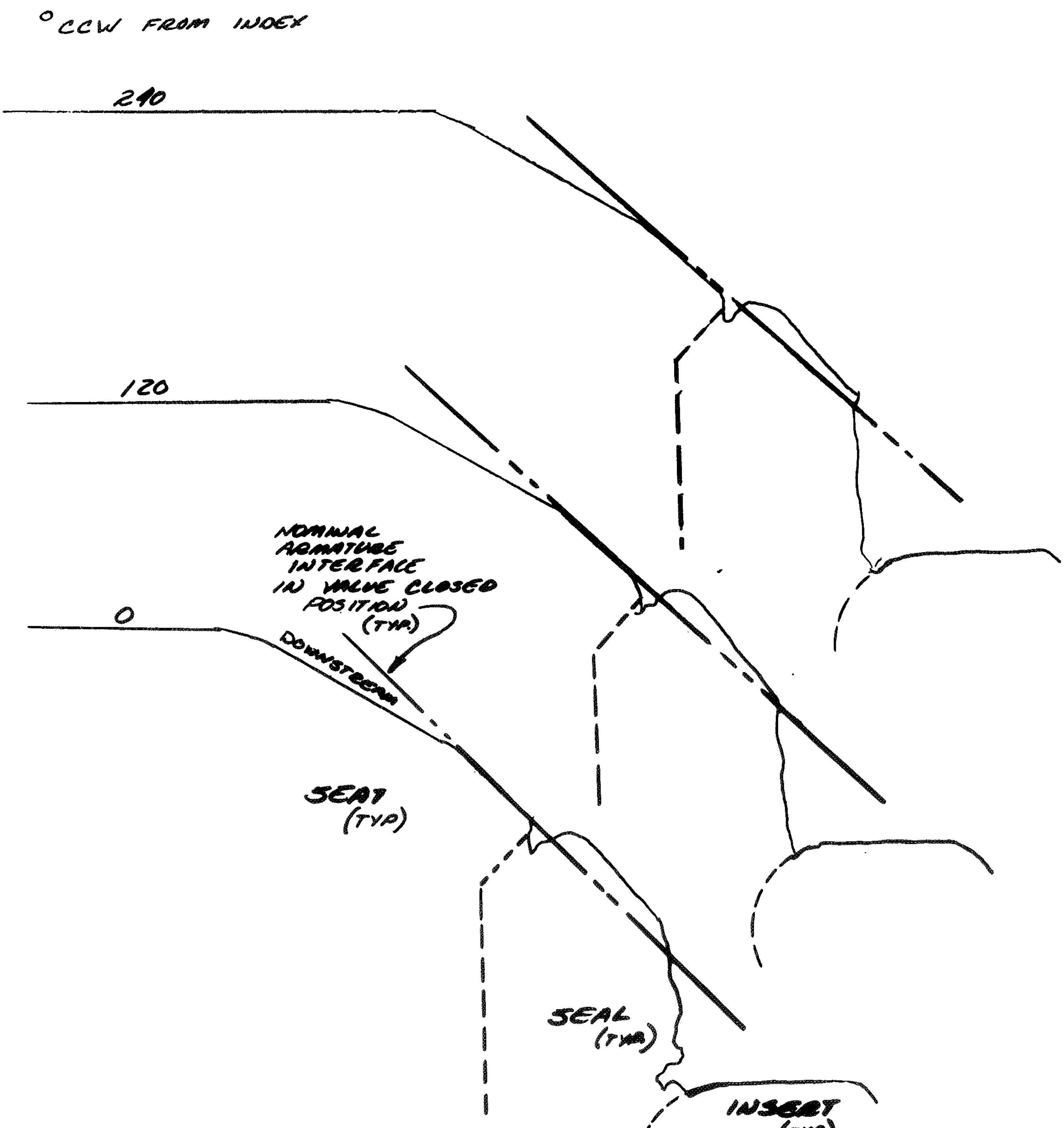
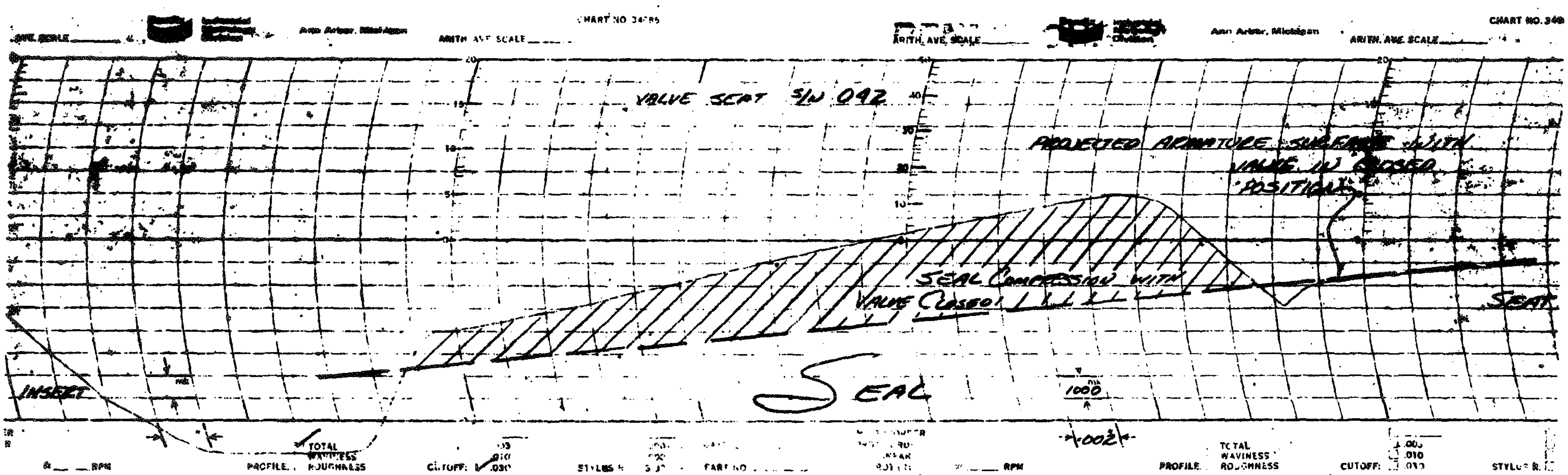


Figure 3



PROFICORDER TRACE, AT INDEX POINT, OF SEAL PROFILE
S/N 042 SEAT ASSY.

Figure 4

SEAT ASSY. S/N 1012
SEALING SURFACE PROFILE
50X SIZE
S/N 003 SEAL

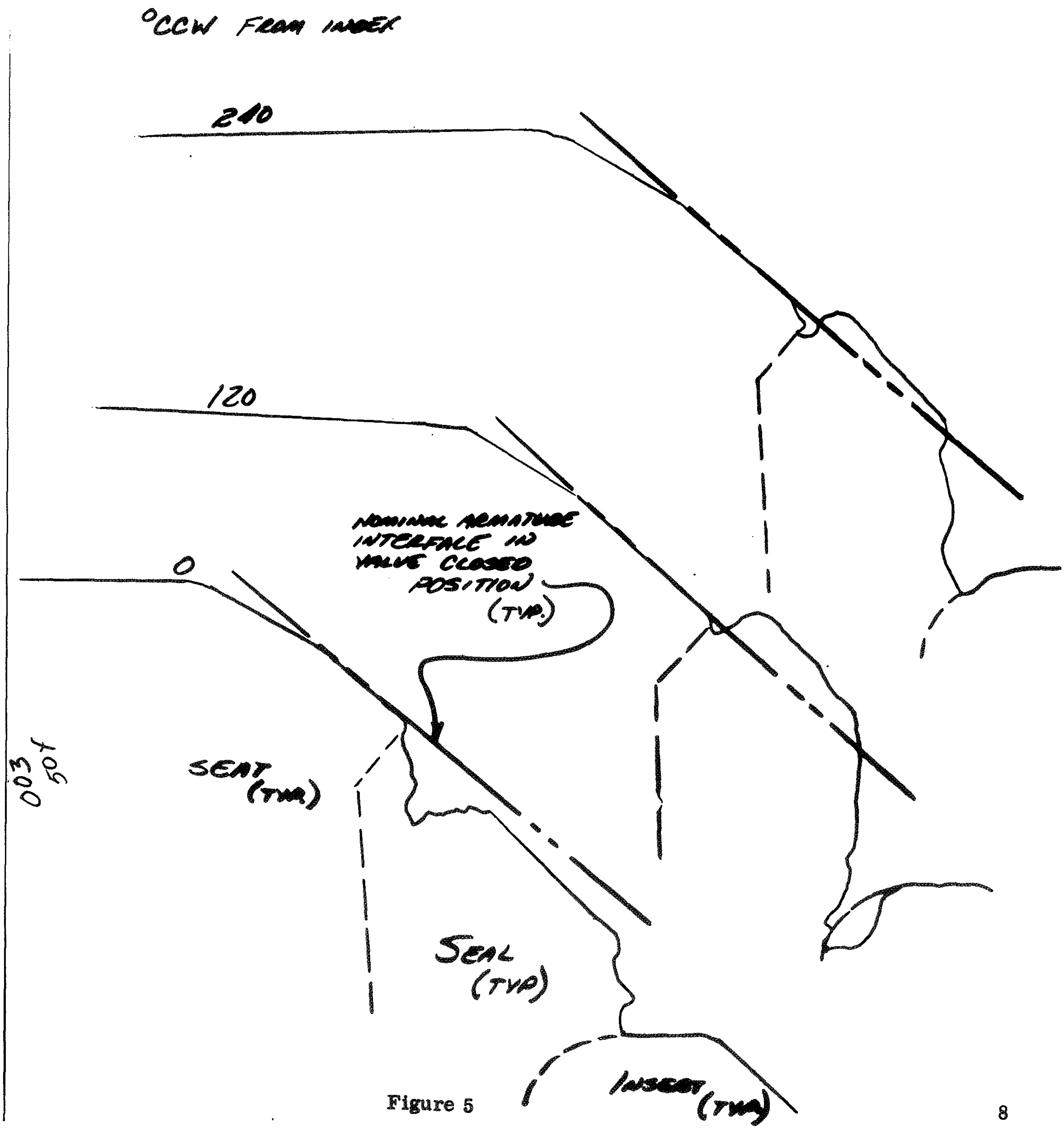
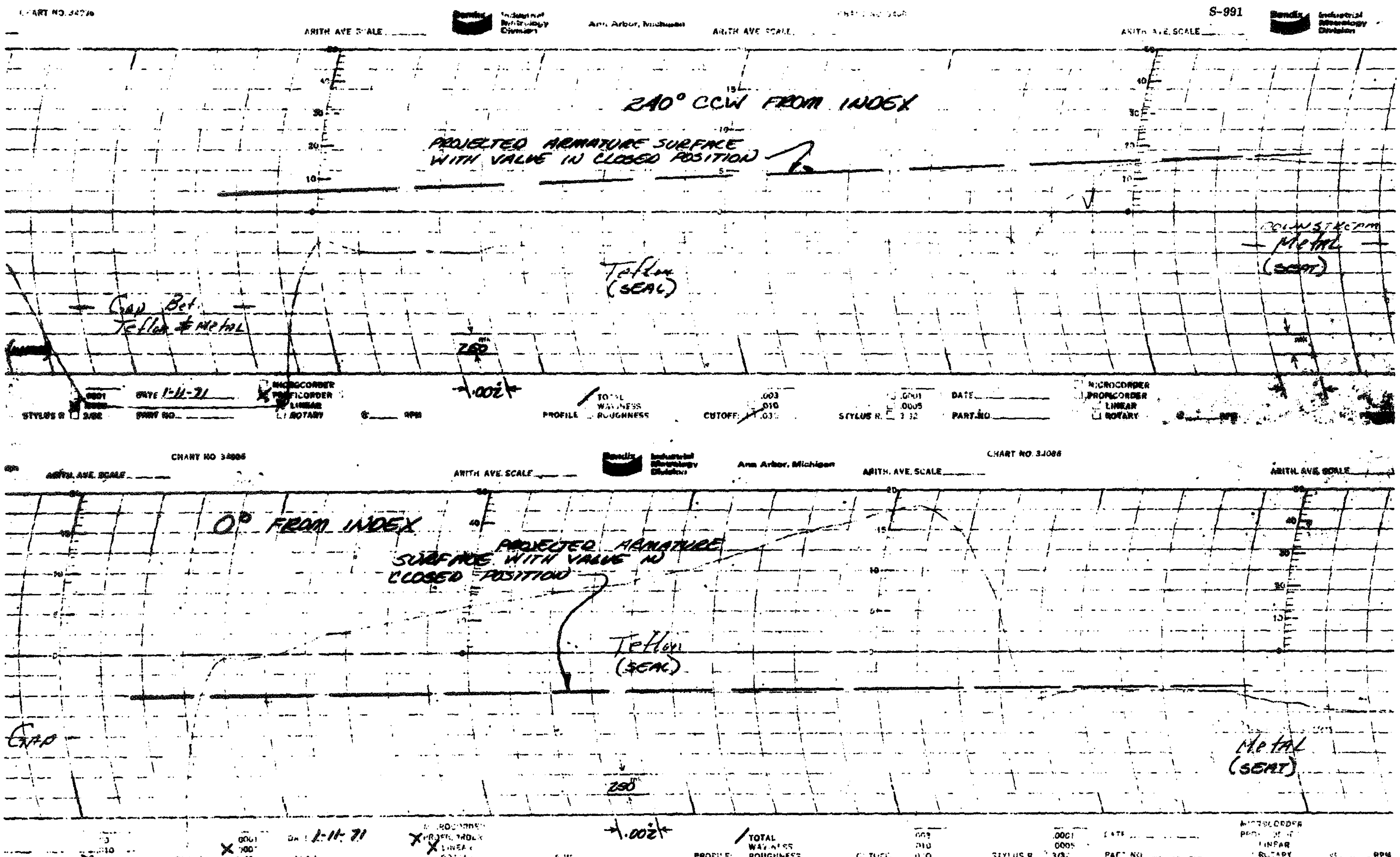


Figure 5



PROFICORDER TRACE S/N 1012 SEAT ASSY. S/N 003 SEAL

Figure 6

from 50 to 400 psig. The seat was reworked and reassembled with a new seal and insert (S/N 005 seal). The RTV mold again indicated an eccentric seal condition and potential inability to seal (Figure 7).

The undersize seal O.D.'s of all the seals was the origin of the eccentricity problems, since this diameter centers the seal in the counterbore of the insert during assembly. Other surfaces which tend to center the seal have inadequate "grip" to maintain concentricity during the assembly operation. Further attempts to reassemble S/N 1012 seat assembly were abandoned and an attempt to recover sealing characteristics was made by machining the metal immediately downstream of the seal, to produce a seal "proud" condition. A total of .0015" of material was removed from this surface and the seat assembled into the S/N 027 valve. Excessive leakage resulted at all pressures and further rework and testing of this valve assembly was suspended.

Valve assembly S/N 028 was tested in C.A. #2 of Bldg. 32 for conformance to nominal R4D acceptance criteria. A summary of these test results are shown in Table II.

During the response test portion of this test series, a flow decay phenomenon occurred. The valve was initially opened and flow rate established at 400 pph with a water temperature of 80°F. Continued flow resulted in the water temperature increasing to 88°F and the flow rate decayed to 290 pph. After rapidly cycling the valve five times, flow rate increased to 320 pph then slowly decreased to a stable 290 pph. It was hypothesized that flow stream impingement on the upstream lip section of the seal (Reference Figure 1) was distorting the seal and restricting the annular flow area between the seal and the armature tip. Since this, in no way, influenced the sealing capability of the seat and appeared to be a repeatable anomoly, testing was continued.

The S/N 028 valve was installed in the water flow bench of Building 37 and cycled 2500 times with water at ambient temperature (78°F). Gaseous nitrogen leakage at 100 and 400 psig, following this cycling, was 0.0 scch leakage, the valve and inlet water well-conditioned at 160°F and 2500 additional valve cycles accumulated. During this cycling, a significant flow decay was observed as cycling progressed. Since flow measurement capability was not incorporated in the test set-up, the magnitude of the decay could not be monitored but the observed flow rate at the end of cycling was less than 10% of the initial. Subsequent GN_2 leak checks at 100 and400 psig indicated 0.0 scch leakage, however, some immeasurable leakage was evident as the valve was first pressurized, but rapidly diminished to zero.

An additional 5000 cycles of valve operation were accumulated at ambient temperature. During this cycling, flow decay was apparent and the throttling valve downstream of the test unit was opened, resulting in some flow recovery. Following the cycling, a GN_2 leak check was made. At 100 psig inlet pressure, a leak rate of 6 scc/min. resulted. Several valve cycles were applied with 100 psig GN_2 inlet pressure, and the subsequent leakage measured was 7 scc/min. Since this leak rate was far in excess of the desired goal, the valve was disassembled and the seat visually examined.

SEAT ASSY S/N 1012
SEALING SURFACE PROFILE
50X SIZE
SEAL S/N 005

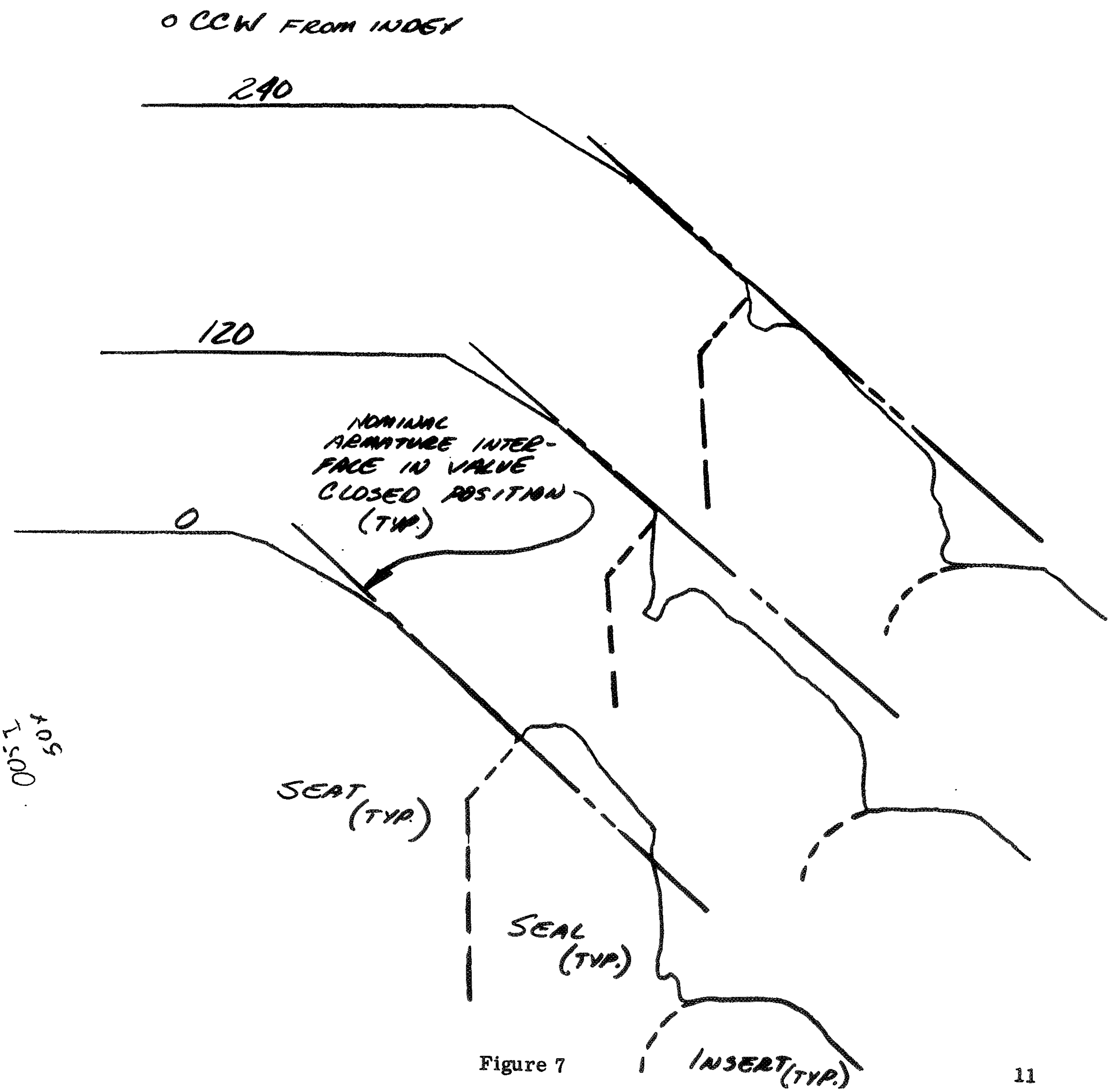


Figure 7

TABLE II

Test	Acceptance Criteria		Test Results	
1. Proof Pressure	No Rupture after 2 min. at 800 psig.		No Rupture or Distortion	
2. External Leakage	No Evidence ("Snoop") from 0-400 psig GN_2		No Bubbles 0-480 psig	
3. Internal Leakage	$<$ 1 scch GN_2 @ 10, 200, 300 & 400 psig		Pressure	Leakage
			10 psig	0.0 scch
			200	0.2
			300	0.0
			400	0.4
4. Response (Auto Coil) (per MTS 0682)	Open	5.7-7.4 ms	Open	6.3 ms
	Close	4.0-7.5 ms	Close	5.0 ms
5. Current-Auto Coil	Pull-in	.55-.85 a	Pull-in	.699 a
	Drop-out	.05-.20 a	Drop-out	.205 a
6. Insul. Resistance	$>$ 50 megohms @ 500 vdc		$>$ 200 megohms @ 500 vdc	

Figure 8 presents a photograph, at 12 x magnification, of the valve seat, after removal from the valve. The severe erosion of seal material, particularly at the downstream edge, is representative of the entire sealing area. In the upper right quadrant of the seal, a large section of seal, extending the full length of the sealing surface, has been eroded away.

In view of the condition of the seat seal, all testing was terminated.

4.0 CONCLUSIONS

Though the test program goal of 2 valves accumulating 25,000 valve cycles with no leakage in excess of of 1 scch was not achieved, the results of this effort indicate that the DuPont LRU 488 material possesses properties which make it an attractive seal material for valve seats. Considering the extensive seal material erosion evident in Figure 8 (after 10,000 valve cycles) the measured valve leak rate of 6-7 sccm (a tolerable gas leak rate for many industrial applications) indicates that the elastomeric material quality is conducive to maintaining a seal. Virgin TFE seals of similar interface configuration are totally ineffective as seals long before interface surface degradation has progressed to the extent of the subject test unit seat seal.

The failure of the test unit seat seal to meet the test goal must be attributed to the seal design, rather than the material, since the flow decay phenomenon observed during initial acceptance testing, is apparently directly related to the ultimate degradation of the seal. Distortion of the seal, due to direct flow stream impingement on the seal, obstructed the normal flow annulus, causing flow decay. During high temperature testing when softening (or weakening) of the seal material occurred, still greater flow decay resulted. During the final valve cycle increment, an attempt was made to compensate for the flow decay by opening the throttling valve downstream of the test unit. The resultant increase in pressure drop across the test unit, in all likelihood, propagated the ultimate seal degradation. The origin of the seal failure, therefore, was the seal design rather than the material. To ensure a LRU 488 seal design of extended life cycle capability, the seal should be protected from flow stream impingement and should be of a design such that minimum structural capabilities are required of the seal material.

The assembly problems of the seat assembly of the S/N 027 test valve are symtomatic of the particular deficiencies of the test unit design. Minor dimensional deviations, from those required of a TFE seal, resulted in an assembly seal-interface contour that was less than optimum. To control the assembly, a design which more totally confines the elastomeric material would result in a controllable seal-interface surface.

The wear properties of the material appear comparable to those of TFE. The erosion of the material which did result does not appear related to wear phenomenon in that large chunks of material are missing and appear to have been torn out in the normal flow direction

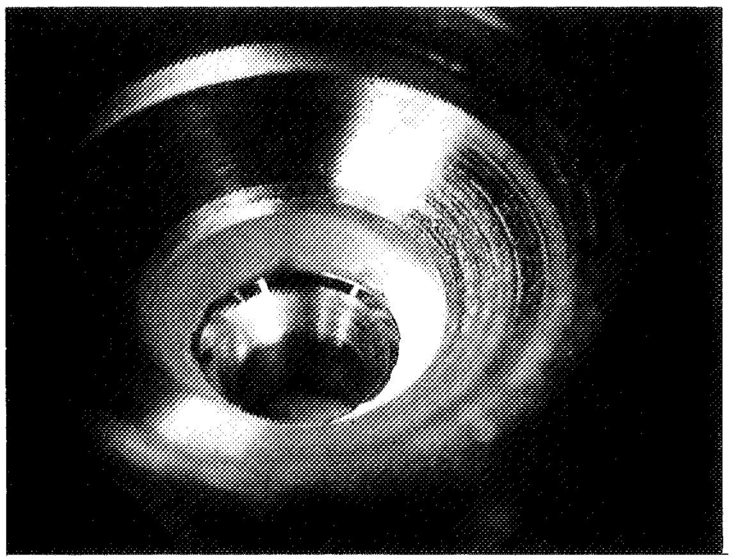


Figure 8

Seat Assembly from S/N 028 Valve After 10,000 Cycles

12X Magnification

or sheared off by the impacting of the armature against the downstream metal surface when the seal was extruded toward the downstream by flow impingement. Seal interface surfaces which remain intact show no evidence of fretting and the mating armature surface exhibits no excessive smears of seal material.

Teflon elastomers, such as DuPont LRU 488 are attractive candidate seat seal materials, but the seat design must accommodate the specific properties of the material. The material cannot generally be interchanged with TFE seat seals and achieve comparable success. The design must be consonant with the high degree of elasticity and lower ultimate strength of the material, and preclude overloads.

5.0 RECOMMENDATIONS

Based upon results of this test program, the following recommendations are made for advancing the development of elastomeric teflon compounds for valve seat seals:

a. Obtain structural and thermal properties of the material and prepare a design, supported by a design analysis, of a valve seat which will result in overall valve performance comparable to that of the Marquardt R4D valve assembly.

b. Fabricate evaluation seat designs and conduct an evaluation test program to assess cycle life, temperature, structural margin, and leakage characteristics, utilizing a R4D valve as a basic unit, modified to accommodate the selected seat/armature design configuration.

(Figure 9 presents several conceptual designs of seat seals which are consonant with elastomeric seal materials.)

ELASTOMERIC SEAL MATERIAL SEAT DESIGN CONCEPTS

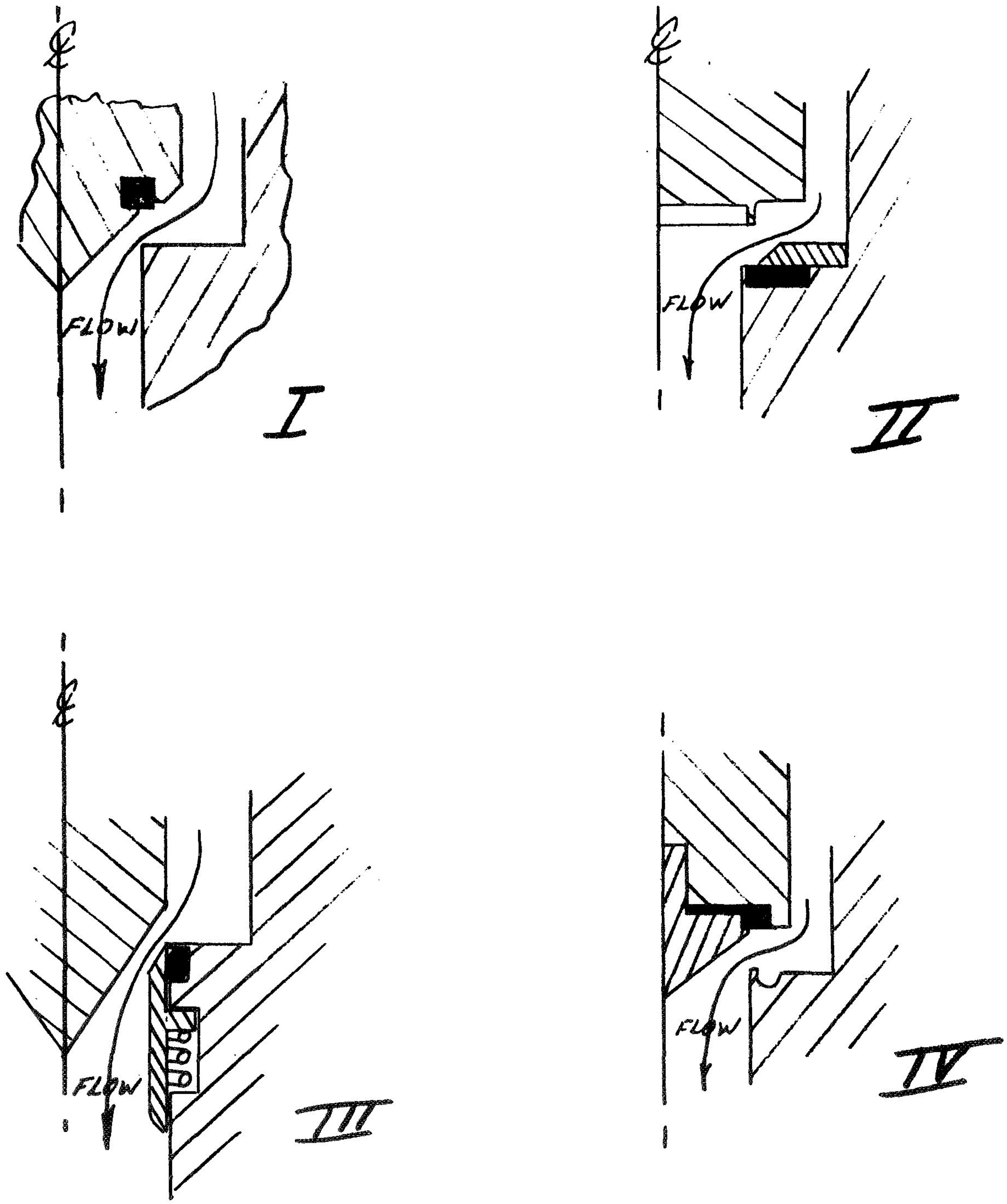


Figure 9