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# AN ANALYSIS OF THE INTERNAL LEAKAGE CHARACTERISITICS OF CERTAIN MAROTTA VALVES

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PREPARED BY F. K. Jacobsen
F. K. Jacobsen
Sr. Reliability Engineer
Mechanical Systems Reliability
Assurance — Centaur

APPROVED BY J. Rusk
J. H. Rusk
Reliability Group Engineer
Mechanical Systems Reliability
Assurance — Centaur



GENERAL DYNAMICS
*Convair Division*

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## SUMMARY

Excessive internal leakage of certain models of Marotta valves had generated an inordinate number of problems during field and qualification testing by Convair Division of General Dynamics. Regular failure analysis of these problems did not disclose the basic cause of leakage, but revealed functional characteristics suggestive of further examination. Therefore, these valves were subjected to special tests for the purpose of obtaining data that would further define the cause of failures.

Results of the special tests revealed that plastic flow (distortion) of valve seats was the basic cause of internal leakage, and that the plastic flow was caused by a combination of the thermal effect of valve cycling and the extreme force of the poppet striking the valve seat.

# SECTION 1

# INTRODUCTION

1.1 PURPOSE AND SCOPE. This report summarizes the results of a study and tests conducted by Convair for the purpose of determining the cause of excessive internal leakage of certain Marotta valves. Test results and analyses are presented to support the conclusion that plastic flow of valve seats is the basic cause of excessive leakage.

1.2 BACKGROUND. In the Centaur testing program, numerous cases of internal leakage of certain models of Marotta valves were encountered. These valves, of the design typified by Marotta model numbers MV544, MV508, MV563, and MV130, correspond to GD/C part numbers 55-02402, 55-02403, 55-02961, and 88-30915.

Normal failure analysis of discrepant hardware disclosed several questionable functional characteristics of the valves but did not isolate the basic cause of excessive leakage. A review of the failure histories showed that most leakage failures occurred at test installations where valves were subjected to long duty cycles. Failure records also showed that the three-way valve had more leakage failures than the two-way valve.

Failure analysis of MV544 units which failed in 1962, 1963, and 1964 ascribed failures to contamination and maladjustment resulting from unauthorized field adjustment. (Unauthorized field adjustment was suspected when low torque values were found on the main valve assembly nuts of many of the analyzed units.) However, in 1964 disassembly of one failed unit disclosed that the cross-section of the seat was distorted into a bulbous protrusion of the seating edge; and drawings specify that the configuration of this cross-section should show a near-sharp corner (see Figures 1 and 2). Subsequent analysis of failed units revealed that distorted seats were common in valves having appreciable service (see Figures 3 and 4). Disassembly of a valve known to have only Marotta acceptance test time disclosed no distortion (see Figure 5).

The exact cause of the seat distortion was not definitely determined although it was suspected that the high operating temperature of the solenoid was in part responsible. Also, the relationship between distortion and leakage was not understood although distortion was assumed to be detrimental to reliable operation. The valve was redesigned to incorporate: 1) a thermal insulator between the solenoid and valve body; 2) an adjusting screw less susceptible to disturbance; and 3) a groove in the seat support. (The groove in the seat support was advocated by Marotta as a solution to the leakage problem.)



Figure 1. Overall View of Marotta Valve Seat from Problem Report A0255CP



Figure 2. Cross Section Photograph of Marotta Valve Seat from Problem Report A0255CP

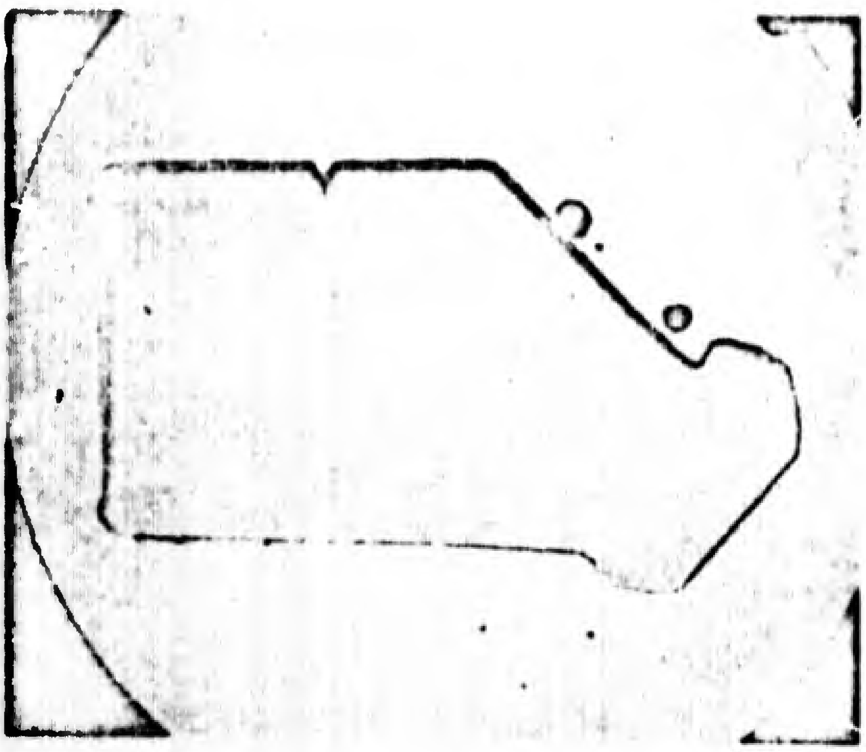

Figure 3. Cross Section of Marotta Valve Seat from Problem Report S0161CP

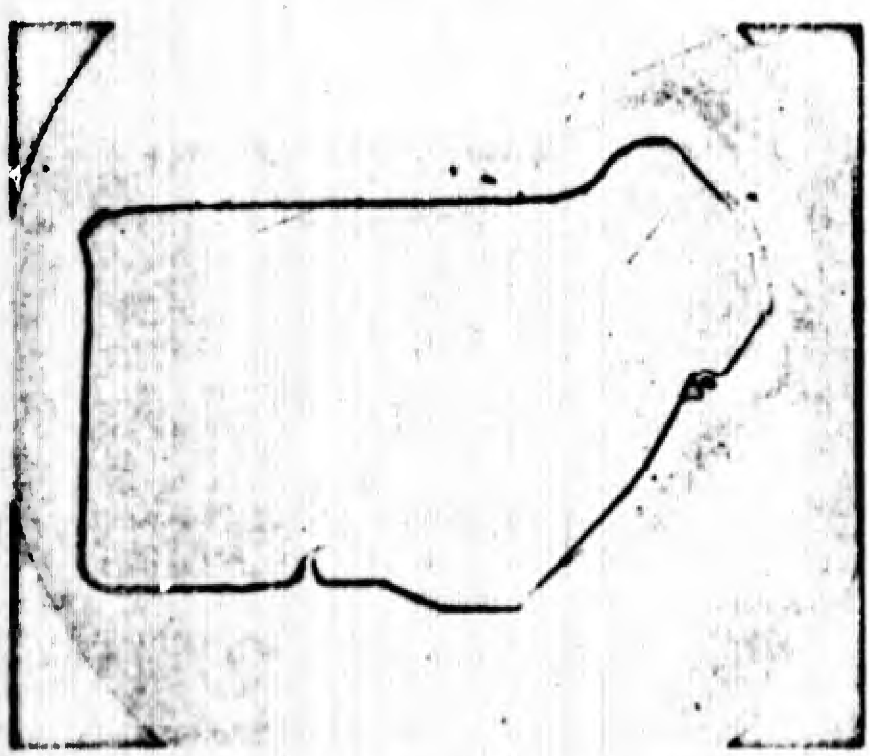

Figure 4. Cross Section of Marotta Valve Seat from Problem Report F1651CP

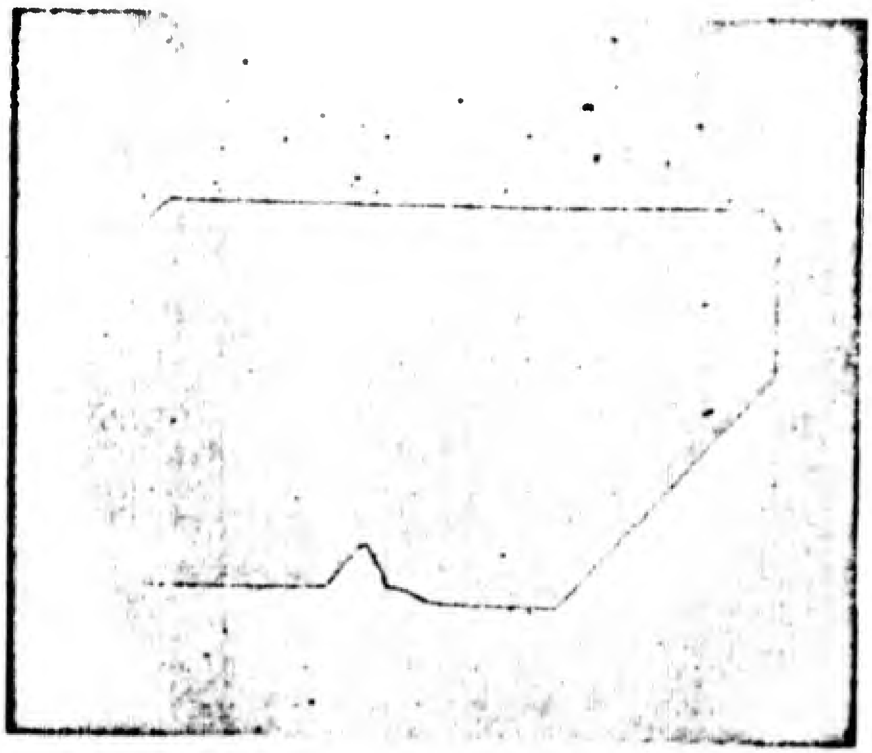

Figure 5. Cross Section of Marotta Valve Seat
from Problem Report F1647CP

Two of three redesigned units failed qualification testing. Failure analysis of these units revealed very low torque on the valve assembly nut and distorted seats. (Figure 4 shows a seat from one of these units.) The failures and analyses of the qualification test units demonstrated that the design changes had not eliminated the leakage or the distorted seats.

A review of detail drawings and hardware revealed that the plastic seats are from 0.002 to 0.006 inches thicker than the depth of the groove in the seat support. The possibility that the seats were not squeezing completely into their grooves offered a reason for the decreasing of torque on the valve assembly nut and for leakage.

Because of the above problems, Convair conducted additional tests and analyses to determine the basic cause of failures. These tests are reported in Section 2.

## SECTION 2

## TESTS AND ANALYSES

2.1 TESTS. A number of carefully controlled experiments were performed with previously analyzed valves and new seats. The results of these experiments are summarized in the following paragraphs.

2.1.1 Valve Assembly Characteristics. The torque versus rotation characteristics of the valve assembly (stackup) nut were measured. To do this a valve was assembled and the nut screwed finger tight. Then the torque on the nut was increased in increments and the nut angular position recorded for each increment. The results, plotted in Figures 6 and 7, showed a linear relationship between torque and rotation with one sharp change in slope. The change in slope is interpreted as resulting from metal-to-metal contact being achieved when the seat was fully squeezed into its support (groove). The torque values required to achieve this condition were estimated by GD/C to be higher than on normally assembled valves although the vendor has declined to prescribe a torque value for the stacking nut.

The conclusion is that in a normally assembled valve, the seats prevent metal-to-metal stackup of the internal parts.

2.1.2 Assembly Force Decay During Valve Operation. Two additional valves were assembled and the stackup nuts were torqued to prescribed values as shown in Figure 8. The valves were then operated and the torque on the stackup nut was monitored morning and evening. The values recorded were those required to cause movement in the tightening direction and the nut was reset to its initial position after each torquing. The curves illustrate that the torques decreased rapidly at first and later appeared to stabilize. The torque values presented on the graphs are those taken in the morning before the unit had been operated. Torques measured in the evening, with the valve hot from operation, were four to eight inch pounds higher.

In the lower curve of Figure 8, the second torque drop-off resulted from a change in the operating cycle used for test. During the first week and a half, the valve was energized 5-seconds-on/5-seconds-off, eight hours per day. Subsequently, the valve was continuously energized for eight hours per day, thereby getting hotter. This valve was not leak-checked as only one seat was installed to conserve the seats available for testing.

The valve used to develop the upper curve of Figure 8 was energized continuously for eight hours per day. It developed a severe leak at the normally open seat after just four days of operation, but the leak was present only with the valve at ambient temperature. With the solenoid energized for as little as five minutes, with no gas flowing through the valve, the leak stopped, presumably from thermal expansion of the plastic seats.

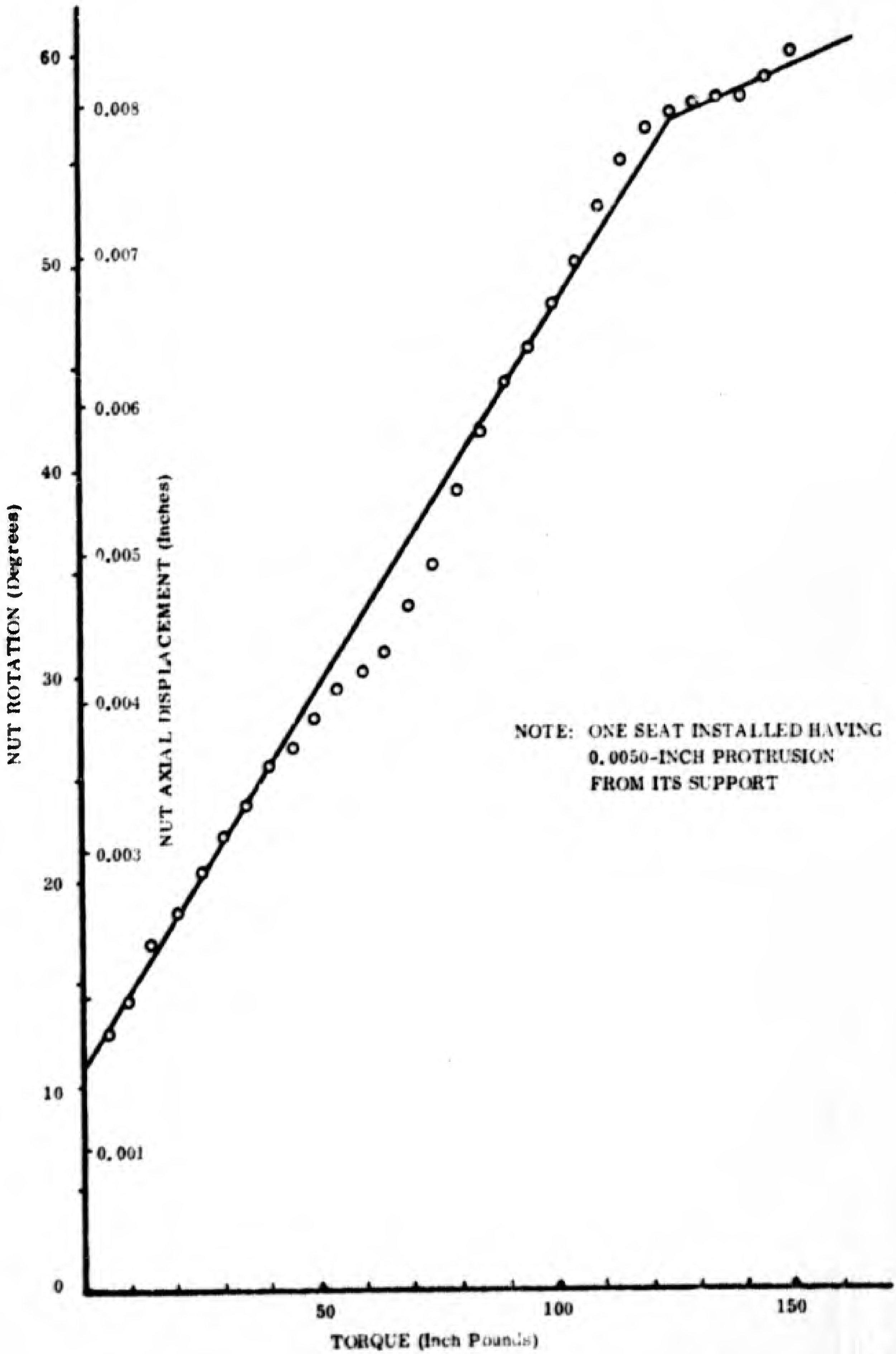


**Figure 6.** Marotta Three-way Solenoid Valve Stackup Nut, Torque vs. Displacement

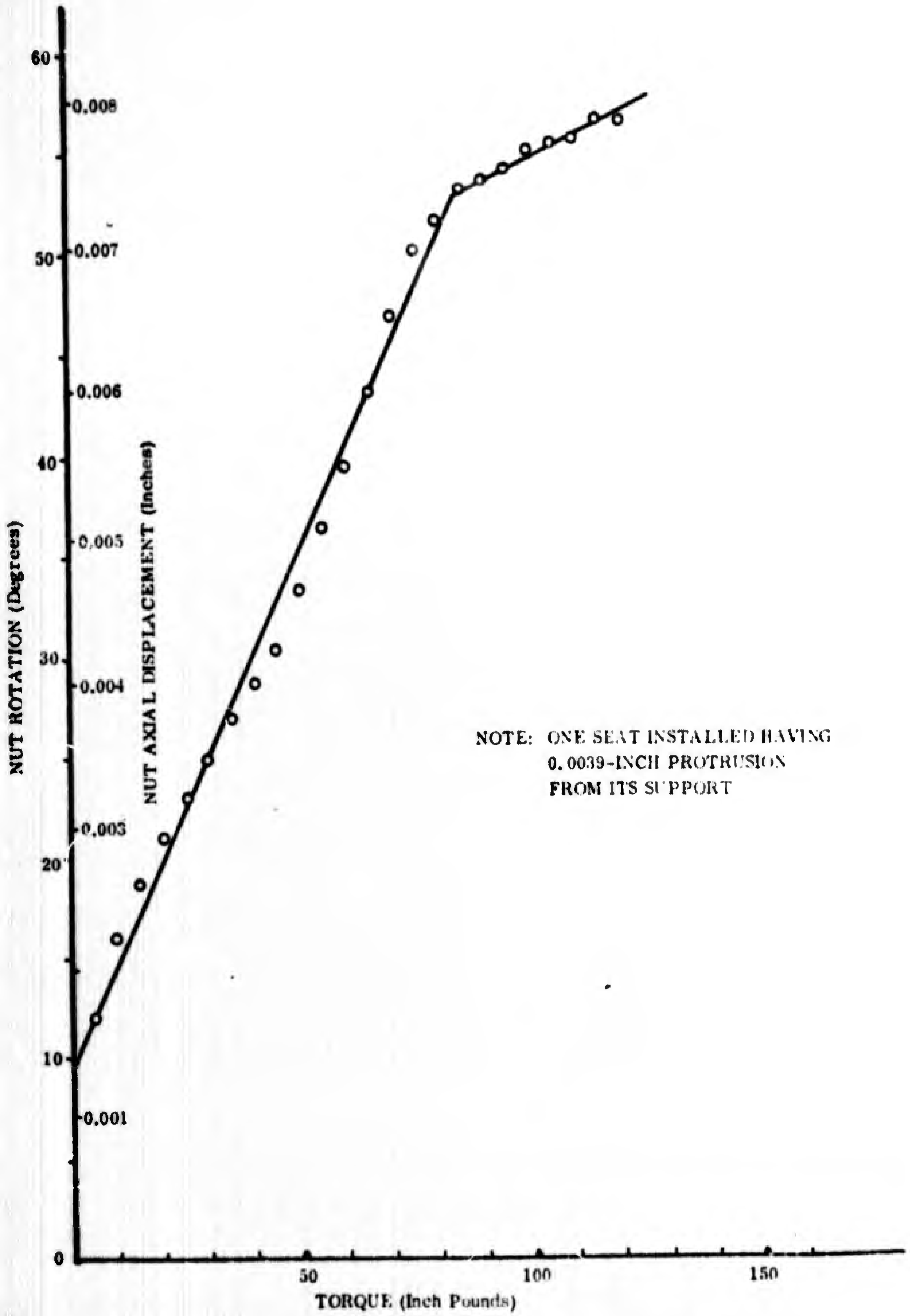


**Figure 7. Marotta Three-way Solenoid Valve Stackup Nut, Torque vs. Displacement**

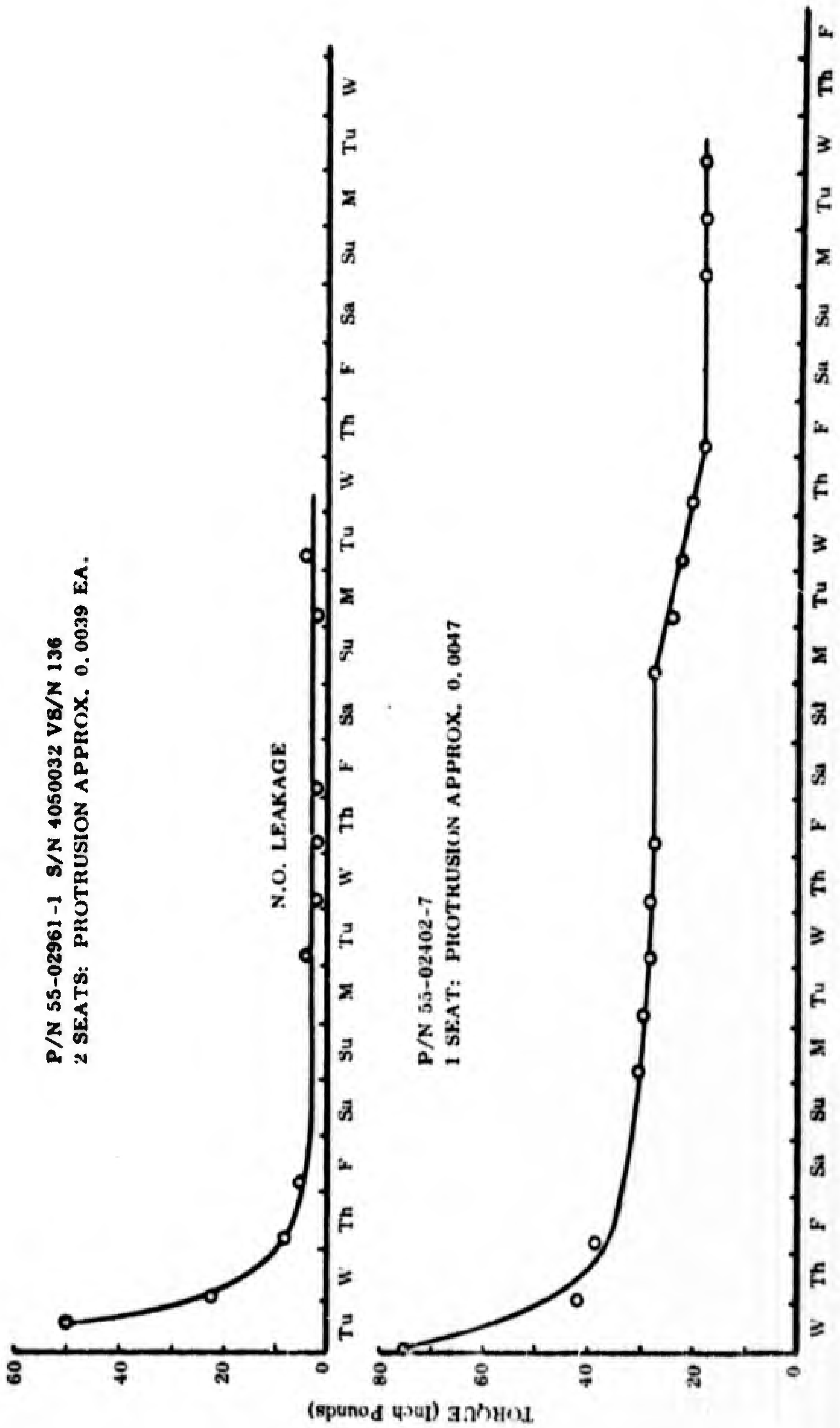


Figure 8. Stackup Nut Torque Decay

In a subsequent test, low pressure gaseous nitrogen was applied to the normally closed port of a valve which had previously developed a blowing leak at its normally open seat. The common port was plugged. When the solenoid was energized, the nitrogen flowed through the valve and out through the leaking normally open seat. After being energized nine minutes, the leakage continued, apparently undiminished. It was concluded that the cooling inherent in the gas flow prevented the solenoid heat from expanding the seats and sealing the leak. The gas flow was then shut off while the solenoid was left energized. A check after five minutes revealed the leak had sealed.

2.1.3 Possible Improvement by Retorquing. In an effort to increase the useful life of the valves, several procedures for retorquing at initial assembly were tried. Even with heating through energizing and using relatively high torques, many retorquings were required to achieve metal-to-metal stackup. However, this procedure would not be practical during manufacturing assembly; and it would not assure tight plastic seats after appreciable operation.

Retorquing a valve which was leaking as a result of testing did stop leakage, but relaxation continued although seemingly more slowly (see Figure 9).

2.1.4 Assembly Force Decay During Valve Storage. Three valves were rebuilt during the last week of August 1965 and stored. During the last week of November 1965 (after three months), the torques on the stackup nuts were checked. The torques, which were initially set to 50 inch-pounds, were found to be 32-1/2, 38, and 45 inch pounds for the three valves checked. This illustrates that torque decay occurs during storage but not as rapidly as when the valve is heated by energizing the solenoid.

2.2 DISCUSSION. The test results provide reasons for many of the valve's internal leakage characteristics which could not be explained previously.

The characteristic of the internal leakage rate decreasing with valve cycling had been noted in previous failure analyses but was attributed to pressure unbalance or contamination. Now it is apparent that because the thermal expansion coefficient of the Kel-F seat is much higher than that of the stainless steel, the rising temperature from solenoid energizing causes the Kel-F to expand into its support and toward the poppet, thereby tightening the assembly and sealing the leak.

The stackup nut had been found loose before but this had been attributed to tampering by technicians. Now it is apparent that, when the valve heats, the Kel-F softens and expands, and consequently extrudes out of its retainer. When the valve subsequently cools, the seat does not return to its original position and consequently does not push as hard against its support and the central cage. This is evidenced by the loose stackup nut. Further consideration of this phenomena leads to the realization that even if the internal parts of the valve were clamped metal-to-metal, temperature

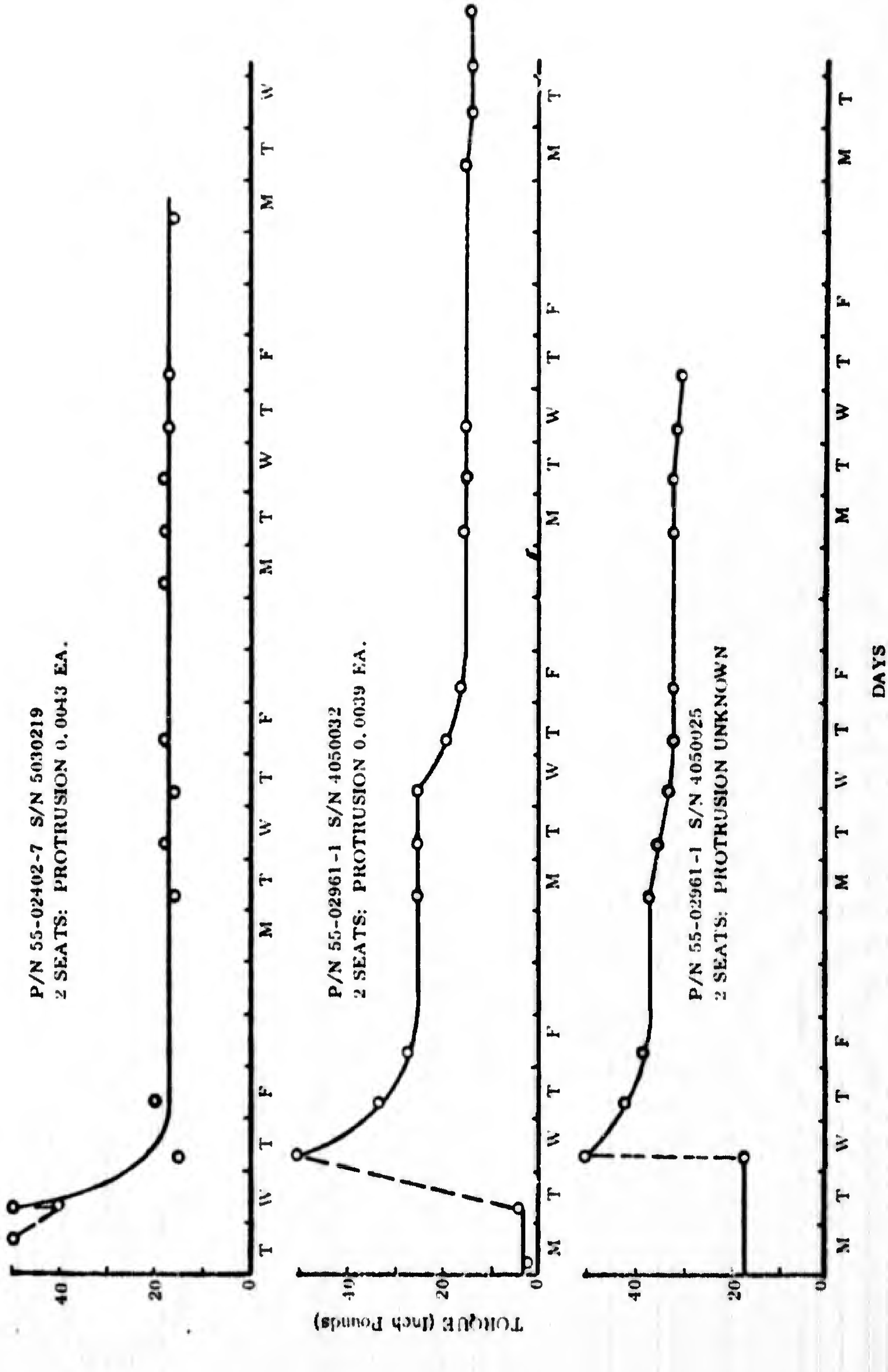


Figure 9. Results of Retorque

cycling would still cause the seats to expand and contract - and consequently loosen in their supports. Thus, higher torques or retorquing will not eliminate the cause of failure.

The dissipation of internal forces is probably not the only condition contributing to leakage. The fact that the normally open seat is more prone to leakage is a key to another cause. A review of the seat section photographs from failure analyses reveals that only one seat in each valve is badly distorted. In those analyses where the identity of the seats has been maintained, the normally open seat is the one which shows severe coining. The fact that the solenoid develops over 200 pounds force and the spring only 10 to 20 pounds is reason for greater coining of the normally open seat. It is pointed out also that bottoming of the solenoid armature on the coil limits travel of the poppet into the normally open seat, whereas poppet travel into the normally closed seat is limited by the seat itself. Thus, when the normally closed seat face recedes (as a result of coining), the spring causes the poppet to follow it. When the normally open seat face recedes, the solenoid armature cannot cause the poppet to follow it. This explains why the normally closed two-way valves, which Centaur has used, have had few excessive leakage failures. It also helps explain the excessive internal leakage during qualification testing of a two-way normally open valve recently selected for use on Centaur.

The normally open two-way valve mentioned in the previous paragraph also demonstrated another principle. This valve utilized a seat of Nylon which is harder and more resistant to plastic flow than is Kel-F. The normally open valve failed its qualification test because of excessive internal leakage. Failure analysis revealed the seat was so deformed that it could not be slipped off the poppet. As a result, it is considered unlikely that this problem can be resolved by selecting a different plastic. It appears that only some means of maintaining initial assembly loads and reducing poppet forces on the normally open seat can effect a solution. This might be accomplished by installing a spring washer between the normally open seat support and the seat retainer.

2.3 <u>FINDINGS</u>. From test results and observations it was found that:

a. Temperature cycling from normal operation will cause the valve seats to distort and loosen in their supports.

b. The high force of the solenoid can cause the poppet to severely coin the normally open seat.

c. Retorquing the main valve assembly nuts did not stop torque decay.

d. The torque value of the valve assembly (stackup) nut decreases during storage, although not as rapidly as when the valve becomes heated during operation.

e. The use of a Nylon seat in place of the standard Kel-F seat did not reduce the tendency for internal leakage.

2.4 CONCLUSIONS. From the findings it is concluded that:

a. Temperature cycling during normal operation, along with the excessive force of the poppet striking against the normally open seat, causes plastic flow (distortion) of the valve seat, resulting in internal leakage.

b. Changes in assembly torquing methods or values, changes in adjustment, or changes in seat materials offer little promise of a solution.

c. The tendency for internal leakage might be reduced if a redesign included the means for maintaining assembly tightness and for reducing poppet loads on the normally open seat.

2.5 RECOMMENDATIONS. Because of the unpredictable leakage characteristics, it is recommended that all valves of this design be replaced with valves which have demonstrated less susceptibility to internal leakage.

In selecting a new valve, the following characteristics should be particularly sought:

a. A continuous-duty solenoid having a small temperature rise.

b. Seating forces compatible with the materials used and temperatures attained.

c. A design configuration which minimizes and compensates for the effects of non-elastic flow of any plastic materials used.