REACTOR BOLT EVALUATION TESTS
(EML-13)

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1.0 SUMMARY

A test program was carried out to evaluate the assembly torque-preload characteristics of various threaded fasteners used in the NRX-A reactors. All of these evaluation tests were performed on specification grade reactor fasteners using test fixtures which provided close simulation of the service environments of these parts. No excessive friction or galling problems were experienced during assembly or disassembly, and the specified design requirements for axial preload and strength at the specified assembly torques were met.

Threaded fastener assemblies of different material combinations were tested at cryogenic conditions to determine whether differential thermal contractions would have an important effect on the disassembly torque. No measurable temperature effect was observed.

The individual tests are described in detail in Paragraph 5.0.

2.0 INTRODUCTION

Friction and galling tests of threaded fasteners currently used in the NRX-A reactor were performed. These tests were conducted in test rigs which simulated reactor conditions that could affect the results. The fasteners were tested with their locking devices in simulated reactor components which would accurately duplicate the fastener friction conditions during reactor assembly and disassembly. The resulting bolt preloads were measured to ascertain their ability to meet the design requirements.

3.0 PURPOSE

The friction and galling characteristics of many of the special materials used for threaded fasteners in the reactor are either unknown or not readily available. Also, the geometry of many of the fasteners particularly of the locking devices, are of unusual design with unknown friction effects.

These tests were performed to ascertain that the threaded fastener specification assembly torques would develop the desired design axial preloads but would not cause overstress conditions, and that excessive friction and galling would not occur as a result of fastener and metal combination incompatibilities.

4.0 GENERAL TEST DESCRIPTION

To obtain axial bolt loads, strain gages were mounted on the bolts in a manner responsive to axial bolt strains. In some cases, the gages were cemented to the external surfaces of the bolts, and in other cases holes were drilled axially through the bolts and the gages were cemented to the interior walls. Typical externally and internally instrumented bolts are shown in Figures 4 and 7, respectively. Standard electronic bridge resistance measuring equipment was used for strain measurements, and calibrated torque wrenches were used for torque measurements.

The torque versus axial load tests were performed at room temperature. Applied torques were limited to values which did not yield the threaded fasteners. Galling tests were performed by torquing the bolts to their specification tightening torques and then measuring the loosening (back-off) torques. After each torque test, the specimens were examined for signs of galling.

To determine the effects of differential thermal contraction on galling, the fasteners were torqued to full design torques and then immersed in liquid nitrogen for a minimum period of 1 hour, after which they were returned to room temperature and disassembled. The loosening (back-off) torques were measured and the fasteners were then examined for signs of galling.

5.0 TEST RESULTS

5.1 Torque Tests - Fuel Cluster Hardware

Tie rod holder part assemblies (see Figures 4, 5 and 6) consisting of reactor grade tie rod holders, cluster nuts and locking devices were assembled in a test block with and without "Neolube" lubricant to determine the relationship between tightening torques and tie rod holder axial loads.

The results of these tests are shown in Figure 1. Envelope No. 1 of this figure includes all the experimentally determined values of tie rod holder axial loads without lubricant on any of the parts. Envelope No. 2 (dotted lines) includes all values for "Neolube" lubricated tie rod holder threads only, and Envelope No. 3 includes all values for "Neolube" lubricated threads and all other bearing surfaces of the cluster nut. The beneficial effect of applying lubricant is obvious from these load envelopes which show that lubrication increases the minimum axial load over the unlubricated condition as much as 73% within the range of specified assembly torque (325 to 410 in.-lb).

The maximum anticipated applied load on each tie rod holder during reactor operation is less than 500 lb compared to the minimum experimentally determined tightening preload, without lubricant, of 1140 lb.

Therefore, although the lubricant is beneficial, it was found unnecessary and the fasteners met their design preload requirements without lubricant.

5.2 Tie Rod Holder Tension Failure Tests

Some of the tie rod holders were tested for axial strength in the tensile test machine. The failing loads ranged from 7175 to 8550 lb, values far exceeding the axial load, 3200 lb, which resulted from the maximum prescribed assembly torque.

5.3 Core Support Plate - Core Support Ring Bolts

Torque versus axial preload tests of specification grade bolts were performed. Neolube lubricant was applied to the threads and all bearing surfaces in accordance with standard reactor assembly procedures before testing. The test fixture and an instrumented test bolt is shown in Figure 7.

The significance of the test results is illustrated by the two curves of Figure 2. These curves envelope all of the axial loads which were measured during the torquing tests on the test specimens. The main area of interest lies between the minimum and maximum assembly torques of 80 and 90 in.-lb, for which the preloads were 1000 and 1830 lb, respectively.

5.4 Core Support Ring - Outer Reflector Tapped Bushing Attachment Bolts

Torque versus axial load tests were performed on these bolts using complete sets of test specimen hardware, including a bolt, a locking device and a Ni-Span-C alloy bushing with silver plated threads. The test specimens are shown in Figure 8.

The results of these tests substantiated the adequacy of the bolts in meeting their design requirements for preload. All of the measured preloads were within the envelope of the two curves shown in Figure 3. The preloads

for the minimum (140 in.-lb) and the maximum (150 in.-lb) specification assembly torques were 830 and 1480 lb, respectively.

5.5 Barrel Retaining Screw Tests

Galling tests were performed on specification grade barrel retaining screws which attach the inner reflector aluminum barrel to the core support ring. Each screw was assembled in a new locking anchor nut (without silver plating) for each test. A test plate, representing the tabs on the support ring, to which the anchor nuts are assembled, is shown in Figure 9. Torque measurements were made on each retaining screw to test their capability of turning in the locking anchor nut at the maximum specification assembly torque of 50 in.-lb and insure that the prescribed assembly torque would properly seat the shoulder of the screw against the plate without galling either the screw or anchor nut threads or causing any other damage to the hardware. Galling effects were determined by measuring the torque necessary to loosen (back-off) the screw after assembling it in the test plate at its specification assembly torque.

Tests were also conducted to determine the failure torques of the internal wrenching heads of the screw specimens.

All of the screws were easily assembled in the anchor nuts without exceeding their specification assembly torques, and seated solidly against the plate within the prescribed 45 to 50 in.-lb, assembly torque value. "Back-off" torques were found to be less than the applied assembly torques, indicative of no galling, and no galling effects were apparent from visual examination of the threads after the tests. The failure torques of the internal wrenching heads of the screws ranged from 60 to 71 in.-lb and were considered satisfactory.

5.6 Instrumentation Support Screw Gallling Test (Lead Holder Attachment Screw)

Galling tests were performed on the screws which attach the instrumentation lead retainers to the core support plate and the nozzle and dome end support rings. Specification grade hardware was tested; each set consisting of a lead retainer, a retainer attachment screw and a test block. Test specimens were tested in aluminum test blocks to represent installations on the core support plate, and in titanium test blocks to represent installations on the nozzle and dome end support rings. These parts are shown in Figure 10. Both room and cryogenic temperature effects on galling were investigated. To perform the tests the screws were torqued to their maximum specification assembly torque of 50 in.-lb and the "back-off" (loosening) torques were measured to test for any galling tendencies.

Cryogenic operational temperature effects were simulated by immersing fully torqued specimens in liquid nitrogen for a minimum period of one hour, after which they were retrained to room temperature. Upon temperature stabilization they were tested for galling by measuring the screw "back-off" torques.

Neither the "back-off" torques nor visual examinations revealed any galling.

5.7 Instrumentation Support Retainer Screw Gallling Tests (Lead Fastening Screw)

Tests were performed on the screws which are used to hold the instrumentation leads in the lead holder slots as shown in Figure 10. These screws were torqued to the specification assembly torque of 20 in.-lb after which the "back-off" torques were measured to test for galling. No galling occurred in any of the specimens.

6.0 CONCLUSIONS

No excessive friction or galling of the threaded fastener assemblies was experienced during assembly and disassembly, and the specified design requirements for axial preload and strength at the assembly torques were met. Cryogenic temperature tests of the instrumentation lead holder hardware indicated that the differential thermal contractions expected during reactor operation would not have any significant effect on the disassembly torque.

TORQUE VS AXIAL PRELOAD
Cluster Nut - Tie Rod Holder Test

FIGURE 1

TORQUE VS AXIAL PRELOAD
Core Support Plate - Core Support Ring Attachment Bolts

FIGURE 2

TORQUE VS AXIAL PRELOAD
Core Support Ring - Outer Reflector Tapped
Bushing Bolts

FIGURE 3

FIGURE 4
INSTRUMENTED TIE ROD HOLDER
FUEL CLUSTER NUT AND LOCKING DEVICE

FIGURE 5
TIE ROD HOLDER HOLES IN SIMULATED CORE SUPPORT PLATE BLOCK

FIGURE 6
LOCKING DEVICE SLOTS IN SIMULATED CORE SUPPORT PLATE BLOCK

FIGURE 7
INSTRUMENTED 1/4-28 BOLT AND TEST FIXTURE

FIGURE 8
INSTRUMENTED 5/16-24 BOLTS, LOCKING DEVICE,
NI-SPAN-C BARREL NUT AND TEST FIXTURE

FIGURE 9
BARREL SCREW AND ANCHOR NUT PLATE ASSEMBLY

FIGURE 10
TEST SPECIMENS
INSTRUMENTATION LEAD RETAINER