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LATERAL SUPPORT SPRING ASSEMBLY TESTS IN MULTIPLE ASSEMBLY TEST RIG

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LATERAL SUPPORT SPRING ASSEMBLY TESTS IN MULTIPLE ASSEMBLY TEST RIG

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INTRODUCTION

Three possible types of Lateral Support Spring Assemblies have been endurance cycled in a multiple assembly test rig. The multiple assembly rig cycles eight spring specimens at once, and it has the capability of driving the spring assemblies in any one of three pre-selected directions of loading -- 0° , 30° , and 45° . The three types of Spring Assemblies tested are as follows:

- a) A compound arrangement of two helical springs of different stiffness.
- b) One helical spring.
- c) Graphite cloth strip rolled into a cylinder.

Static load-deflection tests and length measurements were performed on the assemblies prior to endurance testing, and also at various levels of cycle accumulation, to determine the effect of extended cycling on the spring properties. In a similar manner, graphite dummy components, used to simulate reactor components associated with the spring assemblies, were measured and weighed to evaluate the extent of wear of the graphite after accumulated cycling.

TEST SET-UP AND TEST PROCEDURES

The multiple assembly test rig (see Figure 1) is designed to hold four rectangular graphite blocks, each containing two spring assemblies and to be capable of driving this multiple assembly of springs at angles of 0° , 30° , and 45° in the horizontal plane. The figure shows the test rig set at the 0° direction of drive. The driving angle is selected before a given test by rotating the frame, with the cam-driven push-rod disconnected, to the desired angular position relative to the push-rod. The push-rod is then screwed into the adjustment plate via one of three threaded holes provided at the three driving angles. All test cycling was performed at ± 0.263 inch amplitude and at 10 cps. The graphite housing blocks were located in the test rig in such a manner that the spring assemblies contained therein were loaded in compression at all positions of the pivoted column.

Prior to a test run, the housing blocks were advanced toward the pivoted column (see Figure 1) until the load per individual spring assembly at the extreme travel of the push-rod (± 0.263 inch) reached 75 pounds. The amount of pre-load at the neutral position of the push-rod is then determined by this 75 pound value and the particular load-deflection curve of the spring assembly under test.

After every 25,000 cycles of the test rig, the specimens and associated graphite components were removed from the test rig, photographed, measured and weighed. When re-inserting the specimens and housing blocks for further cycling, the procedure followed was to move each housing block to an adjacent holding fixture. Rotating the blocks in this manner tended to average out variations in the loading histories of the specimens.

Dynamic loads were measured by means of two active strain gages placed on the top and bottom flats of a milled-out section of the push-rod, so as to eliminate any output from bending strains, and provide only the axial strain output. Prior to the endurance tests the push-rod was statically calibrated for strain gage output versus axial load. During the tests, the output from the push-rod gages was fed into one channel of a two-channel Brush recorder to provide a permanent record of the dynamic load on the push-rod.

Figure 1

Dynamic loads on individual spring assemblies were measured by active strain gages mounted on the test plates (see Figure 1). The test plates were calibrated prior to the endurance tests in a manner similar to the calibrated push-rod. During the tests, sample outputs from the test plates were fed to the remaining channel of the Brush Recorder. However, the static tests proved that output readings from the test plates were in general unreliable. Inconsistent readings are attributed to the fact that the face of the plunger covers the entire surface of the cantilevered portion of the test plate, such that the loading distribution and the stress distribution in the vicinity of the strain gage will vary drastically with any small change in the alignment or position of the plunger. Because of unreliable readings, the only purpose served by the test plate strain gages was to establish whether or not the plungers and the spring assemblies were responding quickly enough to maintain continuous contact with the moving test plates.

COMPOUND HELICAL SPRING ASSEMBLY TESTS

Two typical compound helical spring assemblies are shown in Figure 1a. Figure 1b shows the individual springs of the assembly. Graphite plungers, shown in Figure 2, rest on the small metal cups enveloped by the smaller helical spring, as shown in Figure 1a. The graphite plunger simulates the base of the Lateral Support Blocks. The spring assemblies and plungers slide easily into two cylindrical holes provided in each of the four graphite housing blocks. Thus, the housing blocks assume the role of the Inner Reflector in containing the Lateral Support Assemblies.

The test results indicate that any change in the spring rates after 50,000 cycles per assembly was too small to measure within the accuracy limits of the data obtained. Load-deflection curves for a typical assembly are shown before cycling and after 50,000 cycles in Figures 4 and 5, respectively.

Free length measurements were made by micrometer at four locations around the circular boundary of each helical spring, and the readings were averaged. Using this procedure before and after the tests, a very slight permanent set was noticed. The permanent set after 50,000 cycles, with decrease in free length taken as positive, is revealed below in Table I.

TABLE I
DECREASE IN FREE LENGTH OF COMPOUND HELICAL SPRING ASSEMBLIES
AFTER 50,000 CYCLES

<u>Assembly Number</u>	<u>Stiff Spring</u>	<u>Soft Spring</u>
1	.23%	.32%
2	.12%	-.16%
3	.23%	.48%
4	.12%	.40%
5	.23%	.32%
6	.23%	.32%
7	.23%	.48%
8	.23%	0%

Figure 1a. Compound Assemblies

Figure 1b. Compound Assembly Springs

Figure 2. Graphite Plungers

Figure 3. Single Springs

Figure 4

FORCE vs DEFLECTION BEFORE DYNAMIC CYCLING B-1 TEST

Figure 5

FORCE vs DEFLECTION AFTER 50,000 CYCLES B-1 TEST

The dynamic load on the push-rod, while endurance cycling at the 0° angle of drive, is indicated by Figure 6 a., which shows a portion of the Brush Recorder trace. The maximum indicated load of approximately 144 pounds is the resultant force exerted by the two spring assemblies under maximum compression, at 75 pounds each, and the two assemblies opposite, under minimum compression since only the soft springs are compressed, exerting only a few pounds of force in the opposite direction.

The portion of the push-rod output trace with the more gentle slope indicates the region where the pivoted column is acted upon by the soft springs only. The abrupt peaks indicate the regions where the stiff springs come into play. As might be expected, the dynamic trace closely resembles the static load deflection curve of Figure 4 in the higher load region. Lack of smoothness is attributed to the friction from the plungers at the sides, as well as the vibration of the test rig and drive motor.

The dynamic load on the push-rod, while endurance cycling the eight assemblies at the 45° angle of drive, is indicated by the Brush Recorder trace shown in Figure 6 b. It was feared that friction loads between the plungers and test plate surfaces would cause the plungers to rock when driving at 45° . However, when the assemblies were viewed under a stroboscopic light, no rocking was observed - the plungers keeping their alignment with the axis of the cylindrical holes in the graphite housing blocks.

It was observed that the plungers maintained continuous contact with the moving test plates for both 0° and 45° directions of drive.

Figure 6a. Push-Rod Output of Compound Spring Assemblies at 0°
Direction of Drive

Figure 6b. Push-Rod Output of Compound Spring Assemblies at 45°
Direction of Drive

SINGLE HELICAL SPRING ASSEMBLY TESTS

Helical springs, typical of the eight springs tested, are shown in Figure 3. The same graphite plungers and graphite housing blocks that were employed in the Compound Helical Spring Tests were used again in this test. The graphite plungers rest directly on the ground ends of the helical springs.

The test results indicate that any change in the spring rates after 37,000 cycles per assembly was too small to measure within the accuracy limits of the data obtained. Load deflection curves for a typical assembly are shown before cycling and after 25,000 cycles in Figures 7 and 8 respectively.

As in the compound spring assembly tests, the relaxed length of the spring was measured before and after cycling. The permanent set after 37,000 cycles, with decrease in free length taken as positive is revealed below in Table II.

TABLE II
PERMANENT SET OF HELICAL SPRING ASSEMBLIES
AFTER 37,000 CYCLES

<u>Assembly Number</u>	<u>Decrease in Free Length</u>
1	+.56%
2	+.35%
3	+.14%
4	+.42%
5	-.07%
6	-.07%
7	-.07%
8	+.28%

The recorder traces for the Single Helical Spring Assemblies (Figures 9a and 9b) are discussed as follows: In positioning the housing blocks, prior to a test run at 0° direction of drive, the housing blocks at the sides, parallel to the push-rod, are first backed off, so that their plungers do not touch the test plates. (Any force from the side plungers would interfere with the proper adjustment of the other two housing blocks since their adjustment is accomplished by reading the push-rod output.) Figure 9a shows a recorder trace obtained while the blocks at the sides are backed off, as described above.

Figure 7. Static Test of Single Helical Spring No. 1 Before Dynamic Cycling

Figure 8. Static Test of Single Helical Spring No. 1 After 25,000 Cycles

As would be expected, the trace is a perfect sinusoid. Figure 9b shows the recorder trace after all blocks are positioned. The discontinuities in slope are evidently caused by the frictional load from the plungers at the sides.

Figure 9a. Push-Rod Output - Single Spring Assemblies Before Side Plungers Introduced

Figure 9b. Push-Rod Output - Single Spring Assemblies After Side Plungers Introduced

WEAR OF GRAPHITE COMPONENTS

No change in weight of the graphite plungers was detected after the total 87,000 cycles. However, the average diameter at the rounded base of the plunger showed a decrease, indicated as positive in Table III.

TABLE III

<u>Assembly Number</u>	<u>Original Average Diameter (inch)</u>	<u>Decrease in Diameter (inch)</u>
1	1.0968	-.0012
2	1.0979	+.0009
3		
4	1.0961	+.0011
5	1.0972	+.0012
6	1.0962	+.0022
7	1.0960	+.0010
8	1.0977	+.0007

Data for Plunger No. 3 is omitted owing to the fact that it fractured at one edge after 62,000 cycles.

The diameters of the cylindrical holes in the graphite blocks averaged a slight increase as shown below in Table IV.

TABLE IV

<u>Assembly Number</u>	<u>Original Average Diameter (inch)</u>	<u>Increase in Diameter (inch)</u>
1	1.1003	-.0003
2	1.0993	+.0007
3	1.0986	+.0014
4	1.0970	+.0090
5	1.0989	-.0009
6	1.0992	-.0002
7	1.0994	+.0006
8	1.0996	+.0014

One graphite plunger out of the eight used in the endurance tests, fractured along the edge after 62,000 cycles. An extra plunger was substituted for the remainder of the endurance cycling. Figure 10 shows the fractured portion of the plunger along with the corresponding helical spring that was under test at the time of fracture. It is noteworthy that this spring bears directly on the periphery of the plunger, unlike the compound assembly in which the load is distributed more evenly via the metal cups shown in Figure 1a.

Figure 10. Chipped Plunger No. 3 After 62,000 Cycles

GRAPHITE CLOTH SPRINGS - TEST PROCEDURES AND RESULTS

Multiple assemblies of graphite cloth springs (17" x 1-1/8" strip rolled into a cylinder to fit in a 3/4" diameter hole) were endurance tested at $\pm .263$ inch amplitude and 10 cps for 5,000 cycles. Figure 11 shows an unwrapped graphite cloth spring after 5,000 cycles. The springs were housed in graphite blocks, provided with the plungers shown in Figure 12. Prior to the tests, the springs were individually pre-loaded to give a maximum load of 75 pounds per spring at maximum spring compression. Also, prior to the tests, the push-rod was moved slowly through one complete cycle, and it was observed that the plungers maintained contact with the push-rod throughout this cycle. However, when the multiple assembly was tested at 10 cps, it was observed that the plungers broke contact with the push-rod for a part of each cycle. Figure 12 is a photograph of the multiple assembly taken under the illumination of a stroboscope showing separation at 10 cps.

The strain gage output of the test plates, which is the bottom recorder trace of Figure 13, indicates the separation by the flat regions between peaks.

Figures 14 through 16 show static load deflection curves for a graphite spring before cycling and at various levels of accumulated cycles.

Figure 11. Unwound Graphite Cloth Spring After 5000 Cycles

Figure 12. Graphite Cloth Spring Assemblies Cycling at 10 cps in Multiple Assembly Rig

Figure 13. Push-Rod (Upper Trace) and Test Plate (Lower Trace) Outputs for Graphite Cloth Spring Test

Figure 14

Figure 15

Figure 16