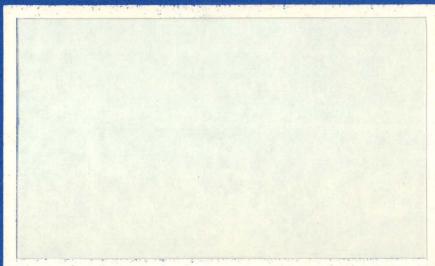
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CCTL MARK I AND MARK II

PROTOTYPIC FFTF

SUBASSEMBLY COMPRESSION TEST

DEVELOPMENT WORK (a)

R. B. Baker and D. E. Blahnik

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ABSTRACT

This report describes the subassembly compression test work performed by the FFTF Fuels Department on fuel subassemblies with 217 wire-wrapped fuel pins. These ductless subassemblies were compressed over a 4-foot length span by flat plates on six sides, and the side wall load was measured as a function of across-the-flats dimensions. The subassemblies were compression tested to determine the springiness that exists within the subassembly when it is compressed symmetrically from a nominal duct internal size down to a region where there are no gaps between wires and fuel cladding and where the fuel pins are temporarily deformed due to bending and torsion loads.

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CCTL MARK I AND MARK II PROTOTYPIC FFTF SUBASSEMBLY COMPRESSION TEST DEVELOPMENT WORK

R. B. Baker and D. E. Blahnik

1.0 INTRODUCTION

The purpose of this report is to describe the subassembly compression test work performed by the FFTF Fuels Department and to summarize the results of compression testing the CCTL Mark I and Mark II subassemblies. The Mark II test will be emphasized most because its design conforms closest to the latest FFTF driver fuel design.

The object of compression testing a prototypic FFTF driver fuel subassembly* is to determine the springiness** that exists within the subassembly when it is compressed symmetrically from a maximum or nominal internal duct size down to beyond a tight subassembly size. † The spring load on the simulated duct wall

^{*} Subassembly - A (driver fuel) subassembly is defined in this test procedure as "an assembly of 217 completed fuel pins banded together by grids at each end." Normally, a fuel subassembly also includes locking bars and the straight flow duct section.

^{**} Subassembly Springiness - When a fuel pin subassembly, such as Mark II, is in the vertical position, the fuel pins cannot bow significantly towards the center. Therefore, most of the outer pins are randomly forced outward by a combination of their own natural bow and the forces transmitted by the natural bow of internal pins. When a subassembly is compressed to a tight subassembly size, all of the natural spring is absorbed. If a subassembly is compressed beyond tight subassembly size, the fuel pins nest together and react as a combination of leaf and torsion springs.

[†] Tight Subassembly Size - Point at which all fuel pins and wires are compressed tightly together without any deformation of the subassembly components. There is no outward displacement due to natural bow of the fuel pins and no gaps between wires and fuel pins. When a subassembly is compressed beyond this point, the load-compression deflection curve becomes linear. This term was previously referred to as "hundle theoretical tightness."

is measured as a function of various across-the-flats dimensions. Figure 1.1 shows a typical curve which can be plotted from compression test data. The data shall be used to:

- Characterize the subassembly's tight size and springiness.
- Analyze the in-reactor cases both of the fuel pins swelling larger than the duct dimensions and the duct dimensions swelling larger than the fuel pins.
- Assist in establishing dimensions and tolerances on the fuel pin OD, wire OD, and the duct internal dimensions to assure proper assembly fit for reactor requirements.

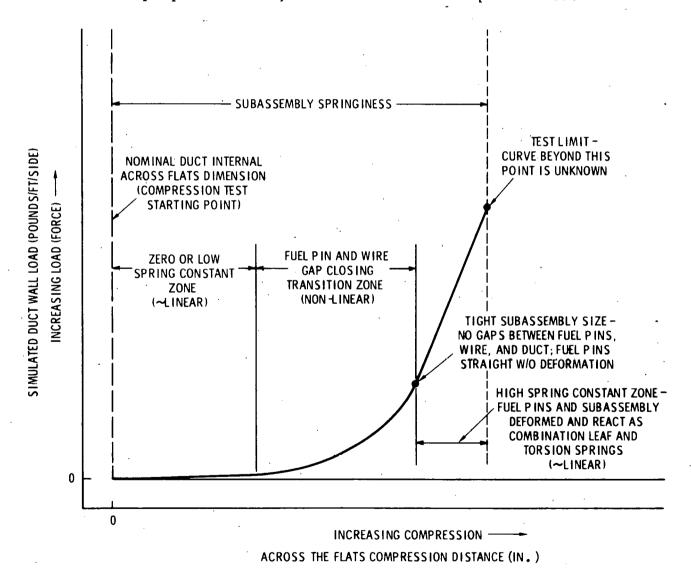


FIGURE 1.1. Typical Subassembly Compression Test Data Curve

2.0 SUMMARY

The subassembly compression test apparatus is illustrated in Figure 2.1. The test equipment is described in detail in Appendix A. Also, the complete test procedures for subassembly compression testing are outlined in Appendix A.

The Mark I and Mark II CCTL Subassemblies were both subjected to compression tests. Each subassembly was tested in the vertical position, as shown in Figure 2.1, to minimize the effect of gravity.

During the tests, all six sides of the subassembly were equally advanced inward by the test apparatus flat pressure plates (maintaining a regular hexagon geometry) over a 4-ft span of the subassembly. One side of the test apparatus had a 2-ft center pressure plate which transmitted force to transducers so that the side load could be measured as a function of hexagon across-the-flats dimensions during subassembly compression or decompression.

The test apparatus was designed for a 250 lb/ft/side limit. Mark I was tested to the test apparatus load limit. The Mark II test, however, was limited to 50 lb/ft/side to ensure that no permanent distortion or surface marking of the subassembly would occur.

Figure 2.2 illustrates a summary of the Mark II compression test data curves. Figure 2.3 compares the average Mark II and Mark I test run curves. All of the test curves were similar to the typical curve and description shown in Figure 1.1.

The Mark II test results showed that an average load of less than 4 oz/ft/side was experienced in the first 0.024 in. of compression. In the next 0.015 in. of compression, the load rapidly increased to about 14 lb/ft/side at the 4.297 in. point of "tight subassembly size." Beyond "tight subassembly size" the curve was linear up to the 50-lb test limit with a spring constant of about 5.15 lb/ft/side per 0.001 in. compression.



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FIGURE 2.1. Subassembly Compression Test Apparatus and Instrumentation

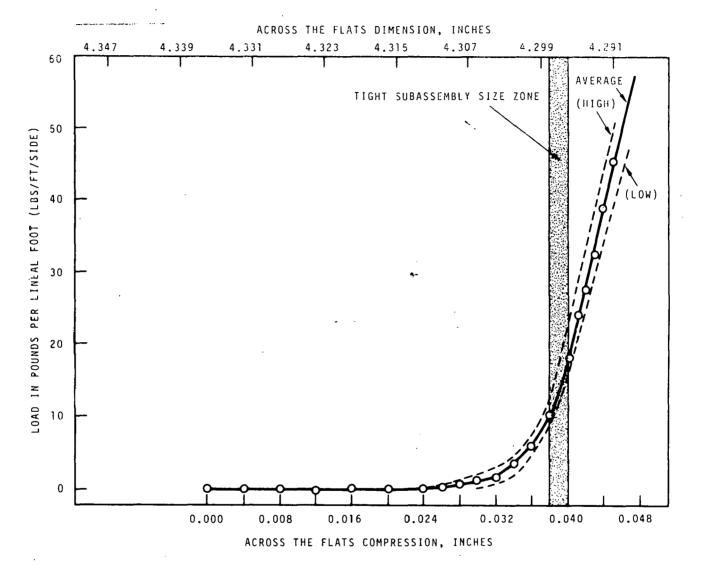


FIGURE 2.2. Summary of Mark II Compression
Tests Run Numbers: One, Two,
and Three Average and Range

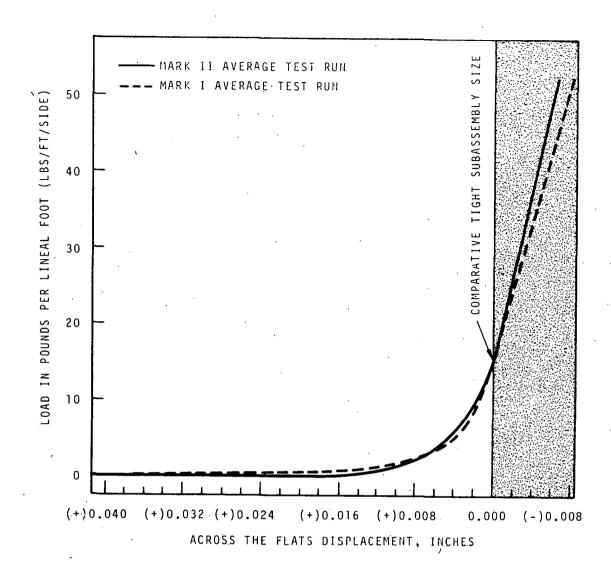


FIGURE 2.3. Summary Comparison of Mark II and Mark I Subassembly Compression Test Run Curves

The Mark II and Mark I test curves show a close relationship up to the point of "tight subassembly size." Compression beyond "tight subassembly size" shows a steeper Mark II curve slope because of the higher spring constant due to Mark II's higher tube-wire moment of inertia in bending and torsion.

During decompression on test runs there was a small amount of hysteresis. There was no residual force indicated when the last zero force compression point was reached during subassembly decompression.

3.0 TEST APPARATUS

The test apparatus is shown and discussed in depth in Appendix A of this report. Figure A.2.1 illustrates some of the key equipment components. The test apparatus was designed to meet the following general criteria:

- A regular hexagon geometry shall be maintained between pressure bars at each test setting.
- A subassembly shall be kept in the vertical position on the same centerline at all times.
- When compressing or decompressing a subassembly, all sides (pressure bars) shall be advanced accurately and equally in increments between 0.0005 to 0.002 in.
- Force transducers shall be located so that loads on pressure bars are transmitted directly towards them to minimize bending and friction. They shall be centered so that the cumulative force will be comprised of the average force generated by nine fuel pins on a side and immediately opposite the row of wires.
- Measure side loads on a subassembly up to 250 lb/ft/side.
- Provide heavy pressure bars with rigid structural support to minimize pressure bar deflection even at the test load limit.
- Provide a 1-ft pressure bar both above and below the load measurement transducer pressure bar to remove the "end effect*" from affecting test results.

These criteria along with other obvious features were incorporated into the equipment described below.

Basically, the test apparatus can be described as follows: A heavy wall steel pipe is supported rigidly in a vertical

^{*} End Effect - This term refers to the location on the subassembly where there is a transition from subassembly restraint by the test apparatus pressure bars to nonrestraint above and below the 4-ft pressure bars section.

position by a heavy base with gussets. Inside the pipe body are located $1 \times 2-5/16$ -in. bars on each of six equally spaced positions. Five sides contain bars that are 48 in. long and supported vertically by four male shafts threaded through the pipe body with drive handles spaced on 1-ft centers. The matching female threads are located in the pipe. The drive handles are turned to move the bars. The pressure bars are held on the ends of the shafts by spring loaded ball plungers.

The sixth side, the one on which the load is measured, contains 1-ft pressure bars at the top and bottom and a 2 ft-bar in the center which is supported by two transducer shafts centered and spaced 1 ft apart on the bar. The 1-ft bars are each supported by two threaded shafts with drive handles which perform the function of preventing the subassembly "end effect" from affecting the load measurement bar readings.

The transducer shafts are fixed in the transducer receptacle, and the transducers are mounted on Gilman slide assemblies which drive the 2-ft load measurement bar. The transducers are connected to amplifier-indicator instruments located on a table for reading out the transducer loads.

Two dial indicators are also mounted on the Gilman slide assembly transducer brackets and are referenced against the pipe body outer diameter. These dial indicators are used to properly locate the load measurement bar by compensating for springback in the transducer spring and the Gilman slide assembly system.

The two force transducers are each Daytronic Model Number 152A-250 and the amplifier-indicators are each Daytronic Model Number 300D-71. The amplifier-indicators have force scale ranges calibrated for 0 to 25 lb, 0 to 125 lb, and 0 to 250 lb (scales 1, 5, and 10, respectively).

4.0 TEST_PROCEDURE

Appendix A provides a detailed outline of the subassembly compression test preparation, equipment setup and calibration, and test procedures. The test procedure in Appendix A was not followed in every detail in Mark I and Mark II tests because Appendix A is based upon the techniques and experience gained in those tests.

Basically, preparation for the Mark II test consisted of:

- Reading the October 22, 1969 issue of the formal test procedure.
- Reading the job hazard breakdown, nuclear safety, and radiation work procedures.
- Reading the test plan requirements.
- Preparing the test subassembly and fabricating a suitable handling fixture for it.
- Recording preliminary data on data sheets and in the log book.

The equipment setup and calibration work consisted primarily of:

- Centering and setting all the pressure bars accurately at a known regular hexagon bore size.
- Establishing a correction curve to compensate for springback from the transducer springs and Gilman slide assembly system for properly locating the load measurement pressure bar.

Instrumentation, dial indicators, and transducers were calibrated at the Standards Laboratory.

The actual test runs were a series of steps which advanced pressure plates to progressively smaller hexagon bore size settings (usually in 0.001-in. increments), and recorded the load force for each transducer. After the test load limit was reached the procedure was reversed to take force readings at progressively larger hexagon bore sizes until the original test size was reached.

5.0 CCTL MARK I SUBASSEMBLY COMPRESSION TESTING

5.1 MARK I SUBASSEMBLY DESCRIPTION

The Mark I subassembly is comprised of 217 wire-wrapped fuel pins assembled into a hexagonal cross-section bundle. The assembly and details of the subassembly components are given in Figures 5.1, 5.2, and 5.3 (BNW Drawings SK-3-13188, Sheets 1 and 2, and Drawing SK-3-13187).

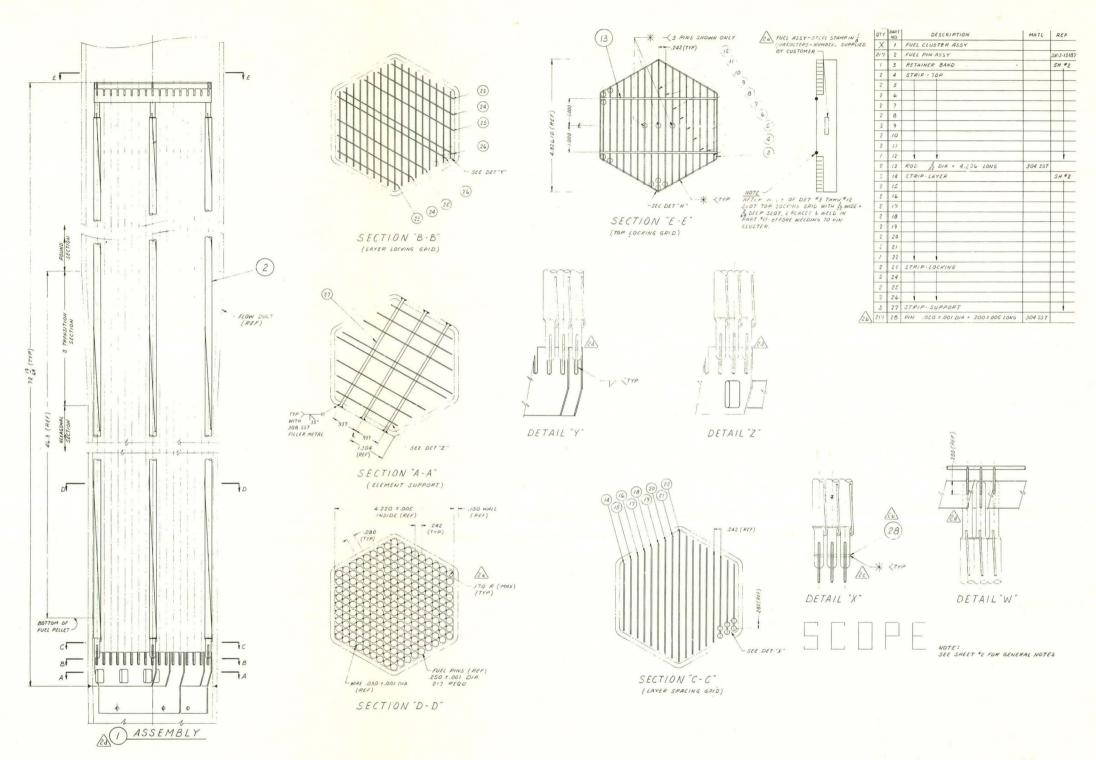
All pins were ~ 0.250 in. in diameter and were spaced by 0.030-in. Type 304 SS annealed wire wrap with a triangular pitch. The wire was wrapped on a 12-in. pitch. The Type 304 SS fuel pin tubing had a 0.218-in. ID, 71-in. length, and the tube column was loaded above the lower end cap with 33 in. of depleted UO_2 pellets, a 6-in. reflector rod, a plenum spring, and a 23.594-in. long plenum tube, in that order. The fuel pins were held together by grids at both ends of the subassembly.

5.2 MARK I HISTORY

The Mark I was first assembled at BNW and shipped to ANL in February 1968. It was inserted into the CCTL loop in May 1968 and tested intermittently until April 1969; at this time it was removed from the loop, cleaned, and returned to BNW. While in the loop, Mark I was subjected to approximately 5067 hr of sodium testing of which over 3686 hr were with 1060°F sodium flowing at approximately 400 gal/min and 30 ft/sec.

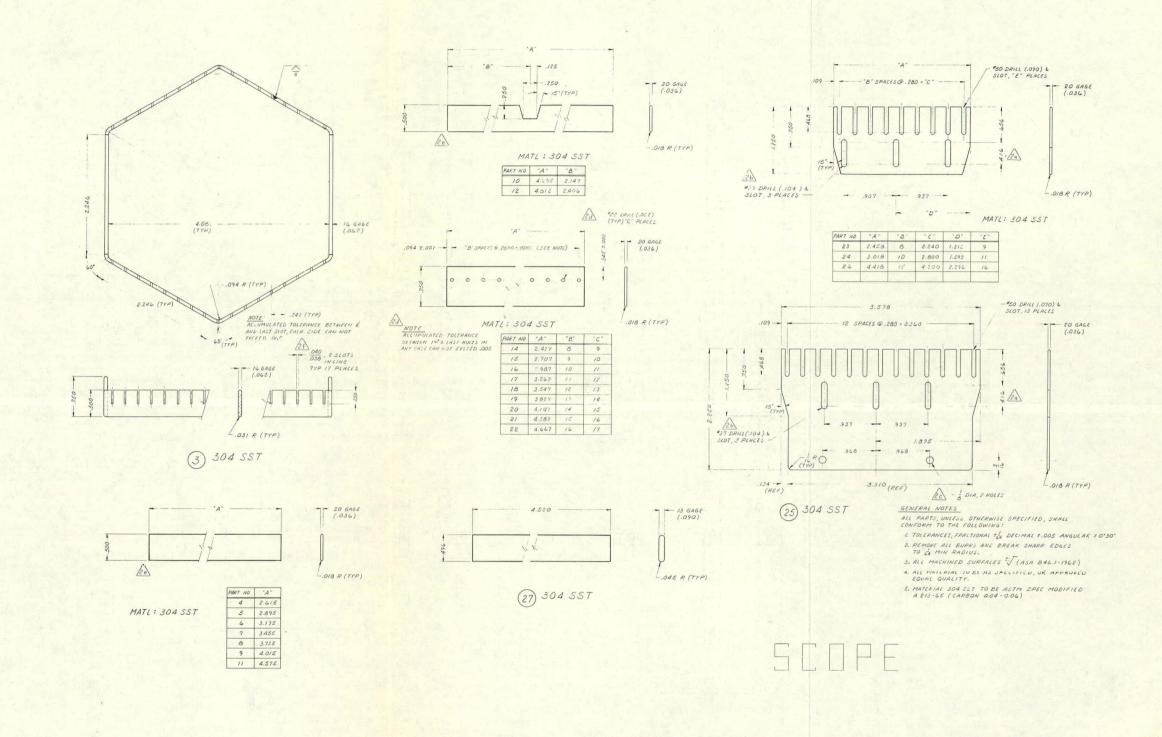
In May 1969, the Mark I was disassembled into strip layers and inspected. Three fuel pins were selected and removed for destructive testing. The only visual changes that occurred during the CCTL test were:

- A longitudinal growth of wire which resulted in three to six mils wire looseness over the entire fuel pin length.
- · Surface rub marks on the cladding from the wires.
- A slight flattening (up to 0.002 in.) of wires in the rows adjacent to the flow duct.



SK-3-13188 Sheet 1 of 2

FIGURE 5.1. Split Core Driver Fuel Subassembly

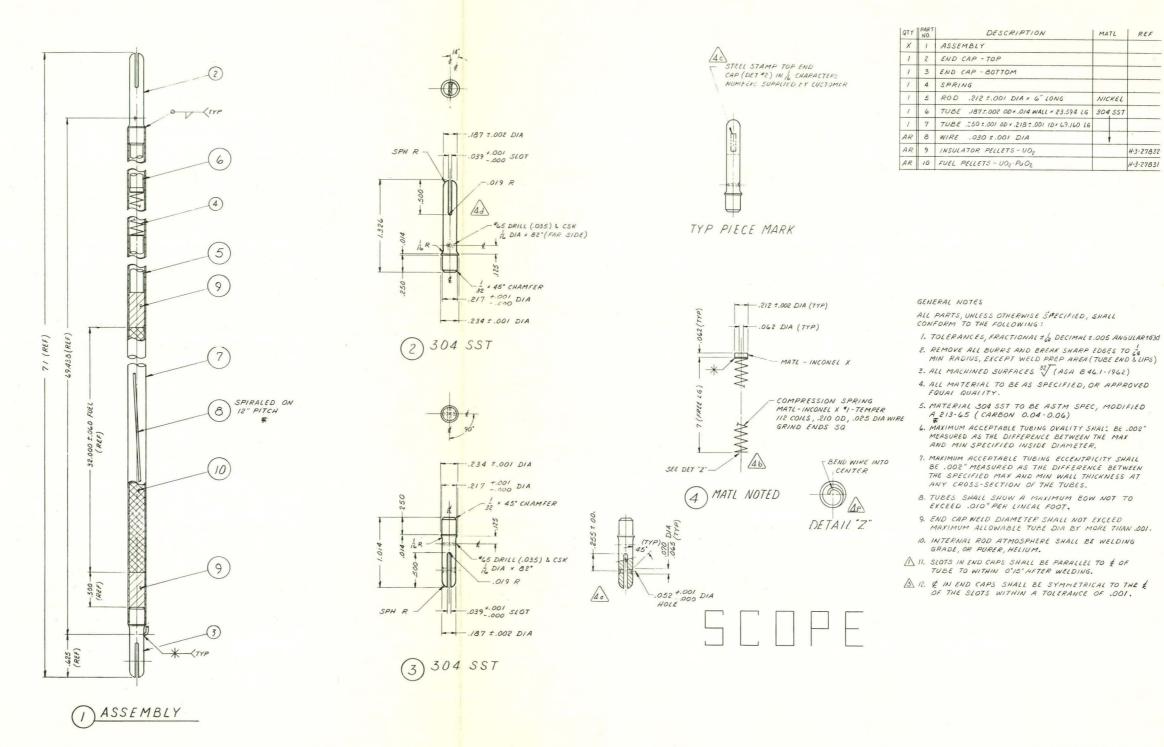


SK-3-13188 Sheet 2 of 2

FIGURE 5.2. Split Core Driver Fuel Subassembly

H-3-27832

H-3-27831



SK-3-13187 Sheet 1 of 1

FIGURE 5.3. Split Core Fuel Pin Assembly and Details

The "subassembly tight size" across-the-flats dimension remained about 0.020 to 0.030 in. less than the duct internal dimensions. No significant surface corrosion was observed on the wire wrap, cladding, or flow duct.

In July 1969, the subassembly was reassembled using recovered and modified components. Three new pins had to be inserted.

An interim compressibility test was made in August 1969 at the request of Westinghouse and the Engineering Department. The subassembly was placed in the horizontal position in the Mark I-type open top-duct section, and a load employing lead bricks was applied to the top side of the bundle. As the subassembly was compressed flat against the 3 lower sides of the duct, displacement of the top load plate was measured.

In October 1969, the subassembly was taken to the 306 Building where the compressibility test apparatus shown in Figure 2.1 was set up. The subassembly was inverted and suspended from a fixture with locking bars through the lower grid.

The precompression test examination showed that some of the wires were skewed (kinked and stretched) during handling and removal from the storage duct. The skewed wires were marked. The pitch of the wire varied between 11 to 13 in. Overall, however, the bundle appeared satisfactory, so the tests were conducted as scheduled.

At completion of the tests we examined the bundle and noted that a few more wires had been skewed in the course of tests (probably due to the previously-described looseness). However, because the percentage of skewed wires was small and the data on all runs was close, we assumed that the skewed wires had only a minor bearing on the test results.

5.3 MARK I COMPRESSION TEST RESULTS

5.3.1 Preliminary Compression Test Results

Eight preliminary runs were made to gain operating experience, establish techniques, and to improve performance of the test apparatus. In the process of running the first eight runs, it was determined that:

- A maximum of 0.002-in. compression steps and 0.004-in. decompression steps were permissible.
- There was spring action in the Gilman Slide assembly system in addition to the transducers.
- The best technique of compression steps was to advance all shaft driven bars first and then the transducer bar, although it made no noticeable difference.
- The decompression step procedure should be carried out in opposite order of the compression step procedures.
- The test results were reproducible.

A test was performed to see if it made any difference to let the subassembly rest on the upper grid rather than to suspend it from a hoist. The test results were practically identical for both methods.

A test was also performed with the subassembly row of wires raised 3 in. above the transducer line of center. Although the two transducers readings differed substantially from each other, when they were added together and divided by two, the load-displacement curve was nearly the same as in the other preliminary test runs.

5.3.2 <u>Final Compression Test Results</u>

Ten final test runs were made. Three test runs were made on side "U", and one run was made on each of the other sides. Also, on side U, one special run was made with the subassembly sitting on the support base, and another special run was made with the subassembly wire row 3 in. above the transducer centers.

Test curves for both special test runs were within the range shown in Figures 5.4 and 5.5. Figures 5.4 and 5.5 are based upon an average of the final six test runs (one run on each side).

5.4 MARK I TEST CONCLUSIONS

Mark I test conclusions were as follows:

- The spring constant for Mark I at the low loads between 0 and about 15 lb/ft/side (Figure 5.4) is not linear. Figure 5.5 shows that the spring constant between 15 to 75 lb/ft/side is approximately 4 lb/0.001 in. and from 75 to 250 lb/ft/side about 7.3 lb/0.001 in.
- After the tests were concluded, the 7.3-1b/0.001-in. spring constant was found to be in error (too high) due to over-correction in advancing the load measurement pressure bars. The correct spring constant value could be determined only by retesting Mark I.
- The Mark I subassembly is resilient. There was no residual forces or permanent deformation during testing.

 Hysteresis was very low, and it disappeared when the subassembly was removed from the test apparatus.
- The subassembly does not become hard after being compressed to a tight subassembly size, but instead has spring compression greater than 250 lb/ft/side.
- The subassembly compressibility test results are practically the same whether the inverted subassembly is suspended by its lower grid with locking bars or resting on the upper grid.
- Forces are transmitted from the subassembly to the test apparatus sides through the wires adjacent to the sides. This is indicated by the fairly well-balanced load measured by the two transducers when wires were lined up on them and is indicated by the difference in individual loads when the wires were offset 3 in. from the transducers.

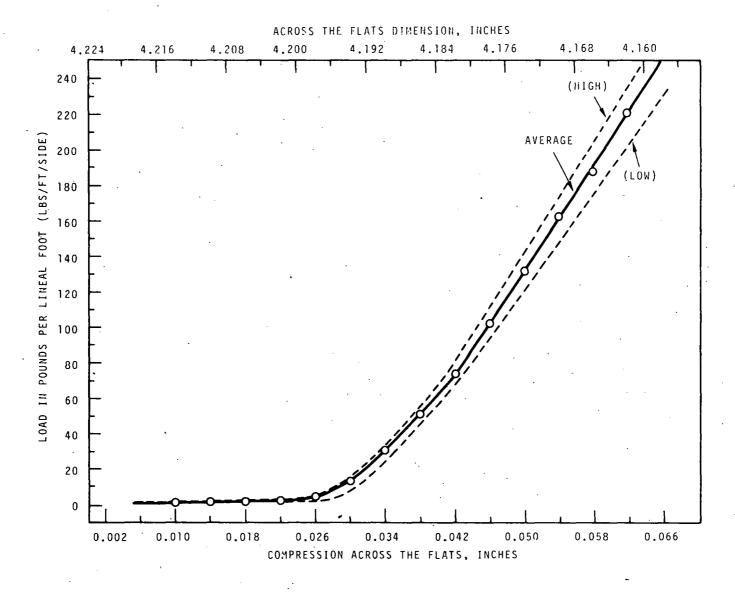


FIGURE 5.4. Summary of Mark I Compression Test Runs

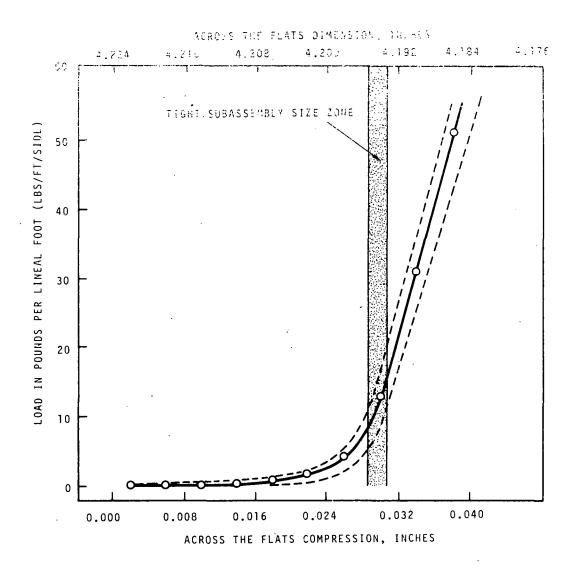


FIGURE 5.5. Summary of Mark I Compression Test Runs

- Although some of its wires were loose and kinked, the Mark I subassembly still represents its original configuration, and it gave representative results.
- The "tight subassembly size" was approximately 4.194 in. across the flats.

6.0 CCTL MARK II SUBASSEMBLY COMPRESSION TESTING

6.1 MARK II SUBASSEMBLY DESCRIPTION

The Mark II subassembly is similar to the Mark I subassembly. It consists of 217 wire-wrapped fuel pins and is assembled into a hexagonal cross-section bundle. The subassembly and details of the unit are shown in Figures 6.1 through 6.3 (BNW Drawings SK-3-15242, SK-3-15243, and SK-3-15244).

The subassembly was made up of 92-in. long \times \sim 0.230-in. diameter pins spaced by 0.056-in. OD, 20% coldwork wire wrap with a triangular pitch. The wire was wrapped on a 12-in. pitch with 8-1/2 lb of tension. The fuel pin was made up of Type 316 SS tubing with a 0.200 in. ID. This was loaded with (starting at the bottom) six 1-in. reflectors, 37 in. of depleted UO₂ pellets (0.197-in. OD), six 1-in.-reflector rods, a plenum spring, and a 34.5-in. long plenum tube. The fuel pins were held together by grids at both ends of the subassembly.

6.2 MARK II HISTORY

The CCTL Mark II fuel assembly was fabricated for a flow test to evaluate potential long-term failure modes for a semi-prototypic FFTF driver fuel assembly. The test will be performed at the Argonne National Laboratory in the Core Components Test Loop. The test will consist of circulating 525 gal/min of 1100°F sodium through the 217 pin assembly for a period of approximately 9000 hr.

After assembling the 217 pins into upper and lower grids, and prior to assembling them into a flow duct, the Mark II subassembly was compression tested in Room 138 of the 308 Building. The compression testing work commenced on February 13, 1970. The subassembly was always kept vertically oriented (right side up) throughout the test period and experienced no more than hand pressure on the sides outside of the compression test apparatus.

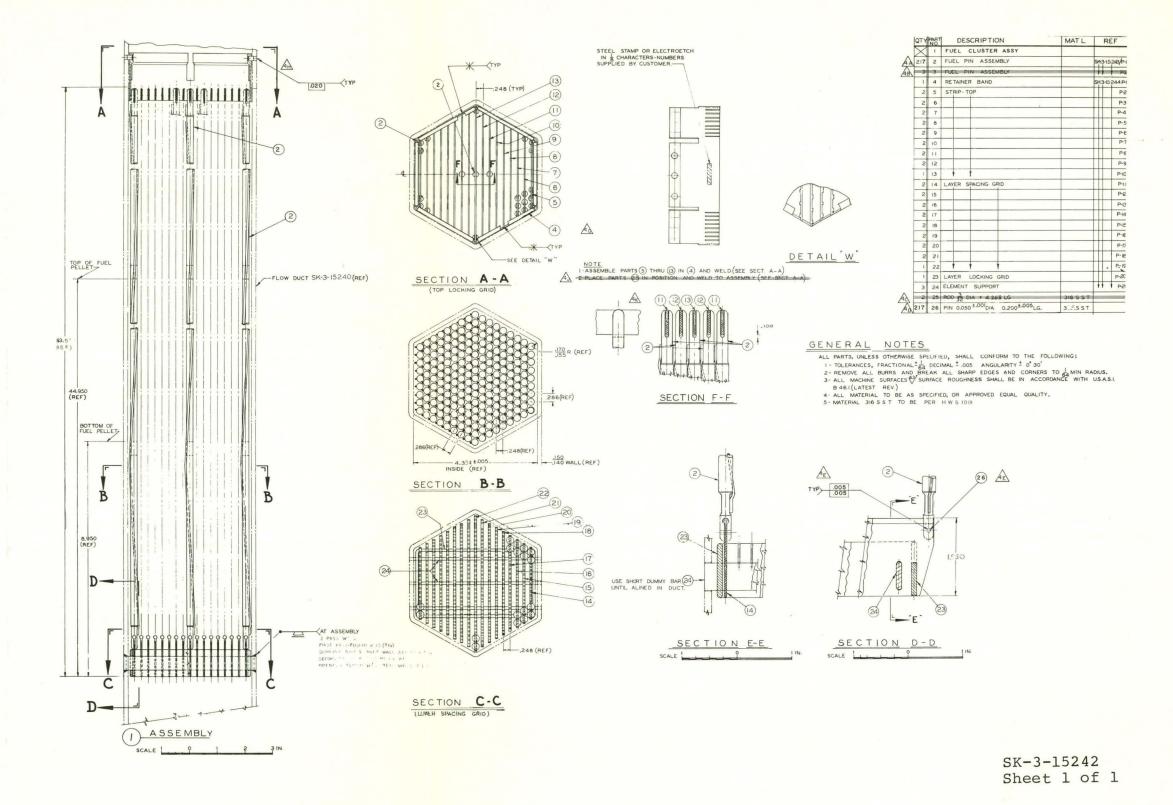
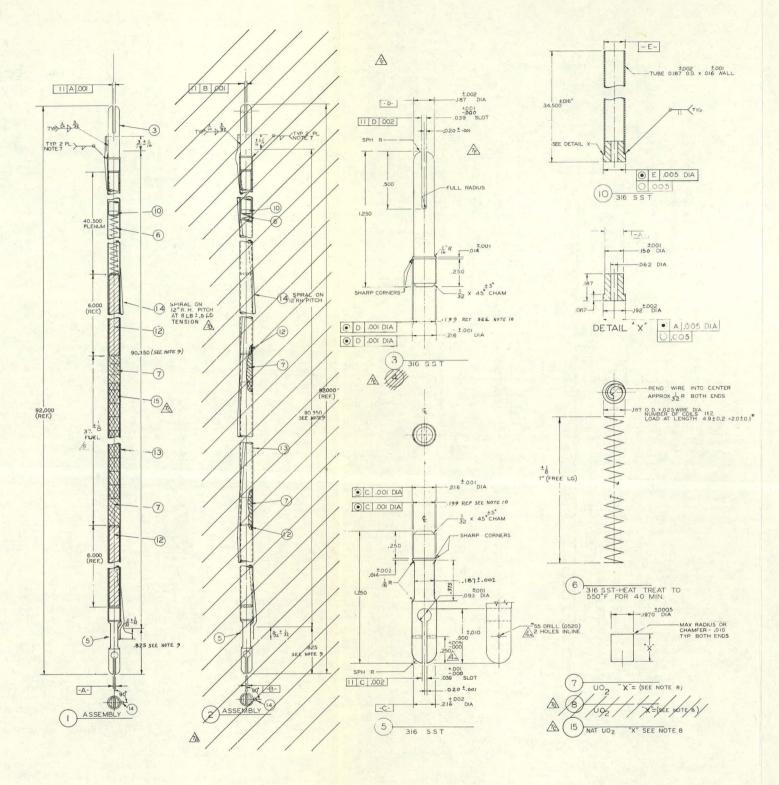
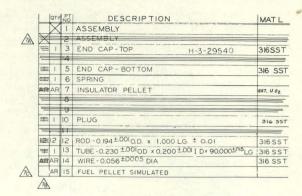


FIGURE 6.1. CCTL Driver Fuel Subassembly







TYP PIECE MARK

GENERAL NOTES

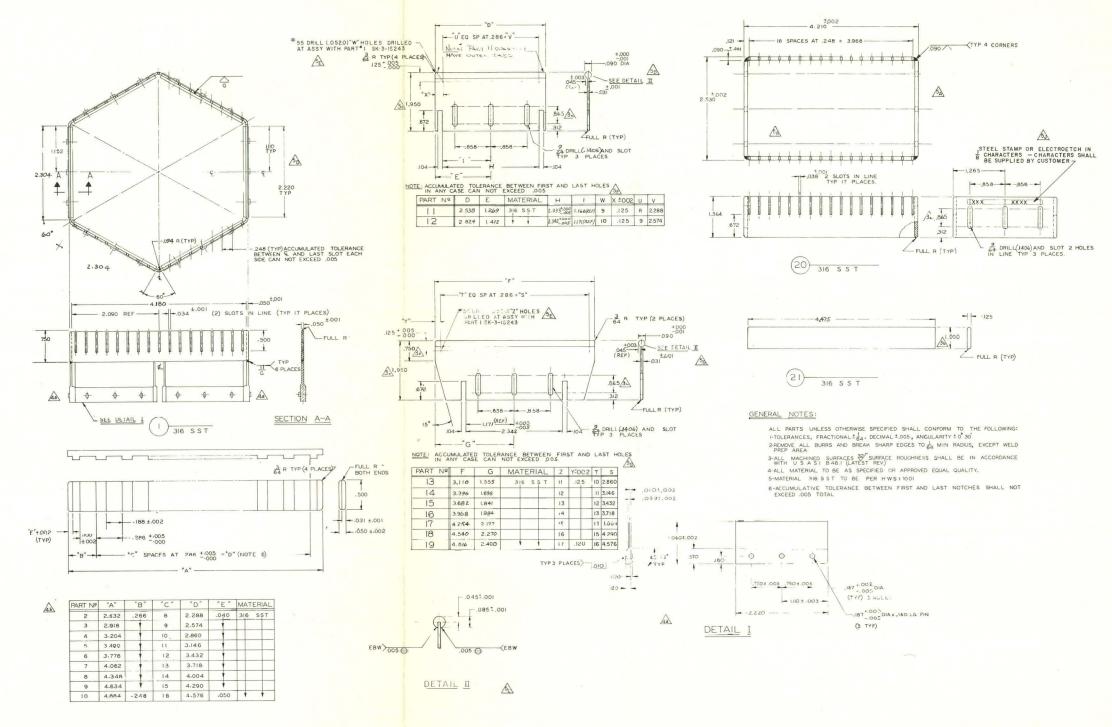
ALL PARTS, UNLESS OTHERWISE SPECIFIED, SHALL CONFORM TO THE FOLLOWING:

- 1-TOLERANCES, FRACTIONAL + 1/64, PECIMAL + 005, ANGULAR + 0 30
- 2-REMOVE ALL BURRS AND HAFAK SHARP EDGES TO 64 MIN MADIUS, EXCEPT WELD PREP AREA (TUBE ENDS & LIPS)

 3-ALL MACHINED SURFACES VSURFACE ROUGHNESS SHALL BE IN ACCORDANCE WITH USASIB46.1 (LATEST REV)
- 1-DIMENSIONS & TOLFRANCES IN ACCORDANCE WITH USASI Y-14.5-1966 5-MATERIAL 316 S.S.T. SPECIFICATION HWS-1001
- 6:FUEL PIN SHALL SHOW A MAXIMUM BOW NOT TO EXCEED .010 PER LINEAL FOOT. TOTAL FOR PIN NOT TO EXCEED .025.
- 7.-END CAP WELD DIAMETER SHALL NOT PROJECT MORE THAN .003 BEYOND THE TUBE DIA .
- 8-PELLET LENGTH TO DIAMETER RATIO SHALL BE .75 \$= 1.00
- 9 REFERENCE POINTS FOR WIRE TWIST START & STOP
- 10-END CAP PLUGS SHALL BE MACHINED TO FIT TUBE. PLUG DIAMETER SHALL BE 0.0007 TO 0.0013 LESS THAN TUBE INNER DIAMETER.
- (1) 308 SST FILLER MATERIAL SHALL BE USED IN WIREWRAP TO END CAP FILLET WELDING

SK-3-15243 Sheet 1 of 1

FIGURE 6.2. CCTL Driver Fuel Pin Assembly and Details



SK-3-15244 Sheet 1 of 1

FIGURE 6.3. CCTL Driver Fuel Locking and Spacer Grid Details

The subassembly was positioned by a handling fixture which was basically a sling that supported the subassembly through dummy locking bars at the lower grid. During compression tests, the handling fixture was removed and the subassembly rested on the test apparatus support base.

6.3 MARK II COMPRESSION TEST RESULTS

6.3.1 Preliminary Compression Test Results

Eight preliminary test runs were made on various sides of the subassembly. These were used to establish techniques for the new bundle and pressure bars. The tests established that:

- The techniques for the tests were basically the same as those used for the Mark I subassembly.
- The runs were reproducible for the subassembly in the same position both for compression and decompression.
- Test data curves were similar in shape to those found for the Mark I subassembly tests.
- The new set of pressure bars had a slight interference on Side 1.
- The correction curve used was slightly incorrect.

The pressure bars were modified and the correction curve was replotted after another setup calibration run.

6.3.2 Final Compression Test Results

Three final test runs were made, each with a side 60° apart from the one previously tested. The test run results are shown in Figures 6.4 through 6.6 and are summarized in Figure 2.2

The compression test summary curve indicates a changing spring constant from 0 to 15 lb/ft/side. From approximately 15 to 50 lb/ft/side, the curve shows a spring constant of about 5.15 lb/ft/side per 0.001 in.

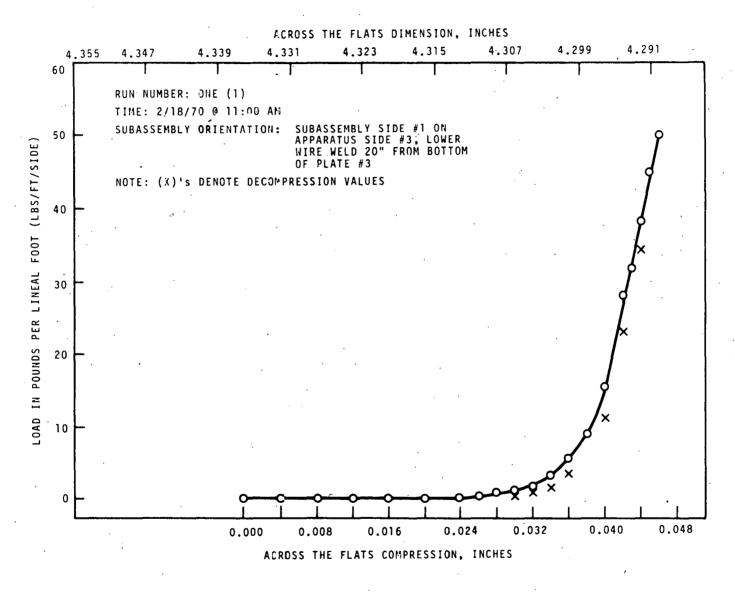
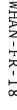


FIGURE 6.4. Mark II Compression Test, Run One



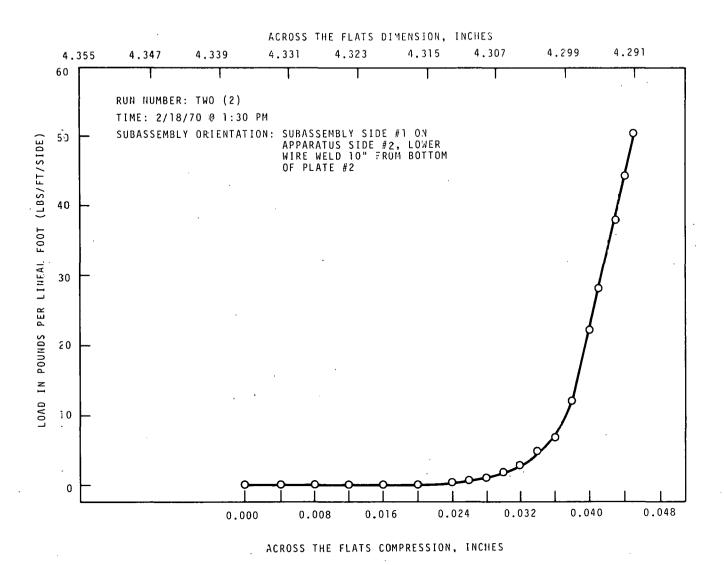


FIGURE 6.5. Mark II Compression Test, Run Two

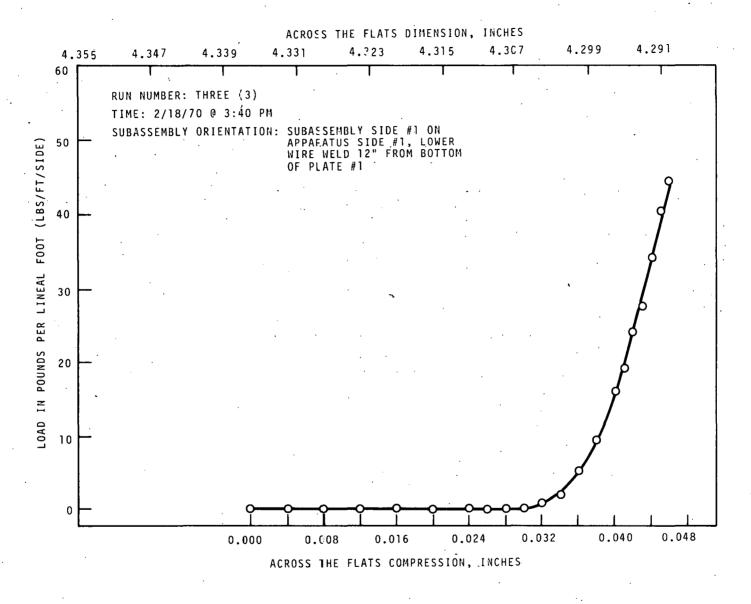


FIGURE 6.6. Mark II Compression Test, Run Three

The hysteresis curve shown in Figure 6.4, Run F-1, was characteristic of all the runs made, based on preliminary run test results. The graphs of the compression and decompression run curves matched at zero force on all runs, thus indicating complete relaxation of the fuel pins.

6.4 MARK II SUBASSEMBLY TEST CONCLUSIONS

The Mark II fuel pin subassembly is resilient. There was no residual forces and no measurable or visible damage during testing. There was little hysteresis shown between the compression and decompression curves. The bundle acts as a spring even beyond the 4.297-in. "tight subassembly size" point.

The test compression curves show a low and upward varying slope until the region just beyond the "tight subassembly size" point. Beyond this region, the curve slope is constant (reflecting the spring constant of the bundle) up to the limit of the test (50/1b/ft/side). The slope in this region is 0.001 in. per 5.15 lb for a 1-ft portion of the bundle side.

7.0 CALCULATIONS

7.1 TIGHT SUBASSEMBLY SIZE

The form of calculation and the calculations used to find the "tight subassembly size" are given in Appendix B.

Calculations for a Mark I "tight subassembly size" could be made only with pre-CCTL test dimensions. The Mark I subassembly would have to be completely disassembled, and selected fuel pins and wires would have to be destroyed to get an accurate post-CCTL measurement. Using the best figure available, the pre-CCTL test dimensions result in a "tight subassembly size" of 4.1898 in. (compared to a 4.194 in. actual test value).

The Mark II subassembly had a calculated "tight subassembly size" of 4.3036 in. (compared to a 4.297 in. test value). This subassembly used measurements which were taken before assembly on the 30 characterized fuel pins.

7.2 COMPRESSION SIDE LOAD (1b/ft/SIDE)

To determine the load on a subassembly side, the loads measured on the two transducers were added together and divided by two for determining the average load in lb/ft/side.

The initial top and bottom transducer force readings are recorded on the Data Run Sheet and the instrument readings are converted to force in lb/ft/side and plotted on the Test Run Graph. The calculation is made as follows:

$$\frac{\text{of scale}}{\text{Oscile}} \frac{\text{Top}}{\text{Reading}} + \frac{\text{Bottom}}{\text{Reading}} \times \text{Full Scale Value, 1b}$$

= Average 1b/ft/Side

i.e.,
$$\frac{3\% + 5\%}{2 \times 100} \times 25$$
 lb scale = 1 lb/ft/side

7.3 ACCURACY

The uncertainty of the distance and force measurements made with the compression fixture are as follows:

- The value and absolute uncertainty for the across-flats distance to which all across-flats measurements were referenced was 4.210 ± 0.0036 in. for the Mark I subassembly and 4.336 + 0.0038 0.0027 in. for the Mark II subassembly (relative uncertainty was thus $\pm 0.09\%$ and $\frac{+0.09\%}{-0.06\%}$, respectively).
- The absolute uncertainty in the amount of compression from the reference across the flats dimension to another size was \pm 0.001 in.
- The uncertainty in the force readings was ± 1%.

The absolute uncertainty in the calculated value of tight subassembly size for each subassembly was fairly large because of the limited measurement accuracy of the diameter of the wire and tubing used in the subassemblies. The tight subassembly size calculation given in Appendix B magnifies these uncertainties much greater because there are 17 rows of pins.

A random sample of outside diameter measurements was taken for the tubes and wires used in each subassembly (Table 7.3). The average of these measurements for each part was used to calculate the tight subassembly size given previously for each subassembly. The averages were considered as having the "measurement uncertainty" of \pm 0.0003 in. which in turn resulted in an absolute uncertainty for the calculated tight subassembly size of each subassembly of \pm 0.009 in.

TABLE 7.3. Random Sample of Outside Diameter Measurements Taken for the Tubes and Wires Used in Each Subassembly

Subassembly	<u>Part</u>	Number of Items In Sample	Measurements Per Item	Average Diam,* in. OD	Uncertainty of Measurements	Range, in. OD
Mark I	Tube	15	1	0.2502	0.0003	0.2510 0.2498
Mark 1	Wire	215	1	0.0298	0.0003	0.0293
Mark II	Tube	41	10	0.2298	0.0003	0.2296 0.2302
Mark II	Wire	40	10	0.0561	0.0003	0.0559 0.0564

^{*} All sizes were taken before exposure to sodium.

8.0 CONCLUSIONS

Both the Mark I and Mark II fuel pin subassemblies responded resiliently to the forces applied during compression testing. The Mark I displayed this characteristic up to 250 lb/ft/side. No perceptible or measurable damage or residual forces were experienced by the Mark II subassembly. Mark I damage was difficult to assess because of the subassemblies' poor precompression test condition.

The compression test curves of both subassemblies were very similar. The curves confirm that the subassemblies do not become solid at the "tight subassembly size" but continue to react like a spring. The compression beyond the "tight subassembly size" point results in combined beam and torsional bending of the fuel pins. The bending before this point is a beam (leaf spring)-type action, because some of the fuel pins have a natural outward bow which is being straightened. The spring constants found for Mark I were:

Simulated Duct Load Compression Spring Constant

<pre>1b/ft/side</pre>	1b/0.001 in.
0 to 15	Varying Upward
15 to 75	4.0/0.001
75 to 250	7.3/0.001*

^{*} This value is incorrect and the correct value is lower but unknown.

The spring constants for Mark II were:

Simulated Duct Load Compression Spring Constant

1b/ft/side	1b/0.001 in.
0 to 15	Varying Upward
15 to 50	5.15/0.001

The steeper slope of Mark II in the 15 to 50 lb range can be partially attributed to: 1) Mark II's higher tube-wire

moment of inertia in bending and torsion, and 2) the fact that Mark II fuel pins contained cladding and wires with 20% cold work while Mark I contained fully annealed cladding and wire. Another contributing factor for the steeper slope could have been the oversized OD of Mark II fuel pellets.

See the individual subassembly test conclusion sections of this report (Paragraphs 5.4 and 6.4) for conclusions drawn solely from that test.

The actual "tight subassembly size" for the two subassemblies were determined during compression testing as follows:

Subassembly Tight Subassembly Size

Mark I 4.194 in. across-the-flats

Mark II 4.297 in. across-the-flats

The compression test result data and curves cannot be used directly to analyze the in-reactor case of both of the fuel pins swelling larger than the duct dimensions and vice versa. The reactor conditions were not simulated in the compression test because in the reactor:

- The fuel pin-duct interaction-length will not be 4 feet long.
- The real growth of the fuel pins subassembly and duct will not have a linear profile.
- In-reactor forces and stresses will be different, because instead of the duct shrinking to compress the subassembly, the subassembly will be growing to interact with a growing duct* (growth of individual fuel pins and ducts will depend upon their position in a subassembly and the reactor core).
- The tests were performed at room temperature, in common air, and during a short period of time (no more than 2 hr for a full test run).

^{*} Component growth - swelling rate of components is theoretical at this point in time; whether the duct-subassembly gap decreases or increases is not factually known. This is the latest thinking.

Thus, it would require a complex solution and work to correct compression test data for such factors as sodium environment, pressure, temperature, end-of-life conditions, radiation-induced and thermal-induced expansion, swelling and creep.

9.0 RECOMMENDATIONS

The Mark II subassembly should be re-tested when it is returned from Argonne National Laboratory. This will help to determine the effect of long-term, hot-sodium flow on the subassembly resilience, the tight subassembly size, and the overall subassembly springiness characteristics for comparison to the pre-CCTL compression test results.

One or two special subassemblies should be built for compression tests only. It should be FFTF prototypic but versatile enough so that tests can be made with various size and shape wire-wrap (that is, wire tapered to match contour of fuel swelling profile). This type of data would not only be helpful in establishing design parameters on cladding, wire, and duct dimensions, but most important, it would help establish the tolerances necessary to meet in-reactor requirements. Development tests could also be performed to determine subassembly creep measurements, damage assessment, etc. When swelling profiles can be predicted accurately, the swelling contour could be ground onto the pressure bars.

10. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the cooperation and assistance of the following individuals in the performance of this study:

- F. C. Schrag and R. J. Glumace who were instrumental in helping prepare tests at PNL by explaining the compressibility test requirements, problems, test apparatus design and test results at Atomics International.
- R. Kolowith and B. G. Smith who provided assistance and helped expedite the test apparatus design and fabrication.
- J. W. Davison of Tech Shops who supervised the fabrication and inspection work.
- M. D. Jackson who was responsible for preparing the facility and setting up the equipment.

APPENDIX A TEST PROCEDURE FOR COMPRESSION OF PROTOTYPIC FFTF FUEL SUBASSEMBLIES

TEST PROCEDURE FOR COMPRESSION OF PROTOTYPIC FFTF FUEL SUBASSEMBLIES

R. B. Baker and D. E. Blahnik

May 26, 1970

Reviewed by: J. C. Thornton	6-23-70
Approved by:	6/24/20
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W. E. Roake	

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TEST PROCEDURE FOR COMPRESSION OF PROTOTYPIC FFTF FUEL SUBASSEMBLIES

R. B. Baker and D. E. Blannik

1.0 SUBASSEMBLY COMPRESSION TEST PURPOSE

The purpose of compression testing a prototypic FFTF driver fuel subassembly* is to determine the springiness** that exists within the subassembly when it is compressed symmetrically from a maximum or nominal internal duct size down to beyond a tight subassembly size. The spring load on the simulated duct wall is to be measured as a function of various across-the-flat dimensions. Figure A.1.1 shows a typical curve which can be plotted from subassembly compression test data.

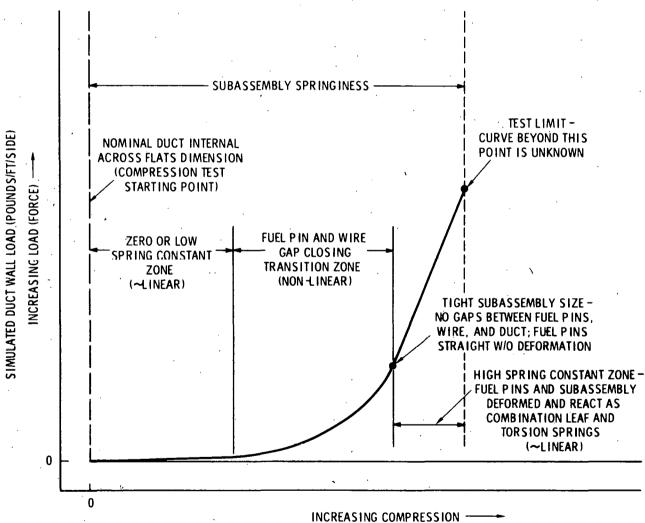
^{*} Subassembly - A (driver fuel) subassembly is defined in this test procedure as being "an assembly of 217 completed fuel pins banded together by grids at each end." Normally, a fuel subassembly also includes locking bars and the straight flow duct section.

^{**} Subassembly Springiness - When a fuel pin subassembly, such as Mark II, is in the vertical position, the fuel pins cannot bow significantly towards the center. Therefore, most of the outer pins are randomly forced outward by a combination of their own natural bow and the forces transmitted by the natural bow of internal pins. When a subassembly is compressed to a tight subassembly size, all of the natural spring is absorbed. If a subassembly is compressed beyond tight subassembly size, the fuel pins react as a combination of leaf and torsion springs.

[†] Tight Subassembly Size - Point at which all fuel pins and wires are compressed tightly together without any deformation of the subassembly components. There is no outward displacement due to natural bow of the fuel pins and no gaps between wires and fuel pins. When a subassembly is compressed beyond this point the load-compression deflection curve becomes linear. This term was previously referred to as "bundle theoretical tightness."

The data shall be used to:

- Characterize the subassembly's tight size and springiness.
- Analyze the in-reactor cases both of the fuel pins swelling larger than the duct dimensions and vice versa.
- Assist in establishing dimensions and tolerances on the fuel pin OD, wire OD, and the duct internal dimensions to assure proper fit for reactor requirements.



ACROSS THE FLATS COMPRESSION DISTANCE (INCHES)

FIGURE A.1.1. Typical Subassembly Compression Test Data Curve

2.0 COMPRESSION TEST APPARATUS DESCRIPTION

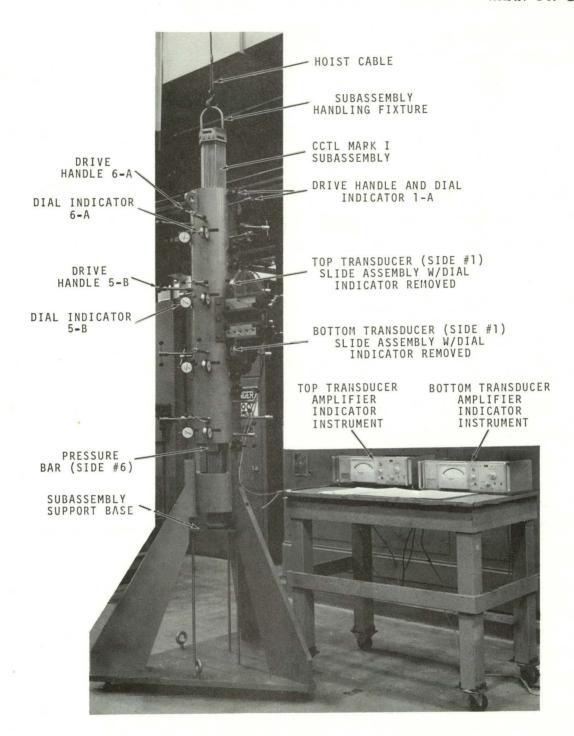
Figure A.2.1 shows the complete subassembly compression test apparatus and related system components. Drawing H-3-29508, sheets 1 through 4, (Figure A.2.2) describe the design of the test apparatus in detail. Closeup pictures of the lower end of the apparatus and the load transducer section are shown in Figures A.2.3 and A.2.4. A closeup view of the transducer amplifier-indicator instruments is illustrated in Figure A.2.5.

2.1 GENERAL DESCRIPTION

Basically the test apparatus consists of a heavy walled steel pipe supported rigidly in a vertical position by a heavy base with gussets. Inside the pipe body are located $1 \times 2-5/16$ -in. bars on each of six equally spaced positions. Five sides contain bars that are 48-in. long, and they are supported vertically by four male shafts threaded through the pipe body with drive handles spaced on one foot centers. The matching female threads are located inside the pipe. The drive handles are turned to move the bars. The pressure bars are held on the ends of the shafts by spring-loaded ball plungers.

The sixth side, the one on which the load is measured, contains 1-ft pressure bars at the top and bottom and a 2-ft bar in the center which is supported by two transducer shafts centered and spaced 1-ft apart on the bar. The 1-ft bars are each supported by two threaded shafts with drive handles; they perform the function of preventing the subassembly "end effect* from affecting the load measurement bar readings.

^{*} End Effect - This term refers to the location on the subassembly where there is a transition from subassembly restraint by the test apparatus pressure bars to nonrestraint above and below the 4-ft pressure bars section.



NEG. 0694656-1

FIGURE A.2.1. Subassembly Compression Test Apparatus

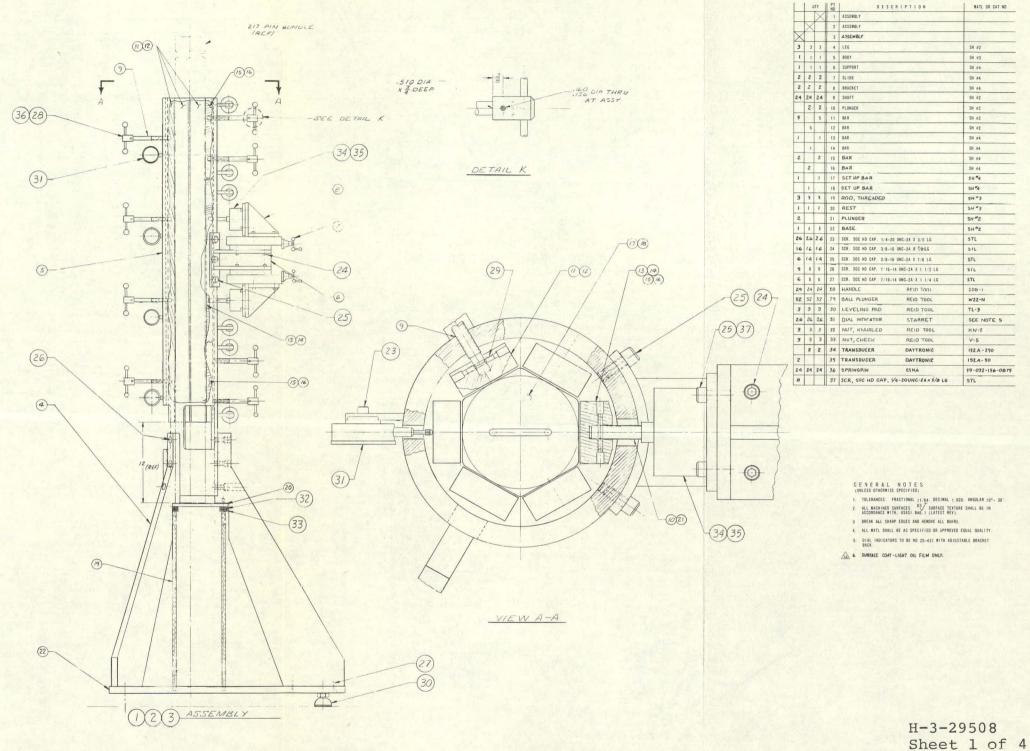
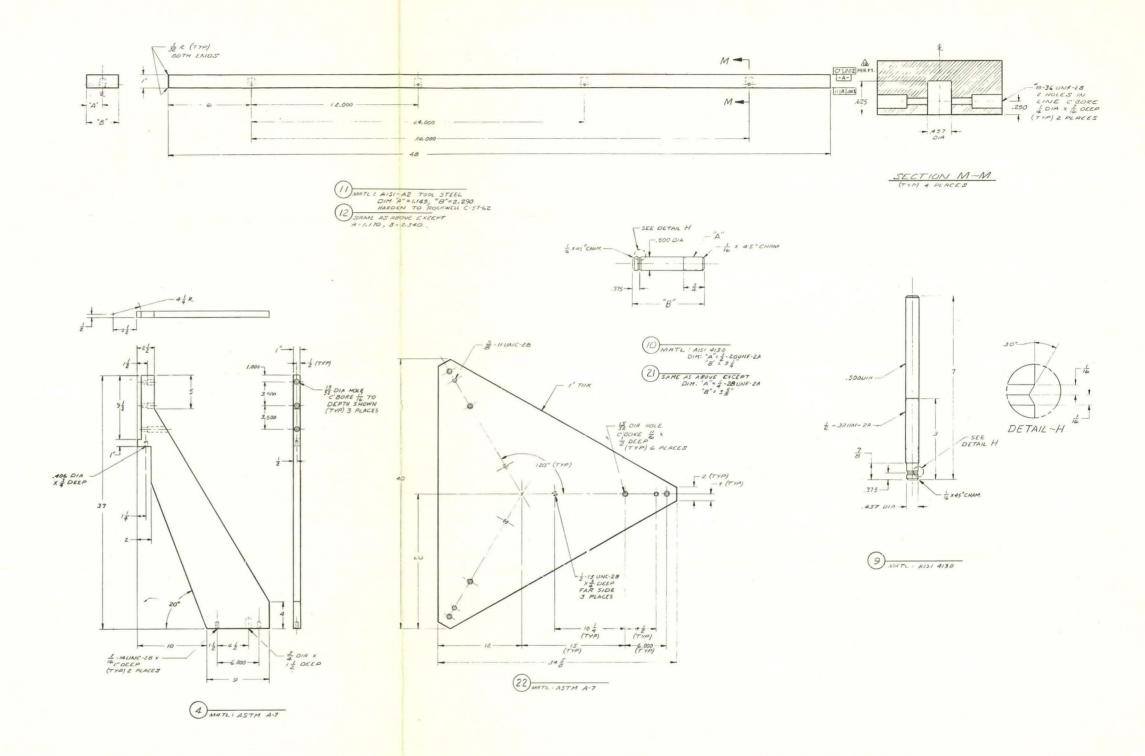
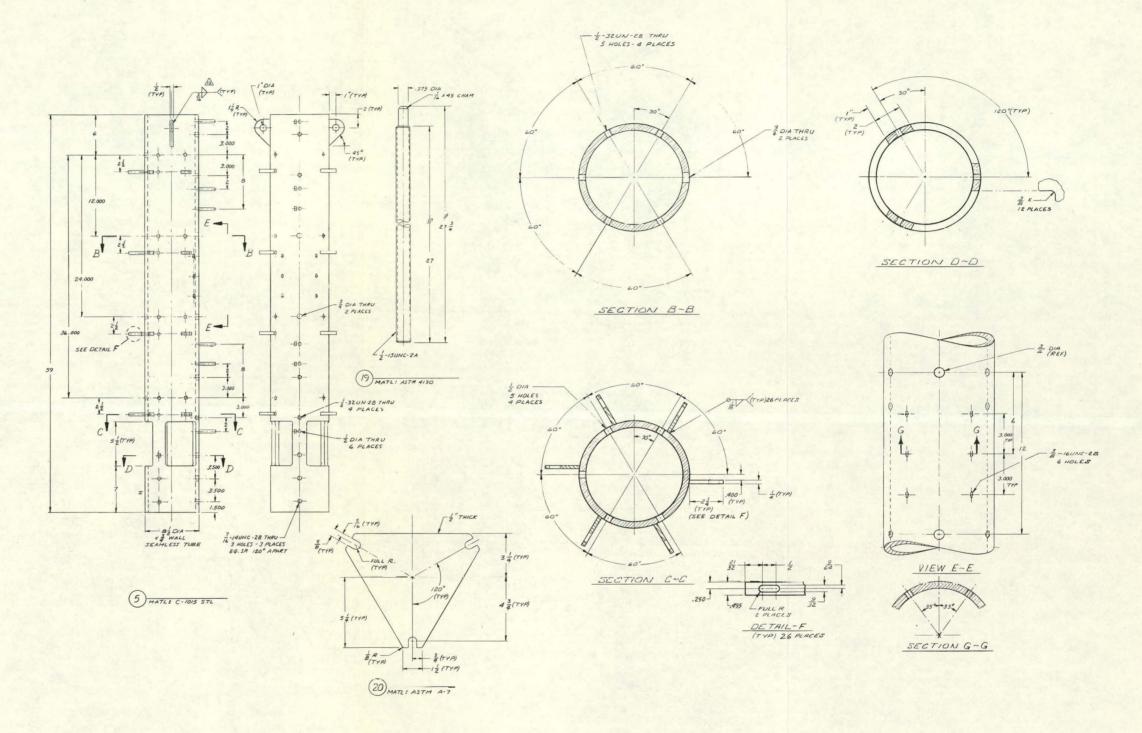


FIGURE A.2.2. Subassembly Compression Test Apparatus Assembly



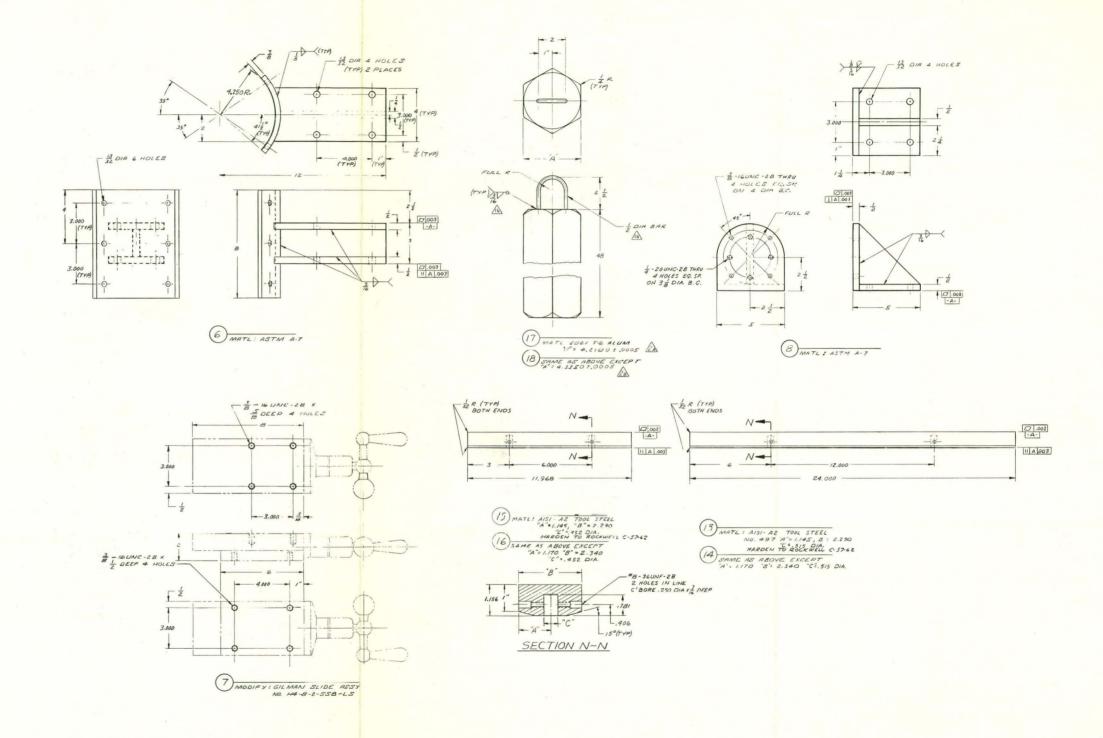
H-3-29508 Sheet 2 of 4

FIGURE A.2.2. (contd)



H-3-29508 Sheet 3 of 4

FIGURE A.2.2. (contd)



H-3-29508 Sheet 4 of 4

FIGURE A.2.2. (contd)

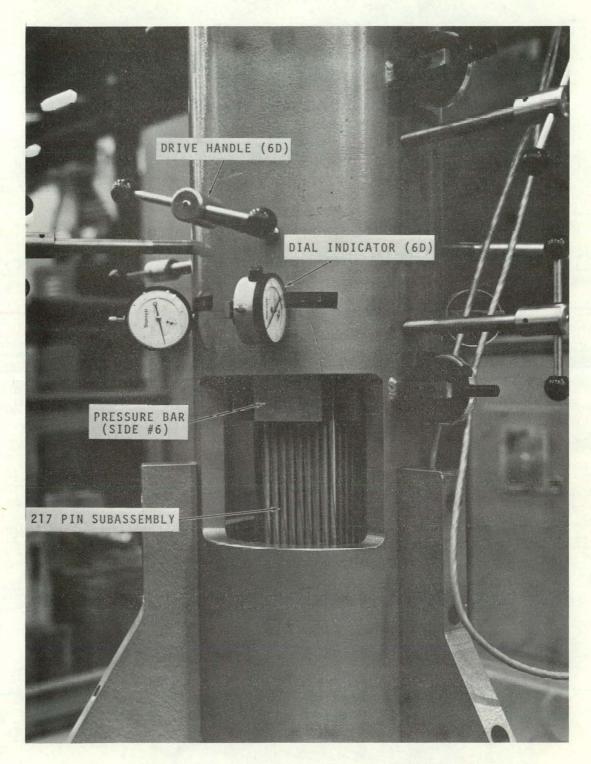


FIGURE A.2.3. Subassembly Compression
Test Apparatus, Lower End

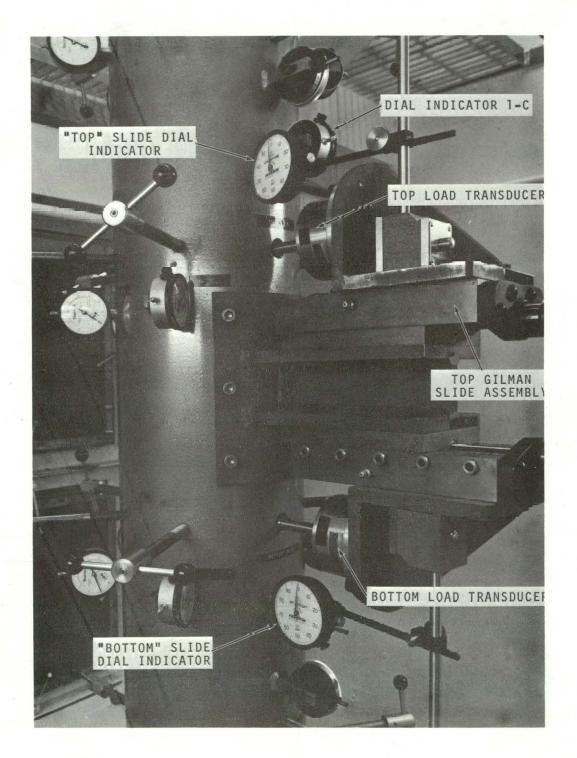
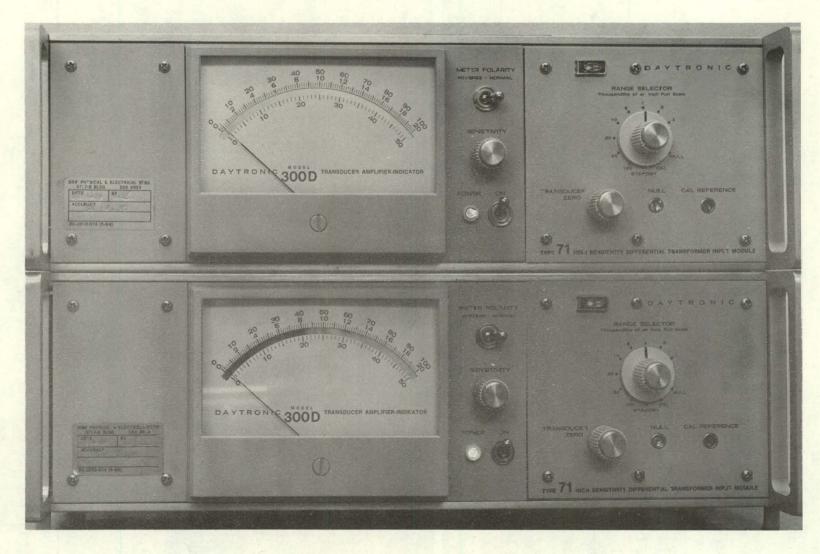


FIGURE A.2.4. Subassembly Compression Test Apparatus, Load Transducer Section



NEG. 702397-4

FIGURE A.2.5. Transducer Amplifier - Indicator Instrumentation

The transducer shafts are fixed in the transducer receptacle, and the transducers are mounted on Gilman slide assemblies which drive the 2-ft load measurement bar. The transducers are connected to amplifier-indicator instruments located on a table for reading out the transducer loads.

Two dial indicators are also mounted on the Gilman slide assembly transducer brackets and are referenced against the pipe body outer diameter. These dial indicators are used to properly locate the load measurement bar by compensating for springback in the transducer spring and the Gilman slide assembly system.

Each of the two force transducers are Daytronic Model Number 152A-250 and each of the two amplifier-indicators are Daytronic Model Number 300D-71. The amplifier-indicators have force scale ranges calibrated for 0 to 25 1b, 0 to 125 1b, and 0 to 250 1b (scales 1, 5, and 10, respectively).

A cross-section of the test apparatus is shown in Figure A.2.2, sheet 1.

2.2 TEST APPARATUS COMPONENT IDENTIFICATION

2.2.1 Side Identification

Side No. 1 is the side equipped with transducers, as shown in Figure A.2.1. The other sides are numbered 2 through 6 counterclockwise as viewed from the top.

2.2.2 Dial Indicators and Drive Handles

The dial indicators are lettered A, B, C and D on each of Sides No. 2 through No. 6. On Side No. 1, they are lettered A, B, C, D, E and F. The designation for a particular dial is the side number accompanied by the dial letter (for example, 2A, 5C, etc.) Such a designation is located close to each dial on the fixture pipe body (Figure A.2.4). The dial indicators on the slide assemblies are referred to as "top" and "bottom" slide dial indicators according to their position.

The pressure bar drive handles are also lettered top to bottom A, B, C and D on each side. They coincide in designation with the dial indicators except for the bottom two handles on Side No. 1. A designation for each handle is affixed to the fixture pipe body.

2.2.3 Load Measurement Section

The transducers, dial indicators, and slide assembly systems are identified as shown in Figure A.2.4. They are referred to as "top" and "bottom" based upon their position.

2.2.4 Remaining Apparatus Components Identification

The remainder of the major components are identified as shown in Figure A.2.1.

2.2.5 Test Subassembly Designations

Each of the subassembly's six sides has a row of nine tubes along its face. Each tube is wrapped with a wire, and the wires on the nine tubes are all oriented so that every 12 in. along a side, there is a row of wire wraps extending beyond the cladding and towards the duct. The side with the row of wires facing the duct closest to the upper grid is side "U", and the remaining sides are lettered V, W, X, Y and Z counterclockwise looking from the top. The series of letters will be temporarily or permanently marked on the proper side of the lower and/or upper grid for identification.

2.2.6 Setup Standard

The setup standard is shown in Part 18 of Figure A.2.2, sheet 4 and Figure A.2.6. This standard will be used to accurately align the pressure bars on all six sides, zero the dial indicator gages, calibrate the spring in the transducer/slide assembly system, and check to ensure that there is no drift in alignment or gage readings during and after the test.

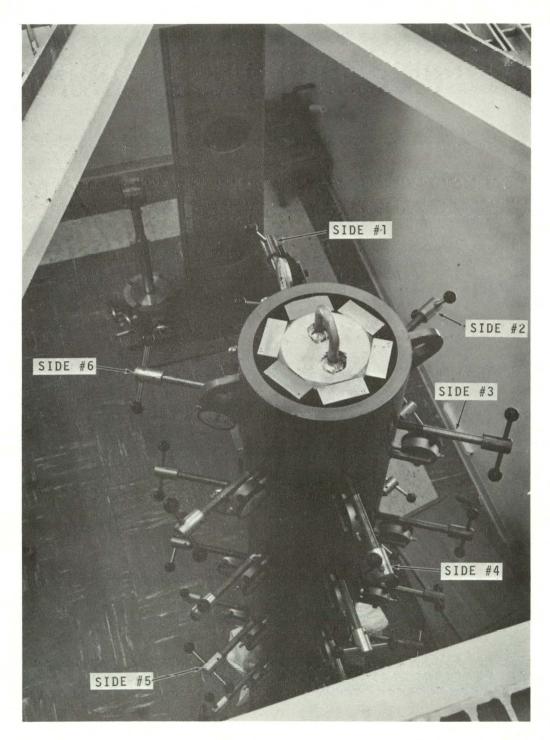


FIGURE A.2.6. Top View of Compression Test Apparatus With Setup Standard in Place

3.0 TEST APPARATUS SET UP AND CALIBRATION PROCEDURES

3.1 JOB HAZARD BREAKDOWN

Prior to starting test associated work, read and understand the Job Hazard Breakdown in Figure A.3.1. Also, read the appropriate hoist operating procedures and Job Hazard Breakdowns.

3.2 TEST PROCEDURE KNOWLEDGE

Prior to starting set up and calibration work, read and understand the "Test Procedure for Compression of Prototypic FFTF Fuel Subassemblies."

3.3 PRE-SET_UP_CALIBRATION

Both the force transducers and their respective amplifierindicator instrumentation shall be calibrated at the Standards Laboratory before mounting them on the test apparatus.

All dial indicators shall be calibrated as deemed necessary by the responsible engineer and between tests if a new setup standard is to be used for zeroing the dial indicators.

Each time the compression test apparatus is physically relocated or structurally changed, the complete apparatus must be releveled and setup steps per Section 3.5 must be redone.

Each setup standard shall be thoroughly characterized at the Standards Laboratory.

3.4 TEST PLAN

An approved Test Plan must be written for each compression test. Read and understand the Test Plan.

(6)

BREAKDOWN REVIEWED BY INDUSTRIAL SAFETY R. B. BAREY/D. E. Blahnik A. 30-70 R. B. Baker/D. E. Blahnik R. Balania R. Bal	JOB HAZARD BREAKDOWN		Subassembly Compression	JHB NUMBER		
REVIEWED BY INDUSTRIAL SAFETY R. B. Baker/D. E. Blahnik A. 30-70 R. B. Baker/D. E. Blahnik REVIEW DATES SAFETY EQUIPMENT REQUIRED NOUS A EQUIPMENT REQUIRED NOUS A STEP HAZAROUS MATERIALS RELIZED REQUIREMENT HAZAROUS MATERIALS RADIATION WORK PROCEDURE PU02 and U02 NUCLEAR SAFETY SPEC. YES NO SAFE PRACTICES 1. Loading subassembly with handling device. 2. Loading test apparatus. 2. Loading test apparatus. Lading test apparatus. Lading test apparatus. Lading reaching under with and reading dials while stepping up, down, and around the platform. 4. Need for applying hand force to face of pressure phand force to face of pressure bars or reaching under unloaded compression fixture. PAGE 1. OF 1. Handles when were procedured as and reading under unloaded compression fixture. PAGE 1. OF 1. Handles hand at least 8 inches above the lower end. Subassembly or setup bar must be lowered slowly with shard and reading dials while stepping up, down, and around the platform. 4. Falling of a pressure phand force to face of pressure bars or reaching under unloaded compression fixture. PAGE 1. OF 1. Shart and procedures are fully assembled and tight. 2. Guide lower part of subassembly or setup bar must be lowered slowly with shard and reading dials while stepping up, down, and around the platform. 4. Need for applying hand force to face of pressure bars or reaching under unloaded compression fixture. PAGE 1. OF 1. Shart and procedures are fully and carefully. A. Falling of a pressure phandles are fully and carefully. A. Handles should not be adjusted when any part of a person is directly under the unloaded compression fixture. Check position of pressure bars in place, if possible, when working under the fixture.			COMPONENT FFTF Fuel Subassembly Dev	velopment Section	1 -	
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FIGURE A.3.1. Subassembly Compression Testing Job Hazard Breakdown

3.5 SET-UP PROCEDURE

3.5.1 Pre-alignment of Pressure Bars

Adjust the pressure bars so their faces are approximately the same distance from the center of the pipe. This can be done by moving all the bars back against the pipe ID.*

CAUTION

Do not back the handles out of the pressure bars when the bars are against the pipe body. Also, ensure that all dial indicators have adequate travel allowance to prevent jamming.

Set the dial indicator scales at zero and move the bars in equally to about a 4.375-in. across-the-flats dimension. Level Side No. 4 so it is plumb.

3.5.2 Pressure Bar Alignment

Clean the 4.335-in. setup bar and carefully lower it into the apparatus. Position the bar so that its bottom edge is flush with the bottom edge of the pressure bars. Leave the setup bar hooked to the hoist.

CAUTION

Ensure that the load measurement bar is at least 0.030 in. further out from the pipe centerline than the top and bottom pressure bars on Side No.1.

Bring in Side No. 1 top and bottom bars until the setup bar is snug** between Side No. 1 and Side No. 4. Bring in Sides Nos. 2, 5, 3 and 6, respectively, one at a time, and

^{*} Side No. 1 pressure plates have beveled corners. Therefore, keep them about 1/8 in. from the pipe.

^{**} Snug - lightly tightened by hand.

position snug to the setup bar. At this point, all pressure bars should be positioned snug but not overly tight on the setup bar. Check this on each handle (especially handles 1-B and 1-C). Place a small level on top of the setup bar and move it all the way around to ensure that the setup bar is plumb.

Next, bring in the transducer pressure bar and tighten the slides until the transducers are almost registering a force. Zero all dial indicators, and record the slide micrometer readings on the data sheet as shown in Figure A.3.2. Record in the log the gross readings from each dial indicator and the direct reading from the slides at this zeroed position.

3.5.3 <u>Correction Calibration Curve Determination</u>

When a load is applied to the load measurement bar, the transducer and slide assembly systems deflect (spring exists primarily in the transducer spring and slide assembly drive system). The amount of spring as a function of force must then be determined so that a correction can be made to assure proper positioning of the load measurement bar during test runs. Plot a correction calibration curve from spring deflection distance versus load data.

Obtain the data by starting with the setup established in Paragraph 3.5.2 and moving the slides inward in 0.001-in. steps according to readings of the "top" and "bottom" slide dial indicators. After each step, record the force readout for each transducer, the slide micrometer readings, and the dial indicator readings. Advance the slides in these steps until you obtain (as shown in Figure A.3.2 example) approximately a 150-1b maximum force readout (60% on 10 scale) on each transducer. If the maximum specified test plan force exceeds 150 lb advance in steps to 250 lb.

SLIDE DIAL INDICATOR CORRECTION CALIBRATION CURVE DATA SHEET

Run No.: Final Run
Standard Size: 4.336"
Temperature: 80°F

Date: 2/12/70
By: D. E. Blahnik
and R. B. Baker

	TOP SLIDE		BOTTOM SLIDE			
Slide Micrometer Reading	Dial Indicator Reading	Percent Full Load Scale	Slide Micrometer Reading	Dial Indicator Reading	Percent Full Load Scale	
8	0	0	2	0	0	
9	.6	10.1	3	. 5	7.4	
10	1.1	44.8	4	1.0	52.0	
11	1.7	97.0	5	1.4	91.2	
12	2.2	15.8×10	6	1.8	14.1 × 10	
13	2.5	21.8 × 10	7	2.1	20.0 × 10	
14	2.9	27.1 × 10	8	2.2	26.0 × 10	
15	3.1	33.2 × 10	9	2.7	32.0 × 10	
16	3.5	39.0×10	10	3.1	38.4 × 10	
17	4.1	45.1 × 10	11	3.5	45.0 × 10	
18	4.3	51.0 × 10	12	3.9	51.6 × 10	
19	4.8	58.2 × 10	13	4.4	59.0 × 10	
20	5.2	65.0 × 10	14	5.0	65.8 × 10	
21	5.7	72.0 × 10	15	5.3	73.0 × 10	
22	6.1	79.0 × 10	16	6.0	80.5 × 10	
23	6.5	87.4 × 10	17	6.4	88.0 × <u>1</u> 0	
24	7.0	94.0×10	18	6.9	95.0 × 10	
22	6.1	78.0 × 10	16 .	5.9	80.1 × 10	
20	5.2	63.3 × 10	14	4.9	66.1 × 10	
18	4.3	49.8 × 10	12	3.9	52.0 × 10	
16	3.7	38.0 × 10	10	3.1	37.9 × 10	
14	2.8	26.9 × 10	8	2.4	26.0 × 10	
12	2.1	15.5 × 10	6	1.7	14.0 × 10	
10	1.2	5.8 × 10	4	. 8	3.1 × 10	
8	. 0	.3 × 10	2	. 0	0	

FIGURE A.3.2. Slide Dial Indicator Correction Calibration Curve Data Sheet (Example)

Reverse the procedure and record readings in the same size steps until the instruments record zero force. If the micrometer, dial indicator, and load readings are not the same both when applying pressure and depressurizing the setup bar, another calibration run should be made. If after the second run the readings do not match, analyze the problem before advancing to further test work.

Plot the dial indicator and corresponding force readings from the calibration test on the type form shown in Figure A.3.3 for both pressurization and depressurization. Use the resulting set of correction curves to correct the slide adjustments during compression of the subassembly. After completing a series of compression tests repeat this procedure to ensure that no gross changes have taken place. If deemed necessary by the responsible engineer, this can be peformed after each compression run.

Back off each bar 0.010 to 0.015 in. Back off the load measurement bar at least 0.030 in. Bring one side out at a time. Note that the nonslide dial indicators move negatively as the pressure bars compress and move positively during decompression.

Carefully remove the setup bar from the test apparatus and store it in a proper container.



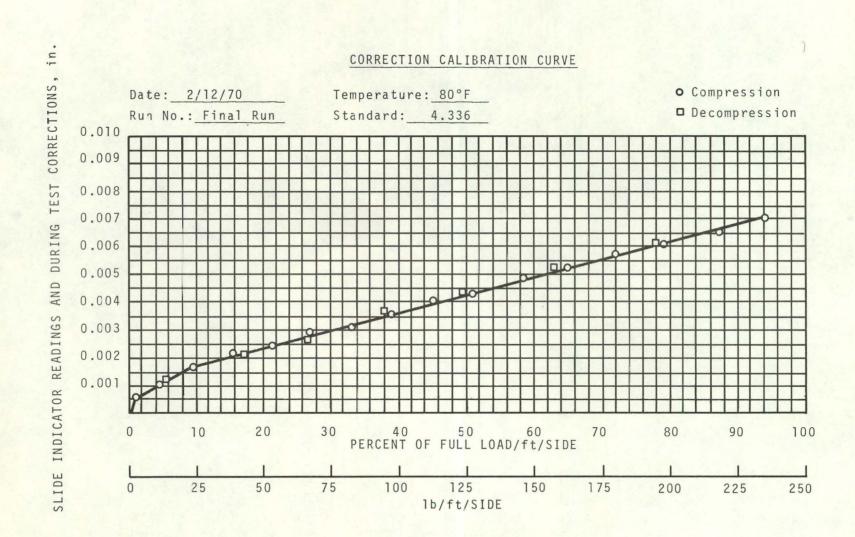


FIGURE A.3.3. Correction Calibration Curve

4.0 TEST PREPARATION AND SUBASSEMBLY SETUP PROCEDURES

4.1 TEST PLAN CONFORMANCE

A Test Plan shall be written for each test. The Test Plan shall include any requested deviations from the standard procedures outlined in this document. It shall also include the test load limits, subassembly orientation and description, a list of other tests to be made with the same subassembly and shall include all the special instructions required.

4.2 LOG BOOK REQUIREMENTS

A log book record shall be maintained of daily progress and history. All data sheets pertaining to calibration, testing, and the fuel pin subassembly must be kept for all tests and runs. As-fabricated dimensions for the subassembly (especially OD of cladding and wire wrap) should be determined to the highest level of accuracy and detail possible. The Test Procedures and Job Hazard Breakdown must also be kept in the log.

4.3 AMPLIFIER-INDICATOR READOUT AND ADJUSTMENTS

Refer to the logbook for instructions on calibration, adjustments, and readout of this instrumentation. The Standards Laboratory must perform the calibration work.

4.4 APPARATUS SUBASSEMBLY LOADING

Load the subassembly into a handling device similar to the ones shown in Figures A.2.1 and A.4.1. The handling device must be fabricated to operate with complete safety to personnel, equipment, and subassembly.

Check the pressure bars in the test apparatus to ensure they are set up according to the last part of step 3.5.3 and to ensure that the load measurement bar is further from the pipe centerline than the other two bars on its side.



NEG. 700642-1

FIGURE A.4.1. Mark II Subassembly Handling Device

Hook the subassembly handling device to the hoist. Carefully lift the subassembly and transfer it to the compressibility test apparatus.

Lower the subassembly until it is about 1/4 in. above the top of the apparatus. Before lowering it further, ensure it is lined up in the X and Y axis. After the subassembly is properly aligned, carefully guide it by hand into the fixture. (Hands should be at least 8 in. above the bottom of the subassembly). Then lower the subassembly to its final position per the Test Plan. While the subassembly is lowered, keep hands in an envelope around the subassembly to keep friction with pressure bars at a minimum. Remove the handling device if it is not required for the compression test.

The subassembly final position should be with the most extreme projection of the nine outer fuel pins wire facing the centers of the two transducers on Side No. 1.

Check to ensure that the maximum wire projection is 6 in. above the top plate on Side No. 1.

CAUTION

To prevent damage to the grids, wire, and cladding during orientation of the subassembly, ensure that both tops and bottoms of pressure bars are no closer than 6 in. from top and bottom grids.

The Test Plan must take this caution into consideration. If the subassembly design is changed substantially from that of CCTL Mark II this whole test procedure must be re-evaluated.

The test can be made with either the bundle hanging or setting on the apparatus subassembly support base. If the support base is used, it must be releveled each time it is adjusted prior to starting a test run.

5.0 COMPRESSION TEST PROCEDURE

5.1 DATA SHEET PREPARATION

Prepare the Data Run Sheet and Test Run Graphs (Examples are shown in Figures A.5.1, A.5.2 and A.5.3) by filling in all pretest data prior to starting the test run. These two sheets are to be used for every test run made in the overall test.

5.2 TEST RUN DESCRIPTION

5.2.1 Bring the pressure bars into approximately the nominal across-the-flat duct inner dimension (that is, 4.335-in. dimension for Mark II). Set all dial indicators at zero for the setup bar readings. Because of the fabrication tolerances and bow of the pressure bars it will not usually be possible to get all dial indicators on one bar to read the exact same number at the low force readings. The pressure bars should therefore be adjusted until at least the center two dial indicators on Sides No. 2 through No. 6 are at the desired reading and the others as close as possible. Ensure that all bars are tight against the drive handles.

5.2.2 Record the initial top and bottom transducer force readings on the Data Run Sheet. Convert the instrument readings to force of 1b/ft/side and plot them on the Test Run Graph.

$$\frac{\text{of scale}}{\text{of scale}} \frac{\text{(Top}_{\text{Reading}} + \text{Bottom}_{\text{Reading}})}{2 \times 100} \times \text{Full Scale Value, 1b}$$

= Average lb/ft/Side

that is, $\frac{3\% + 5\%}{2 \times 100} \times 25$ lb scale = 1 lb/ft/side

5.2.3 Compress the subassembly in across-the-flats steps of 0.002 in. (0.001 in. inward on each pressure bar per the dial indicator readings).

DATA RUN SHEET

Run Number:	F-1	Date: 2/18/70				
Temperature:	80°F	By: D. E. Blahnik and R. B. Baker				
Subassembly Orientat	tion: 1 on 3	Subassembly No: <u>CCTL Mark II</u>				
Starting Across-the- Flats Dimension:		Subassembly Dwg. No.: SK-3-15242 Rev. 4				

COMPRESSION					DECOMPRESSION		
Across-The- Flats Compression, in.	Top Transducer Force, % of Scale	Bottom Transducer Force, % of Scale	Top Slide Dial Indicator Read., in.	Bottom Slide Dial Indicator Read., in.	Pressure Bar Dial Indicator Read., in.	Top Transducer Force, % of Scale	Bottom Transducer Force, % of Scale
0.000	0.5	1.	0	0	0		
0.004	0.5	1.	2	2	48.		
0.008	0.5	1.	4	4	46.		
0.012	0.5	1.	6	6	44.		
0.016	0.5	1.	8	8	42.		
0.020	0.5	1.	10	10	40.		
0.024	1.0	1.5	12.	12.	38.	ļ	
0.026	1.5	2.0	13.	13.	37.		
0.028	3.0	4.0	14.	14.	36.		-
0.030	4.5	5.0	15.	15.	35.	2.	3.
0.032	9.0	8.0	(16.2)	(16.2)	34.	4.	5.
0.034	16.0	13.5	(17.5)	(17.5)	33.	8.	9.
0.036	24.5	24.5	18.5	18.5	32.	ļ5.	15.
0.038	38.5	32.5	(19.7)	(19.7)	31.		
0.040	63.0	60.0	(21.)	21.)	30.	48.0	42.0
0.042	11.5 × 10	11.0 × 10	23.	23.	29.	97.5	86.5
0.043	13.0 × 10	12.5 × 10	23.5	23.5	28.5		
0.044	15.5 × 10	15.0 × 10	(24.3)	24.3	28.	14.5 × 10	13.0 × 10
0.045	19.0 × 10	17.0 × 10	(25.0)	25.0	27.5		
0.046	21.0 × 10	19.0 × 10	25.7	25.7	27.0		
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FIGURE A.5.1. Data Run Sheet



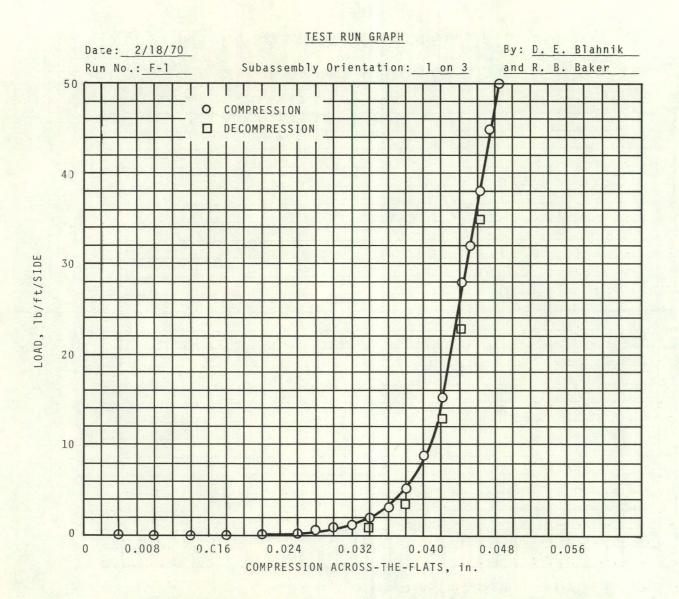


FIGURE A.5.2. Example Test Run Graph, 0 to 50 lb

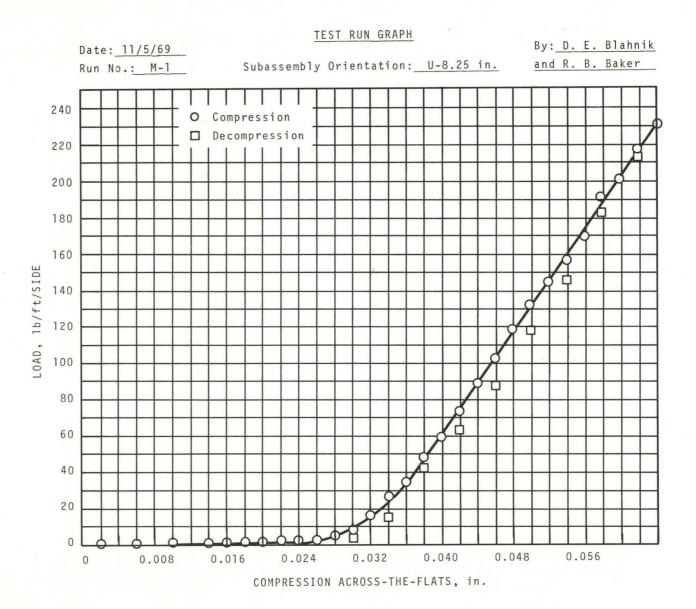


FIGURE A.5.3. Example Test Run Graph, 0 to 250 lb

First advance the top and bottom pressure bars on Side No. 1 and the bar on Side No. 4. Advance the bars on Sides No. 6 and 3. Then advance the bars on Sides No. 2 and 5. Finally, advance the load measurement section and make any required corrections in the slide dial indicator readings. Record the readings on the Data Run Sheet and Test Run Graph after each step.

- 5.2.4 Corrections must be made to the slide dial indicator readings to ensure that the load measurement bar is properly located. The correction, taken from the Correction Calibration Curve (Figure A.3.3) must be made to compensate for spring in the transducer and slide assembly systems. (An average force reading of 20% of the 10 scale, 50 lb would require advancement of an extra 0.0024 in. on the slide dials to compensate for the load, based upon the example in Figure A.3.3) A circle should be placed around the slide dial indicator readings on the Data Run Sheets for each correction.
- 5.2.5 After the load limit specified in the Test Plan has been reached, reverse the procedure and take readings for each 0.002 in. decompression step back to the test starting across-the-flats dimension. The Test Run Graph should be plotted for at least the first decompression cycle. Thereafter, decompression on a particular subassembly side can be made in 0.004 in. across-the-flat steps or can be eliminated.

CAUTION

Never exceed the 250-1b load limit because of design limitations of the drive handle threads, transducers and the slide drive systems.

 $\underline{5.2.6}$ With the subassembly in the same orientation, rerun the test at least two more times to be certain of results and reproducibility. If necessary, remove the subassembly from

the test apparatus between test runs to ensure complete relaxation of the pins. In such cases, replace the subassembly in its previous orientation.

During the first run the Test Run Graph should indicate the point of "tight subassembly size." In the following two runs reduce the compression steps to 0.001-in. increments within about 0.002-in. of the tight subassembly size so that the point can be more accurately determined.

Prior to removing the subassembly from the test apparatus, back off all bars 0.010 to 0.015 in. from the setup dimension. Back off the load measurement bar at least 0.030 in.

5.2.7 Next remove the subassembly from the fixture, rotate it 60° clockwise (top view), and reload it. Repeat the procedures described in 5.2.1 through 5.2.6. The subassembly will be 2 in. higher than at the previous orientation.

At least one test run, but preferably two, must be made. The number of test runs required will depend upon how closely test results compare with the first subassembly orientation results.

5.2.8 Repeat step 5.2.7. Thus, three different sides of the subassembly, each 60° apart, will have been tested against the load measurement section (Side No. 1) at the end of this step. A minimum of five test runs, and preferably seven, will have been performed to complete a full compressibility test of a subassembly. If the minimum specified number of test runs are made and the test results are close, perform (with concurrence by the responsible engineer) additional test runs with compression steps of up to 0.004 in. in the low spring constant zone.

If the test curves on the three sides tested show a spread of greater than 0.004 in. at a 20 lb/ft/side load, it is recommended that all six sides be tested at least once. If the spread is greater than 0.006 in., further analysis of the subassembly and test equipment should be performed.

5.2.9 Recheck the Correction Calibration Curve per Section 3.5.3. The curve should be within ±0.0005 in. of the original curve. Record and plot the data for comparisons.

6.0 SUMMARY OF TEST RESULTS

Compare the results of individual test runs. Draw up a summary graph showing the average test curve and the range of curves. Determine discrepancies and take necessary corrective action.

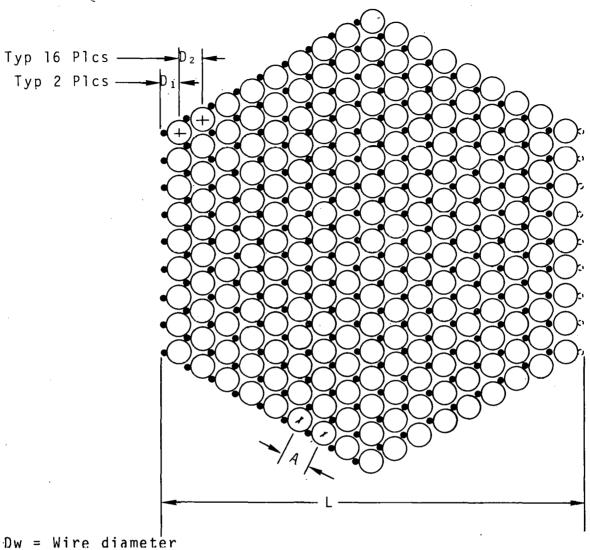
Complete and update logbook and data sheets. Summarize the logbook data into a report which is detailed sufficiently to meet the Test Plan objectives.

APPENDIX B

CALCULATIONS OF

"TIGHT SUBASSEMBLY SIZE"

MARK I AND II SUBASSEMBLIES



Dc = Cladding outside diameter

$$D_1 = Dw + \frac{Dc}{2} \qquad A = Dc + Dw$$

 D_2 = A cos 30° = (Dc + Dw) Cos 30°

L* = Tight subassembly size across flats dimension

= $16 D_2 + 2 D_1$

= 16 (Dc + Dw) Cos 30° + 2 (Dw + $\frac{Dc}{2}$)

FIGURE B.1. Tight Subassembly Size Calculation

^{*}Point at which there are no gaps between wires and fuel pins in the subassembly.

TIGHT SUBASSEMBLY SIZE CALCULATIONS

CCTL Mark II

Dw = 0.05606

Dc = 0.22984

 $D_1 = 0.5606 + 0.11492 = 0.17098$

 $D_2 = (0.05606 + 0.22984) \cos 30^\circ = 0.24760$

L = 16 (0.24760) + 2 (0.17098) = 4.3036 in.

CCTL Mark II

Dw = 0.0298

Dc = 0.2502

 $D_1 = 0.0298 + 0.1251 = 0.1549$

 $D_2 = (0.0298 + 0.2502) (\cos 30^\circ) = 0.24248$

L = 16 (0.2425) + 2 (0.1549) = 4.1898 in.

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