ATTACHMENT 6
TO P-85040

WATTMETER USE TO DETERMINE INSERTED ABSORBER STRING POSITION

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I. ABSTRACT

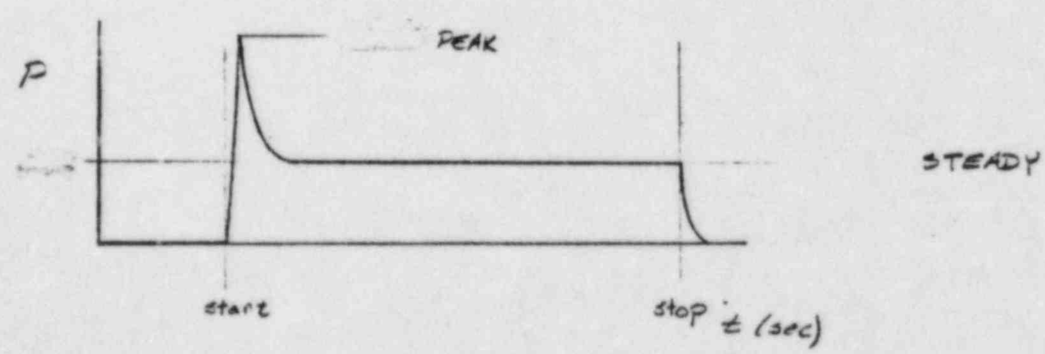
A wattmeter has been used on two occasions to determine "in" rod position and on many other occasions in the recent past to establish conditions such as freedom of motion, high loads, or other abnormal parameters. A request was made in the near past to justify the basis for this test; the following document provides a sound technical basis for the use of this test.

II. BACKGROUND

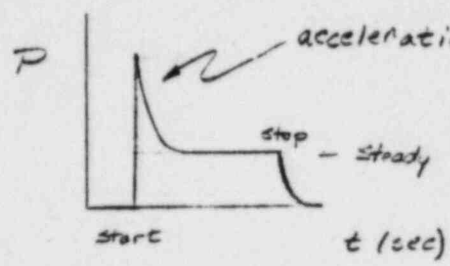
When a control rod is shimmed in either direction, the drive motor is activated which in turn raises or lowers the absorber pair via a gear train and wire rope riding over a drum and guide pulleys to the absorber pair itself. Normal mechanical losses (bearing, gear, pulleys, seal, etc.) in addition to absorber weight represent a load on the motor against which work must be done when the rod pair is raised. In addition, I^2R losses in the motor represent a regular electrical loss. The result of these is that movement of a control rod pair in either direction causes distinctive transients which, to a knowledgable observer, contains a multitude of information that goes far beyond the provided instrumentation (motor overload trip, etc.) and can be used in unusual circumstances to establish condition and location (in some specific cases) of the absorber pair.

III. DESCRIPTION - TRANSIENTS IN/OUT

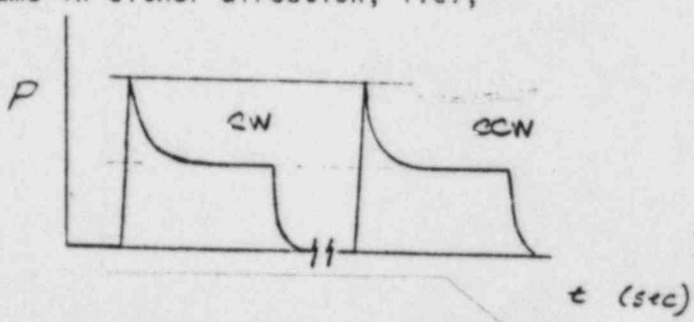
A typical shim wattage transient always includes (in and out) a jump in wattage to a peak as the mechanism accelerates, a reduction to an approximately steady value in 5-10 seconds, and a steady (but slowly varying) wattage for the shim duration as the cable winds or unwinds on the drum sheave. The shim always terminates with a decay in wattage to a zero baseline in 5-10 seconds.



The theory for this behavior is as follows: the shim motor consists of a 4-pole, 3 phase induction motor. A capacitor bank is paralleled across the motor winding phases, but has no effect on torque when the unit is driven from the AC power supply, since the bank's only effect is to change power factors. An induction motor develops torque by the principle of rotor slip; it is assumed that the reader is familiar with this idea. The greater the slip, the larger the induced fields on the rotor, the larger the torque, and the larger the electrical load. Wattage will increase rapidly for a freely-moving mechanism as the transient begins, and the rotor and mechanism acclerate. As the driving torque is developed, the rotor approaches steady speed (corresponding to some steady slip value), and the wattage declines to a steady value.



Note that, for no load on the motor (i.e.; such as during a bench test), a positive power consumption results due to I^2R losses in the stator windings and bearing friction, which should be the same in either direction, i.e.;



This is a useful reference item for the following discussion.

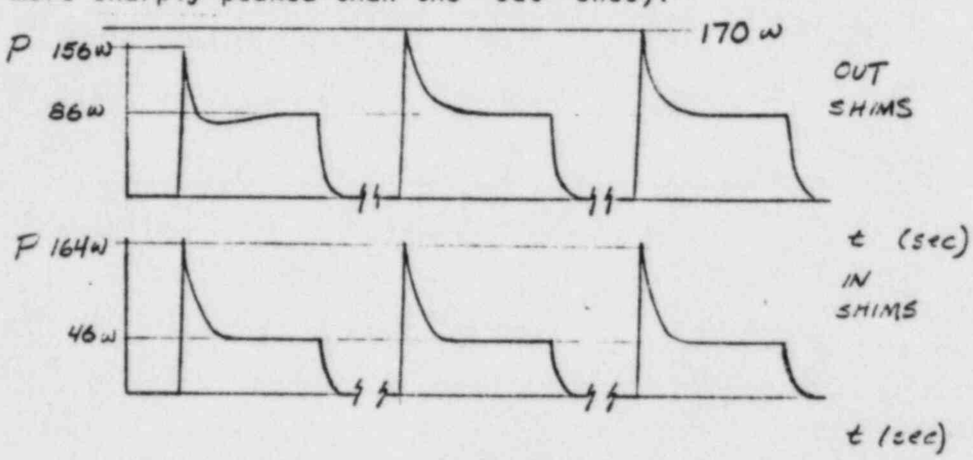
For an outward shim, the opposing weight of the rod pair causes more slip due to the greater rotor load. Hence the rotor-stator field interaction is greater, greater current demand on the stator occurs, and a higher motor load results.

For an inward shim, the assisting weight of the rod pair causes <u>less</u> slip, tending to drive the rod in. (Note that the direction is reversed.) In this case, a reduction in the field interaction occurs, and less motor load results (or equivalently, the operating point is closer to the synchronous speed).

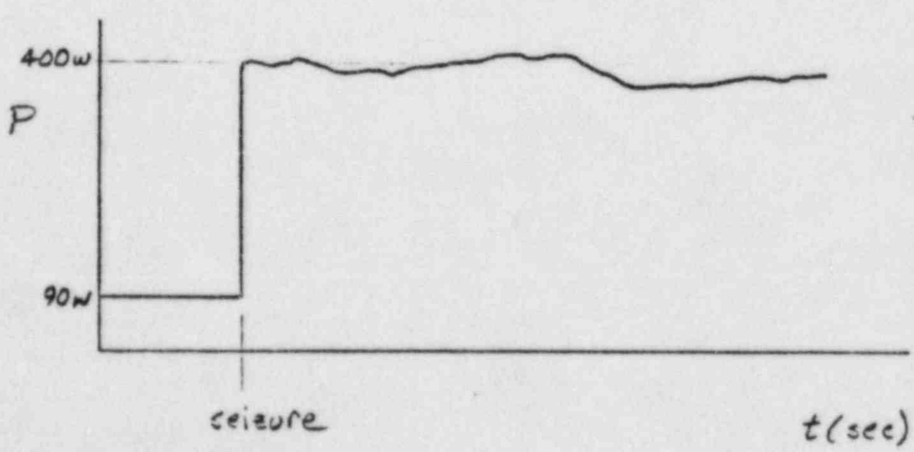
Note that if the motor could be driven externally at exactly synchronous (stator) field speed, no load would result, and any power consumption would represent only the I^2R losses of the stator field.

Also note that physically, one expects a higher load for an outward shim, when the motor must do work against gravity in addition to its own internal losses, than an inward shim, where work is actually done on the motor.

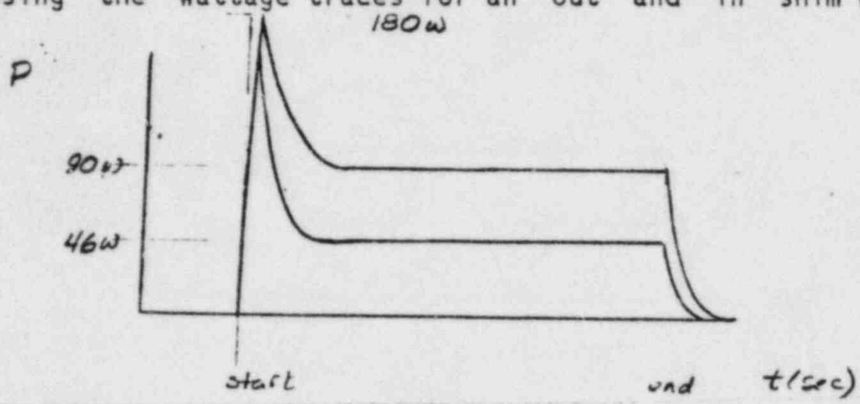
Note also that for an inward shim, again, the mechanism inertia means that instantaneously after the start of the shim, the rotor fields are moving slower than the stator fields. In this case, however, both the gravity torque and the developed torque assist to accelerate the rotor in the "in" direction, so that the transient duration is shorter (i.e.; the "in" shims tend to be more sharply peaked than the "out" ones).



Any sort of impeded mechanism motion shows up as extreme changes in power consumption due to the dramatic slip changes that occur. To some extent, elasticity of the wire rope may mitigate these, however, they are still obvious should any sudden rod pair motions occur.



Superimposing the wattage traces for an "out" and "in" shim we have



Average of nominal in/out steady values;

$\frac{90 + 46}{2} = \frac{136}{2}$ watts or 68 watts.

The work done raising the control rods, neglecting I^2R losses, and neglecting any frictional load (from viscous drag on the absorber pair, drag in the graphite/guide tube channels, and gear train losses), should be less than 90 watts. The following check, assuming no frictional loss in the mechanism confirms this.

Nominal speed 1.05 in/sec $\left(\frac{190 \text{ in}}{180 \text{ sec}} \right)$

$$P = FV \text{ (Physics)}$$

Where F = weight of 2 rods = 240 lbf
and V = 1.05 in/sec

$$P = (240 \text{ lbf}) \quad 1.05 \text{ in/sec} \quad \frac{1}{12} \quad \frac{\text{ft}}{\text{in}}$$

$$= 21.0 \text{ lbf ft/sec} \quad 1.3558 \quad \frac{\text{watt}}{\text{lbf ft/sec}}$$

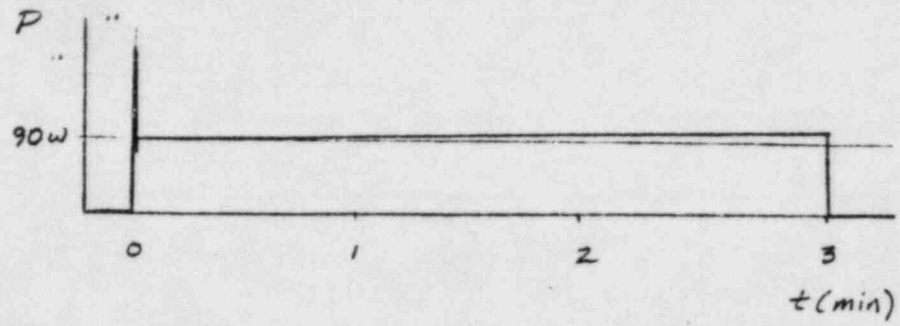
$$= 28.5 \text{ watts}$$

Hence 90 - 29 = 61 watts represent the nominal electrical and mechanical losses in the system. For a mechanical transmission efficiency of 90% per mesh, and a motor efficiency of 80% (both nominal values for similar equipment), the expected out shim power would be

$$\frac{28.5}{0.8 \ (0.9)^4} \text{ watts} = 54.3 \text{ watts.}$$

This compares with an observed range of steady values varying from 80 to 110 watts from all testing, for outward shims.

Finally, note that over a 190 inch rod pull (insertion), the cable drum will wind (unwind), starting from (ending at) the fully inserted position. At this position, the cable drum is completely unwound, i.e.; the rod pair hangs free from the anchor pins.



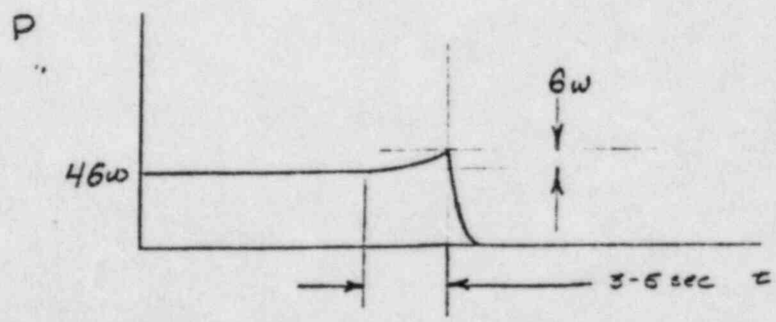
Instantaneously, a shim, since the drum is not wound, does no work against the rod pair weight; i.e., until the drum reaches one-quarter turn, the motor is not working <u>fully</u> against the weight of the rods, as the moment load has not completely developed. The distance travelled by the rods is

$$d = \frac{C}{4} = \frac{2\pi r}{4} = \frac{2\pi(6\text{ in})}{4} = 9.42 \text{ inches, and}$$

$$t = \frac{9.42\text{ inches}}{1.05\text{ in/sec}} \approx 9 \text{ seconds.}$$

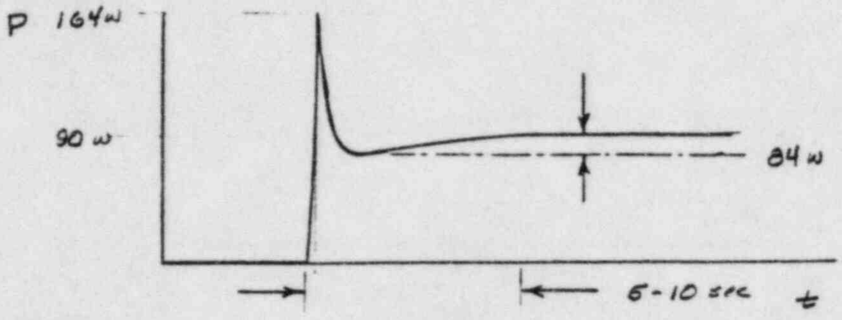
The actual moment load increase functional form is probably a sine-type relation, based on drum rotation.

For the last 5 seconds on an "in" shim, or the first 5 seconds on an "out" shim, a change in the steady wattage value should be seen; this is the observation. All "in" shims terminate with the following:



Note that normally, as the full "in" position is reached, the power to the motor is cut off as the "in" limit switch is activated.

An "out" shim is not so simple, as the initial peak transient must occur. Nonetheless, the same behavior is observed here. The transient peak decays to a value below the steady value and then recovers.



These transient characteristics are unique to the fully inserted position. Many normal rod shim wattage traces have been reviewed and the pattern is entirely consistent.

Finally, note that the direction of drum rotation is irrelevant. If the motor could be driven in beyond the "in" limit switch cutoff position, the rod pair would be raised as the mechanism wound around the drum in the reverse direction. In this case, an "in" shim transient should appear as an "out", and vice versa.

It is on these observations that the wattage verification of rod position incorporated in TSP-30 (proposed) is based.

IV. TSP-30 LOGIC

Objectives

First, the test must verify freedom of rod motion. Second, it must establish position for rods as being in (not just cam drum or equivalent pulley position). Third, it should establish that both rods are supported on the mechanism, if possible (actually, this is only "nice to have").

The wattage test establishes freedom of gear train motion obviously; impeded motion or locked rotor conditions are easy to identify. Rod motion is determined by observing correct nominal values for in/out shims, with the magnitude of the out wattage in excess of 78 watts, (if, in fact, both strings are supported). A steady value of less than 68 watts should be taken as evidence that one rod is not supported, particularly in conjunction with slack cable indication.

Background

TSP-30, Evaluation of Shim Motor Wattage Characteristics, is the culmination of an extensive review of all applications of wattmeter testing performed in the past, particularly that done under T-214, Wattmeter Testing. As a result of an intense examination, a number of clarifications and conclusions can be made.

Refer to Attachments 1-4. These represent a summary of measurements of data on shim transients collected under T-214 in two general time periods. The first was post-third refueling, from about March 11, 1984 to April 15, 1984; the second was post June 23, 1984 Failure-to-scram Event, collected June 23, 1984 to June 25, 1984. There remains additional data collected from July 1, 1984 through November 1, 1984 which was taken on mechanisms in the Hot Service Facility, primarily, and has not been extensively evaluated. It appears, from preliminary review, to be completely consistent with the other data, very similar to that collected in the March 11, 1984 to April 15, 1984 time period.

Results

Evaluation of the data revealed the following qualitative and quantitative results.

1. Normal in/out shims always start with transient peaks occurring over a range from 140 to 200 watts. These decay to a steady value over about 2-4 divisions on the strip chart, where each division is about 2.5 seconds long.

2. "Out" shim transient peaks are higher than "in" shim ones, being about 160-190 watts versus 144-160 watts for "in" shim peaks. On any given CRDDA shim motor, these peaks are distinctive, with a nominal 16-24 watt difference.

3. The rate of decay of "in" shim transient peaks is similar to that of "out" shim peaks, with the exception of the first outward shim from the inserted position.

4. For a continuous shim in the "out" direction from 0 to 192 inches, a very slight wattage increase is seen, of about 6 watts; the nominal steady wattage observed is 90 watts with a range of 80 to 110 watts observed.

5. For a continuous shim in the "in" direction from 192 to 0 inches, a very slight wattage decrease is observed, of about 6 watts; the nominal steady wattage observed is 46 watts, with a range of 30-64 watts observed.

6. An "out" shim transient starting at the fully inserted position is distinctly different from any other "out" shim transient. Two aspects of the transient are different - the peak wattage value and the rate of decay. In almost all cases the rate of the transient decay is so much faster that a pronounced "dip" in wattage below the final steady-state value is observed, due to the winding of the drum sheave phenomena; in every case, the decay to the steady value is significantly faster.

7. An "in" shim transient terminating at the fully inserted position exhibits a distinct rise in steady wattage value as the drum sheave unwraps not observed at any other location.

8. Even on mechanisms with poor wattmeter traces, the above behavior is distinct from other transients since the results can be repeated (i.e., spontaneous variations in the wattage record of a poor rod are not duplicatable).

9. A mechanism with only one absorber pair supported will have an "out" steady wattage of about 60 watts, based on Instrumented Control Rod Drive (ICRD) data.

10. Rotor seizure or other erratic mechanism behavior is indicated by erratic wattage recordings exhibiting sudden variations in wattage while shimming.

11. A periodic oscillation of about 4 watts magnitude is commonly seen on "in" shims. This has no significance with regard to mechanism performance.

12. Variations in voltage at the MCC can have a significant effect on the level of all values observed. For effective test results, voltages should be at 105 nominal phase-to-ground RMS volts.

13. Although T-214 did not have provision for voltage measurement and control, cursory examination of applied voltage during drive, performed under T-227 periodically, indicated the nominal phase-to-ground RMS voltage to be close to 105 volts. However, the failure to monitor and record voltage during test presents a significant limitation to data interpretation, except where results are "normalized".

14. When driving the mechanism in beyond the "in" limit, a change in transient behavior does occur; continued shimming in the "in" direction exhibits characteristics of an "out" shim, while shimming out exhibits characteristics of an "in" shim (while the mechanism is still beyond the normal inserted position.).

Operations and Maintenance (O&M) Manual and FSAR

References to shim motor wattage are made in the O&M Manual and FSAR, as indicated on Attachments 14 and 15.

No steady wattage outside the 80-110 watts for outward shims of normal rods has been observed, although that referenced by the O&M Manual is 72 watts. This might be consistent with references to an 18 watt increase being required to cause failure to scram, although there is another reference to 60 watts as the value at which failure to scram is possible (steady out wattage), at 105 volts, which is clearly inconsistent. Operational measurements, indicated nominal values of 90 watts, with the lowest values being 80 watts on a normally configured CRDOA. It must be emphasized that all measurements collected were done without voltage monitoring or control, hence were subject to wide variation.

The FSAR also references 72 watts for normal outward shims, and 90 watts as the steady outward shim wattage beyond which scram capability cannot be assured.

The manner in which a wattage device is hooked up can affect the output. The Fort St. Vrain devices have been carefully checked to verify that they are correctly installed and providing correct output values.

Procedure Logic

Technical Services Procedure (TSP-30) allows measurement of wattage for monitoring purposes, as done in the past, with a clear guide for interpreting the results. This can be used to establish freedom of motion, estimate position from a known position, and verify cable weight. These functions are useful for monitoring purposes during maintenance, trending, and monitoring performance in the PCRV under various operating conditions.

With regard to rod "in" position verification, TSP-30 uses a three-step approach which starts with the most easily identifiable (and obtainable) indication of rod full-insertion, progressing to a second more detailed evaluation if the requirements for the first evaluation are not met, and proceeds to a final, definitive test and evaluation if the first two simpler evaluations cannot meet the test basis requirements. Each step involves repeated step performance so that postulated data collection irregularities should have an almost trivial chance of affecting the conclusion. Note that in the volumes of data reviewed, no da . has been observed that would indicate invalidation of these tests.

Because of the repetition requirements, it is possible that a given test performance would not meet the requirements for concluding the rod pair was inserted, even though a preponderance of data indicated that it was. Failure to reach the requirements for certifying insertion does not mean that the rod is <u>not</u> inserted or that additional testing may not be done. In fact, the best approach to the test would be to perform the test, and if there was very marginal indication of insertion based on that step approach, continue on to the next, stronger version of the test. (If the results looked very good except that one data point was not distinct, repetition of that step should allow conclusive results).

Two major points should be made with regard to criticism voiced on these tests in the past. First, the acceptance criteria are now spelled out formally in terms of numerical values and guidelines based on data collected under T-214 on all CRDOAs. There are margins included here that in many instances would invalidate position conclusion from data runs on rods that were known inserted at the time of collection (under T-214). Most data runs would however, allow the correct conclusion without repetition of that test step. Secondly, each test sequence repeats the sequence.

This provides additional assurance that electrical system variations will not yield any transient which could be incorrectly taken to indicate inserted condition. In addition, note that all results are normalized, and absolute levels not used for acceptance criteria, again minimizing any effects of electrical system variations.

For the scrammed condition, for freely-running rod pairs, the rods will be bottomed out. Each test sequence starts from this condition (scrammed), so that presumably the rods are bottomed.

The first test approach merely shims the rod pair "out", then "in", repeating twice, and looks for the dip in wattage on the "out" shim (after the peak) and the rise in wattage at the end of the "in" shim. If these location indicators are observed (within the numerical limits specified), the rods are considered "in".

This second test is based on results observed consistently under depressurized/cooled-down conditions seen in T-214. Its one weakness is that the initial dip is not quite so pronounced under other conditions, so that the requirements might not be met if the test were desired to be used under other conditions. Hence the second test.

This test consists of evaluating the inserted condition again based on shimming "out" from the "in" position, but using the combination of wattage peaks and decay times to discern the difference between the first "out" shim and the subsequent "out" shim characteristics in the sequence of three shims. Again, these two aspects of behavior are easy to discern, and the test, although more complicated to evaluate, is still straightforward with respect to data collection. The possibility occurs, however, that the results will not allow a definite conclusion due to data spread, poor test conditions, or otherwise.

The final test, and most definitive, is the worst to actually perform because it will almost certainly break the multijaws coupling, hence should only be used on a damaged mechanism with a damaged multijaws coupling (no analog/digital indication or inconsistent indication compared to in/out limit switches), with no "in" limit indication. This test involves scramming to establish "in" position (presumably), and then performing an "out"/"in" shim pair, which should approximately return the rod pair to its original "in" position, to establish reference shim values, for normal shims. An "in"/"out" sequence is then performed, which should drive the drum sheave beyond its normal limit, raising the rod pair on the drum in the reverse direction. Hence the characteristic is reversed. The "in" shim is actually lifting the rod pair, while the "out" shim is lowering it. By observing this reversal "in" shim behavior, which is easily discernable so long as the drum wraps to a quarter turn (to develop the moment arm, where the wattage values are nominally 90 watts to raise and 44 watts to lower), the rod pair position is absolutely determined. Again, the sequence is repeated to confirm the behavior.

Finally, the question of the condition of the absorber pair, supported or not, can be addressed in part using data collected from an ICRD (only one supported rod). The nominal wattage observed here was 60 watts for an "out" shim, compared to 90 watts for a normally configured rod (range 80-110 watts for "out" shims). This suggests a limit of between 60 and 80 watts to determine the normal condition with both strings supported. In conjunction with trending, any sudden reduction in nominal steady "out" wattage could probably be used to confirm slack cable indication. A review of the slack cable shimming on Region 7 CRDOA SN 25 done July 20, 1984 indicated a steady wattage value of 76 watts (the same CRDOA, SN 25, exhibited 88 watts on March 13, 1984 and 86 watts on June 25, 1984 for nominal out shim steady wattage), while installed in Region 14).

V. CONCLUSION

The CRDOA wattage test is viable for monitoring motor, train, and rod condition, can extract substantial information under a variety of conditions, and can be used to establish rod pair inserted position. Additional testing should be done under more controlled conditions to confirm results obtained thus far and determine data spreads. Trending of this information should continue to monitor performance. Apparent discrepancies between FSV data and the FSAR and O&M Manual should be resolved and corrected.

Examination of a digital or other wattrecording device to increase the sensitivity of the measurements should be considered, although may not be necessary if voltage variation is found to be the factor limiting test sensitivity. The test is entirely normalized with respect to test values so that absolute levels are not important.

Attachments 1-15

List of Attachments

1. Control Rod Drive and Orificing Assembly

   - Installed in PCRV, rod pair inserted

2. Control Rod Drive Mechanism

   - Shim motor/brake assembly
   - Gear train
   - Cable drum
   - Guide pulleys
   - Slack cable assembly
   - Indication pots/switches

3. Shim Motor/Brake Assembly

Wattmeter Chart Data

Two general time periods for data collection occurred:
Data I - March 11, 1984 - April 10, 1984
Data II - June 23, 1984 - June 25, 1984

All following references to I and II refer to two sets of wattmeter data, each generally consisting of summary data for each of 37 CRDOAs (as available) in the indicated Region.

4. Out Shims Data I

5. Out Shims Data II

   - Summaries of key data values for CRDOAs for outward shim data

6. Out Shims Analysis I

7. Out Shims Analysis II

   - Summaries of key differences used to support position verification by out shim data.

8. In Shims Data/Analysis I

9. In Shims Data/Analysis II

   - Summaries of key differences used to support position verification by in shim data

10. In Shims Transient Decay Time Analysis II

    - Summaries of decay time data for comparison against "out" decay times

11. Individual CRDOA Shim Sequence Variation Analysis

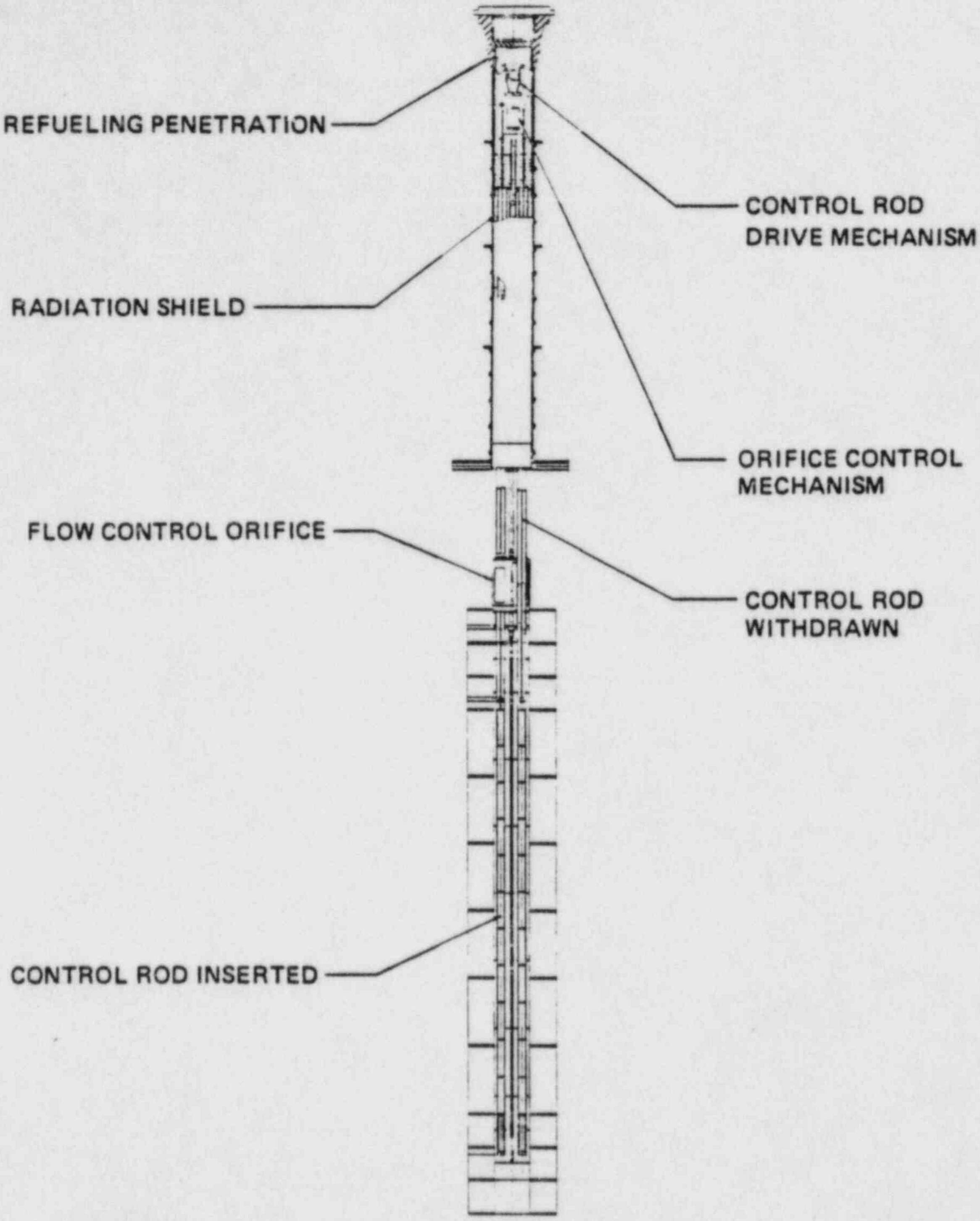
    - Detailed Analysis of discrete values on ten individual CRDOA strip charts that identifies the variation that occurs in key parameters used in the test.

12. Explanation of Wattage Test Evaluation supporting data, items 4-11 above.

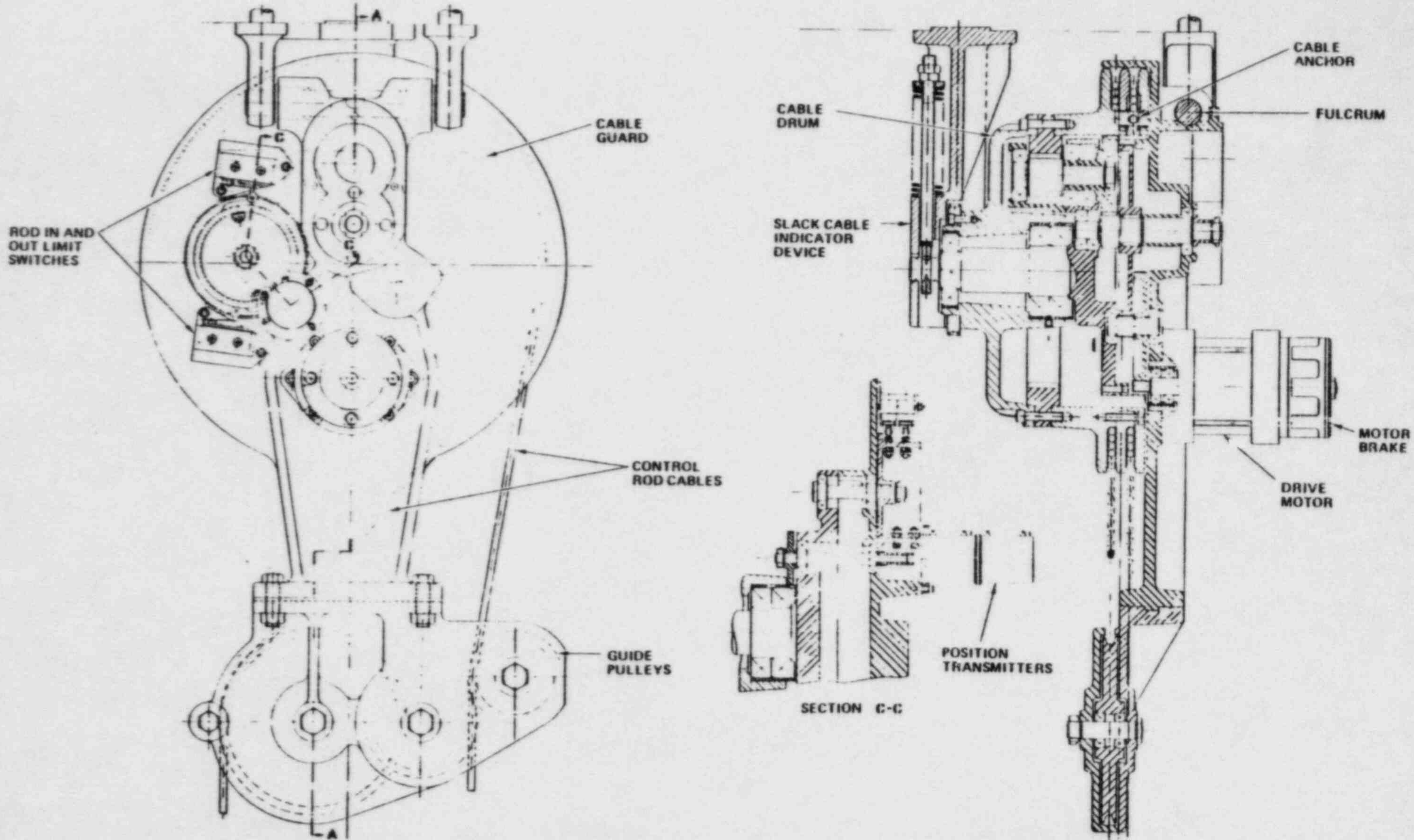
13. TECHNICAL SERVICES PROCEDURE NO. 30, EVALUATION OF SHIM MOTOR WATTAGE CHARACTERISTICS (PROPOSED)

14. O&M Manual Wattage References

15. FSAR Wattage References

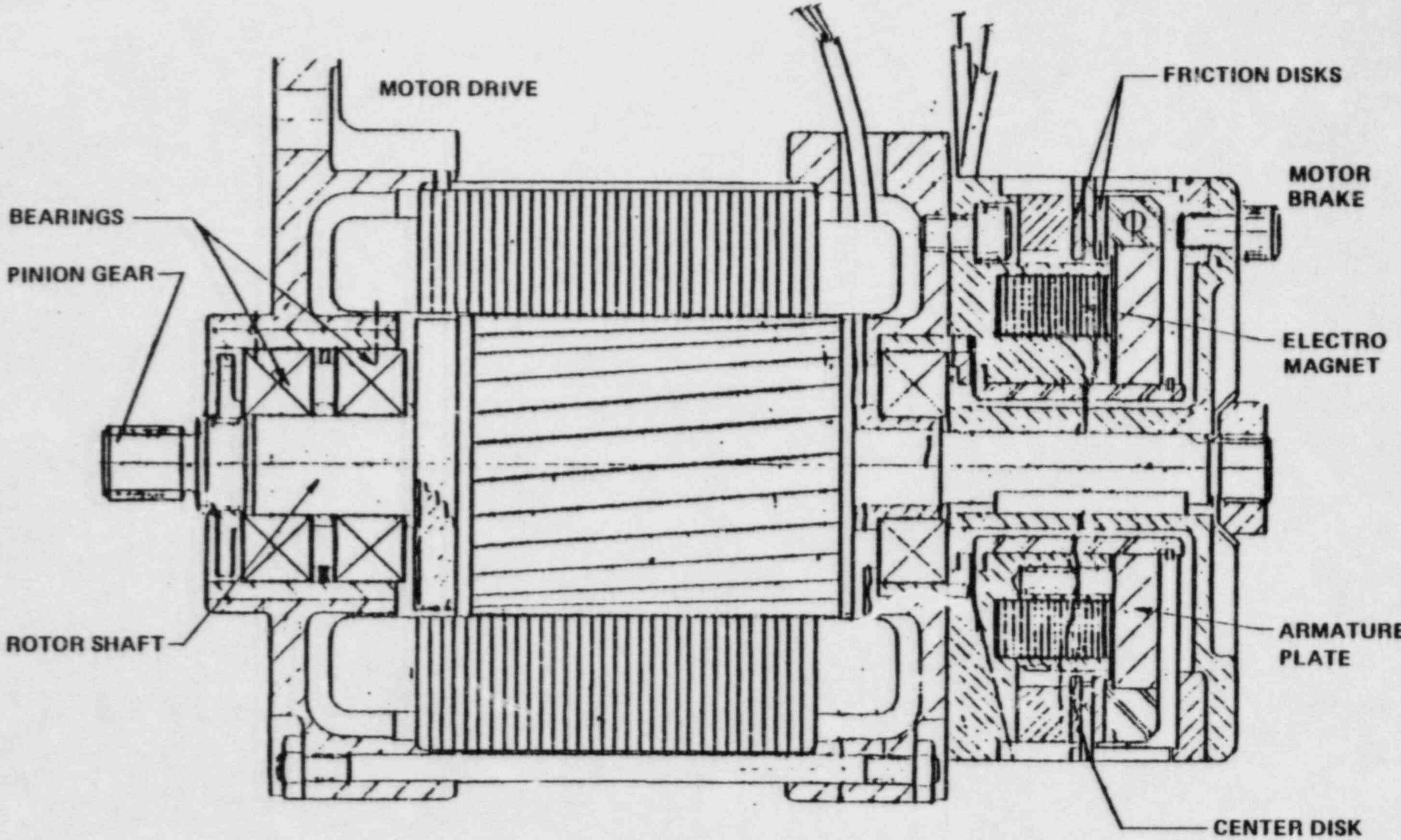


CONTROL ROD DRIVE AND ORIFICE ASSEMBLY



CONTROL ROD DRIVE MECHANISM

Attachment 2



MOTOR AND BRAKE ASSEMBLY

ATTACHMENT 4

OUT SHIMS DATA I

DATE	REGION (SN)	FIRST MINIMUM (X2 WATT)	NOMINAL STEADY VALUE (X2 WATT)	TRANSIENT PEAKS INITIAL VALUE (X2 WATT)	TRANSIENT PEAKS NOMINAL VALUE (X2 WATT)	TRANSIENT PEAKS INITIAL DECAY TIME	TRANSIENT PEAKS NOMINAL DECAY TIME
03/11/84	1(24)	38	44	80	86	0.7	1.5
03/11/84	1(24)	38	43	80	85	0.4	1.5
03/11/84	1(24)	39	42	80	--	0.2	---
03/11/84	1(24)	38	48	80	--	0.2	---
03/11/84	1(24)	37	43	77	--	1.2	---
03/11/84	1(24)	38	42	77	--	0.8	---
03/11/84	1(24)	37	44	78	--	0.8	---
	Mean:	37.86	43.71	78.86	85.5	*	*
--------	2(3)	56	56	82	92	1.0	3.5
03/23/84	3(37)	50	51	80	90	1.0	3.0
03/28/84	4(31)	46	50	80	85	1.2	3.0
03/13/84	5(10)	34	40	80	85	0.7	1.5
03/13/84	6(29)	37	44	80	89	0.7	2.0
--------	7(18)	39	42	80	86	0.7	1.5
03/28/84	8(38)	47	50	82	90	1.2	1.5
03/28/84	9(26)	50	52	84	95	0.8	2.7
03/28/84	10(14)	43	50	84	95	1.5	1.9
03/28/84	11(30)	47	50	83	95	1.2	2.0
04/09/84	12(36)	52	54	83	90	0.8	2.5
04/09/84	13(16)	47	50	80	87	1.6	2.5
03/13/84	14(25)	36	44	80	89	1.0	1.7
--------	15(12)	40	48	80	85	0.9	1.6
--------	16(33)	39	46	80	87	1.0	1.2
--------	17(41)	38	45	78	88	0.8	1.3
--------	18(40)	43	48	80	87	1.0	1.0
--------	19(13)	47	50	85	90	1.3	1.9
04/09/84	20(32)	42	50	81	90	1.0	2.1
04/09/84	21(28)	--	50	82	90	---	2.0
04/09/84	22(5)	46	50	78	88	1.2	2.0
04/09/84	23(39)	47	50	85	91	1.4	1.6

-- Data Not Available.
* No mean or standard data.

Notes: 1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 4

OUT SHIMS DATA I

DATE	REGION (SN)	FIRST MINIMUM (X2 WATT)	NOMINAL STEADY VALUE (X2 WATT)	TRANSIENT PEAKS			
				INITIAL VALUE (X2 WATT)	NOMINAL VALUE (X2 WATT)	INITIAL DECAY TIME	NOMINAL DECAY TIME
04/10/84	24(23)	48	54	--	89	1.2	2.0
04/10/84	25(7)	45	54	82	90	1.1	1.3
04/10/84	26(1)	46	50	83	90	1.6	1.7
04/10/84	27(2)	45	53	81	90	1.2	2.0
--------	28(44)	44	48	74	80	1.1	1.5
--------	29(35)	43	47	83	89	1.2	1.4
--------	30(11)	43	43	77	87	0.7	1.1
--------	31(17)	40	45	79	87	1.2	1.4
--------	32(15)	37	45	80	88	0.9	1.3
--------	33(34)	42	46	81	88	1.3	1.3
--------	34(22)	37	45	80	86	0.9	1.4
--------	35(21)	38	45	80	86	0.8	1.4
--------	36(8)	Not performed due to motor failure.					
04/10/84	37(4)	50	54	84	94	1.2	2.0
	Mean:	43.48	48.41	80.85	88.71	*	*
	Standard:	5.13	3.87	2.32	3.14	*	*

-- Data Not Available.
* No mean or standard data.

Notes: 1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 5

OUT SHIMS DATA II

DATE	REGION (SN)	FIRST MINIMUM (X2 WATT)	NOMINAL STEADY VALUE (X2 WATT)	TRANSIENT PEAKS			
				INITIAL VALUE (X2 WATT)	NOMINAL VALUE (X2 WATT)	INITIAL DECAY TIME	NOMINAL DECAY TIME
06/25/84	1(6)	42	45	74	82	1.0	3.5
06/23/84	2(3)	48	53	80	95	1.6	3.0
06/23/84	3(37)	47	49	75	82	1.4	4.0
06/23/84	4(31)	43	47	74	87	1.5	4.0
06/25/84	5(10)	40	42	74	80	1.5	4.0
06/25/84	6(29)	44	46	74	84	1.0	4.0
06/25/84	7(18)	40	45	71	80	1.3	4.0
06/23/84	8(38)	42	45	74	88	1.6	4.0
06/23/84	9(26)	50	50	83	88	---	3.0
06/23/84	10(14)	46	48	80	88	1.6	3.0
06/23/84	11(30)	44	45	77	84	2.0	3.5
--------	12(42)	47	50	80	87	1.3	2.5
06/23/84	13(16)	43	44	75	81	1.7	4.0
06/25/84	14(25)	42	43	72	81	1.1	4.0
06/25/84	15(12)	47	48	75	81	0.9	2.5
06/23/84	16(33)	47	49	77	84	0.9	2.7
06/25/84	17(41)	47	49	75	85	1.1	4.0
06/25/84	18(40)	46	48	73	83	1.4	5.0
06/23/84	19(13)	44	45	73	75	---	4.0
06/23/84	20(32)	43	45	77	87	1.4	4.0
06/23/84	21(28)	48	49	78	88	1.3	3.4
06/23/84	22(5)	42	45	75	82	1.6	3.0
06/23/84	23(39)	41	44	77	85	1.3	3.0
06/23/84	24(23)	52	52	77	87	1.5	---
06/23/84	25(7)	49	49	77	89	1.3	2.3
06/23/84	26(1)	48	50	80	90	2.0	3.0
06/23/84	27(2)	46	47	78	85	1.3	4.0
06/25/84	28(44)	43	45	72	81	1.0	3.0
06/25/84	29(35)	47	48	77	85	1.4	3.5
06/25/84	30(11)	42	43	74	81	1.0	3.5
06/25/84	31(17)	44	45	74	82	1.2	3.6
06/25/84	32(15)	46	46	76	84	2.5	4.5
06/23/84	33(34)	44	44	74	84	1.2	2.8

-- Data Not Available.
* No mean or standard data.

Notes: 1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 5

OUT SHIMS DATA II

DATE	REGION (SN)	FIRST MINIMUM (X2 WATT)	NOMINAL STEADY VALUE (X2 WATT)	TRANSIENT PEAKS INITIAL VALUE (X2 WATT)	TRANSIENT PEAKS NOMINAL VALUE (X2 WATT)	TRANSIENT PEAKS INITIAL DECAY TIME	TRANSIENT PEAKS NOMINAL DECAY TIME
--------	34(22)	43	44	75	82	1.0	2.0
06/25/84	35(21)	42	45	72	81	1.1	2.3
06/25/84	36(8)	42	45	74	83	1.3	3.5
06/23/84	37(4)	44	48	78	89	1.5	2.3
	Mean:	44.73	46.62	75.70	84.32	*	*
	Standard:	2.87	2.62	2.70	3.71	*	*

-- Data Not Available.
* No mean or standard data.

Notes: 1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 6

OUT SHIMS ANALYSIS I

DATE	REGION (SN)	DIFFERENCE, NOMINAL AVERAGE - FIRST MIN		DIFFERENCE, NOMINAL PEAK - FIRST PEAK		DIFFERENCE, NOMINAL DECAY - FIRST DECAY	
		(X2 WATT)	(%)	(X2 WATT)	(%)	(TIME)	(%)
--------	1(24)	6	14	6	7	0.8	53
--------	1(24)	5	12	5	6	1.1	73
03/11/84	1(24)	3	7	-	-	---	--
03/11/84	1(24)	10	21	-	-	---	--
03/11/84	1(24)	6	14	-	-	---	--
03/11/84	1(24)	4	10	-	-	---	--
03/11/84	1(24)	7	16	-	-	---	--
	Mean:	5.86	13.43	5.5	6.50	*	*
--------	2(3)	0	0	10	11	2.5	71
03/23/84	3(37)	1	2	10	11	2.0	67
03/28/84	4(31)	4	8	5	6	1.8	60
03/13/84	5(10)	6	15	5	6	0.8	53
03/13/84	6(29)	7	16	9	10	1.3	65
--------	7(18)	3	7	6	7	0.8	53
03/28/84	8(38)	3	6	8	9	0.3	20
03/28/84	9(26)	2	4	11	12	1.9	70
03/28/84	10(14)	7	14	11	12	0.4	21
03/28/84	11(30)	3	6	12	13	0.8	40
04/09/84	12(36)	2	4	7	8	1.7	68
04/09/84	13(16)	3	6	7	8	0.9	36
03/13/84	14(25)	8	18	9	10	0.7	41
--------	15(12)	8	17	5	6	0.7	44
--------	16(33)	7	15	7	8	0.2	17
--------	17(41)	7	16	10	11	0.5	38
--------	18(40)	5	10	7	8	0.0	0
--------	19(13)	3	6	5	6	0.6	32
04/09/84	20(32)	8	16	9	10	1.1	52
04/09/84	21(28)	-	--	8	9	---	--
04/09/84	22(5)	4	8	10	11	0.8	40
04/09/84	23(39)	3	6	6	7	0.2	13
04/10/84	24(23)	6	11	--	--	0.8	40

-- Data Not Available.
* No mean or standard data.

Notes: 1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 6

OUT SHIMS ANALYSIS I

DATE	REGION (SN)	DIFFERENCE, NOMINAL AVERAGE - FIRST MIN (X2 WATT)	(%)	DIFFERENCE, NOMINAL PEAK - FIRST PEAK (X2 WATT)	(%)	DIFFERENCE, NOMINAL DECAY - FIRST DECAY (TIME)	(%)
04/10/84	25(7)	9	17	8	9	0.2	15
04/10/84	26(1)	4	8	7	8	0.1	6
04/10/84	27(2)	8	15	9	10	0.8	40
--------	28(44)	4	8	6	8	0.4	27
--------	29(35)	4	9	6	7	0.2	14
--------	30(11)	0	0	10	11	0.4	36
--------	31(17)	5	11	8	9	0.2	14
--------	32(15)	8	18	8	9	0.4	31
--------	33(34)	4	9	7	8	0.0	0
--------	34(22)	8	18	6	7	0.5	36
--------	35(21)	7	16	6	7	0.6	43
--------	36(8)	Not collected.					
04/10/84	37(4)	4	7	10	11	0.8	40
	Mean:	4.88	10.30	7.81	8.84	*	*
	Standard:	2.47	5.39	1.98	1.96	*	*

-- Data Not Available.
* No mean or standard data.

Notes: 1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 7

OUT SHIMS ANALYSIS II

DATE	REGION (SN)	DIFFERENCE, NOMINAL AVERAGE - FIRST MIN (X2 WATT)	(%)	DIFFERENCE, NOMINAL PEAK - FIRST PEAK (X2 WATT)	(%)	DIFFERENCE, NOMINAL DECAY - FIRST DECAY (TIME)	(%)
06/25/84	1(6)	3	7	8	10	2.5	71
06/23/84	2(3)	5	9	15	16	1.4	47
06/23/84	3(37)	2	4	7	9	2.6	65
06/23/84	4(31)	4	9	13	15	2.5	63
06/25/84	5(10)	2	5	6	8	2.5	63
06/25/84	6(29)	2	4	10	12	3.0	75
06/25/84	7(18)	5	11	9	11	2.7	68
06/23/84	8(38)	3	7	14	16	2.4	60
06/23/84	9(26)	0	0	5	6	---	--
06/23/84	10(14)	2	4	8	9	1.4	47
06/23/84	11(30)	1	2	7	8	1.5	43
--------	12(42)	3	6	7	8	1.2	48
06/23/84	13(16)	1	2	6	7	2.3	58
06/25/84	14(25)	1	2	9	11	2.9	73
06/25/84	15(12)	1	2	6	7	1.6	64
06/23/84	16(33)	2	4	7	8	1.8	67
06/25/84	17(41)	2	4	10	12	2.9	73
06/25/84	18(40)	2	4	10	12	3.6	72
06/23/84	19(13)	1	2	2	3	---	--
06/23/84	20(32)	2	4	10	11	2.6	65
06/23/84	21(28)	1	2	10	11	2.1	62
06/23/84	22(5)	3	7	7	9	1.4	47
06/23/84	23(39)	3	7	8	9	1.7	57
06/23/84	24(23)	0	0	10	11	---	--
06/23/84	25(7)	0	0	12	13	1.0	43
06/23/84	26(1)	2	4	10	11	1.0	33
06/23/84	27(2)	1	2	7	8	2.7	68
06/25/84	28(44)	2	4	9	11	2.0	67
06/25/84	29(35)	1	2	8	9	2.1	60
06/25/84	30(11)	1	2	7	9	2.5	71
06/25/84	31(17)	1	2	8	10	2.4	67
06/25/84	32(15)	0	0	8	10	2.0	44
06/23/84	33(34)	0	0	10	12	1.6	57

-- Data Not Available.
* No mean or standard data.

Notes:
1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 7

OUT SHIMS ANALYSIS II

DATE	REGION (SN)	DIFFERENCE, NOMINAL AVERAGE - FIRST MIN (X2 WATT)	(%)	DIFFERENCE, NOMINAL PEAK - FIRST PEAK (X2 WATT)	(%)	DIFFERENCE, NOMINAL DECAY - FIRST DECAY (TIME)	(%)
---------	34(22)	1	2	7	9	1.0	50
06/25/84	35(21)	3	7	9	11	1.2	52
06/25/84	36(8)	3	7	9	11	2.2	63
06/23/84	37(4)	4	8	11	12	0.8	35
	Mean:	1.89	4.00	8.62	10.14	*	*
	Standard:	1.33	2.88	2.49	2.61	*	*

-- Data Not Available.
* No mean or standard data.

Notes: 1. Units of time are in divisions of the strip chart.
2. Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 8

IN SHIMS DATA/ANALYSIS I

DATE	REGION (SN)	NOMINAL STEADY VALUE (X2 WATT)	PEAK AT IN LIMIT (X2 WATT)	DIFFERENCE (X2 WATT)	DIFFERENCE (%)
---------	1(24)	18	22	4	18
---------	1(24)	19	21	2	10
03/11/84	1(24)	20	25	5	20
03/11/84	1(24)	16	20	4	20
	Mean:	18.25	22.0	3.75	17.0
---------	2(3)	22	25	3	12
03/23/84	3(37)	30	34	4	12
03/28/84	4(31)	30	33	3	9
03/13/84	5(10)	15	22	7	32
03/13/84	6(29)	20	27	7	26
---------	7(18)	18	23	5	22
03/28/84	8(38)	32	36	4	11
03/28/84	9(26)	31	34	3	9
03/28/84	10(14)	28	31	3	10
03/28/84	11(30)	27	30	3	10
04/09/84	12(36)	30	33	3	9
04/09/84	13(16)	24	28	4	14
03/13/84	14(25)	19	27	8	30
---------	15(12)	21	25	4	16
---------	16(33)	18	22	4	18
---------	17(41)	20	24	4	17
---------	18(40)	21	24	3	13
---------	19(13)	23	30	7	23
04/09/84	20(32)	26	30	4	13
04/09/84	21(28)	29	31	2	6
04/09/84	22(5)	25	34	9	26
04/09/84	23(39)	24	27	3	11
04/10/84	24(23)	33	34	1	3
04/10/84	25(7)	30	34	4	12
04/10/84	26(1)	25	27	2	7
04/10/84	27(2)	21	24	3	13
---------	28(44)	22	26	4	15
---------	29(35)	22	26	4	15

-- Data Not Available.

Note: Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 8

IN SHIMS DATA/ANALYSIS I

DATE	REGION (SN)	NOMINAL STEADY VALUE (X2 WATT)	PEAK AT IN LIMIT (X2 WATT)	DIFFERENCE (X2 WATT)	DIFFERENCE (%)
---------	30(11)	18	21	3	14
---------	31(17)	20	25	5	20
---------	32(15)	21	26	5	19
---------	33(34)	19	22	3	14
---------	34(22)	16	24	8	33
---------	35(21)	17	20	3	15
---------	36(8)	Data not collected due to faulty motor.			
---------	37(4)	33	36	3	8
	Mean:	23.56	27.69	4.13	15.39
	Standard:	5.21	4.70	1.82	7.20

-- Data Not Available.
Note: Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 9

IN SHIMS DATA/ANALYSIS II

DATE	REGION (SN)	NOMINAL STEADY VALUE (X2 WATT)	PEAK AT IN LIMIT (X2 WATT)	DIFFERENCE (X2 WATT)	DIFFERENCE (%)
06/25/84	1(6)	32	35	3	10
06/23/84	2(3)	39	43	4	10
06/23/84	3(37)	29	34	5	17
06/23/84	4(31)	30	35	5	17
06/25/84	5(10)	22	30	8	36
06/25/84	6(29)	35	38	3	9
06/25/84	7(18)	30	30	0	0
06/23/84	8(38)	26	33	7	27
06/23/84	9(26)	40	42	2	5
06/23/84	10(14)	24	28	4	17
06/23/84	11(30)	24	32	8	33
06/00/84	12(42)	25	30	5	20
06/23/84	13(16)	26	30	4	15
06/25/84	14(25)	29	34	5	17
06/25/84	15(12)	30	32	2	7
06/23/84	16(33)	29	30	1	3
06/25/84	17(41)	30	34	4	13
06/25/84	18(40)	32	35	3	9
06/23/84	19(13)	25	31	6	24
06/23/84	20(32)	28	31	3	11
06/23/84	21(28)	28	33	5	18
06/23/84	22(5)	24	32	8	33
06/23/84	23(39)	25	28	3	12
06/23/84	24(23)	34	35	1	3
06/23/84	25(7)	29	33	4	14
06/23/84	26(1)	28	35	7	20
06/23/84	27(2)	28	33	5	18
06/25/84	28(44)	29	31	2	7
06/25/84	29(35)	30	38	8	27
06/25/84	30(11)	27	31	4	15
06/25/84	31(17)	30	32	2	7
06/25/84	32(15)	31	34	3	10

-- Data Not Available.

Note: Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 9

IN SHIMS DATA/ANALYSIS II

DATE	REGION (SN)	NOMINAL STEADY VALUE (X2 WATT)	PEAK AT IN LIMIT (X2 WATT)	DIFFERENCE (X2 WATT)	DIFFERENCE (%)
06/25/84	33(34)	30	32	2	7
---------	34(22)	No data available.			
06/25/84	35(21)	26	31	5	19
06/25/84	36(8)	29	32	3	10
06/23/84	37(4)	31	34	3	10
	Mean:	29.00	33.08	4.08	14.72
	Standard:	3.86	3.28	2.10	8.70

-- Data Not Available.

Note: Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 10

IN SHIMS TRANSIENT DECAY TIME DATA/ANALYSIS II

DATE	REGION (SN)	TIME TO DECAY
06/25/84	1(6)	3.8
06/23/84	2(3)	2.0
06/23/84	3(37)	2.4
06/23/84	4(31)	2.0
06/25/84	5(10)	2.8
06/25/84	6(29)	3.6
06/25/84	7(18)	4.4
06/23/84	8(38)	3.8
06/23/84	9(26)	1.4
06/23/84	10(14)	3.8
06/23/84	11(30)	2.2
06/00/84	12(42)	3.2
06/23/84	13(16)	4.0
06/25/84	14(25)	3.8
06/25/84	15(12)	1.6
06/23/84	16(33)	1.6
06/25/84	17(41)	2.0
06/25/84	18(40)	3.2
06/23/84	19(13)	2.2
06/23/84	20(32)	3.4
06/23/84	21(28)	1.8
06/23/84	22(5)	2.6
06/23/84	23(39)	2.6
06/23/84	24(23)	1.8
06/23/84	25(7)	2.8
06/23/84	26(1)	2.4
06/23/84	27(2)	4.0
06/25/84	28(44)	4.4
06/25/84	29(35)	4.4
06/25/84	30(11)	4.2
06/25/84	31(17)	2.8
06/25/84	32(15)	2.4
06/23/84	33(34)	1.8
--------	34(22)	1.8

-- Data Not Available.
Note: Units of time are in divisions of the strip chart.

ATTACHMENT 10

IN SHIMS TRANSIENT DECAY TIME DATA/ANALYSIS II

DATE	REGION (SN)	TIME TO DECAY
06/25/84	35(21)	1.8
06/25/84	36(8)	2.0
06/23/84	37(4)	1.6
	Mean:	2.77
	Standard:	0.96

-- Data Not Available.
Note: Units of time are in divisions of the strip chart.

ATTACHMENT 11

INDIVIDUAL CRDOA SHIM SEQUENCE VARIATION ANALYSIS

DATE	REGION/(SN)	OUT SHIM					IN SHIM		
		FIRST PEAK (X2 WATT)	MEAN PEAK* (X2 WATT) (STANDARD DEVIATION)	FIRST DECAY TIME	MEAN DECAY TIME/ (STANDARD DEVIATION)	NO. OF DATA POINTS USED	MEAN PEAK* (X2 WATT) (STANDARD DEVIATION)	MEAN DECAY TIME/ (STANDARD DEVIATION)	NO. OF DATA POINTS USED
08/23/84	HSF/(7)	86.00	92.57 (1.51)	0.4	0.94 (0.10)	7	80.43 (0.53)	0.69 (0.11)	7
08/28/84	HSF/(11)	84.00	94.14 (1.07)	0.2	0.83 (0.08)	7	81.14 (0.38)	1.0 (0.13)	7
09/28/84	HSF/(26)	88.0	97.14 (1.07)	0.4	0.86 (0.10)	7	81.14 (0.69)	0.94 (0.22)	7
08/18/84	HSF/(29)	88.0	96.78 (0.67)	0.2	0.62 (0.16)	9	83.63 (1.51)	0.75 (0.09)	8
03/23/84	3/(37)	80.0	89.47 (1.37)	0.6	1.70 (0.14)	17	79.22 (1.20)	1.36 (0.17)	7
03/28/84	10/(14)	83.0	96.47 (2.21)	0.4	1.27 (0.17)	17	84.14 (1.57)	1.83 (0.36)	7
03/28/84	11/(30	82.0	93.94 (1.14)	0.8	1.40 (0.14)	17	81.14 (0.38)	2.08 (0.38)	7
06/23/84	16/(33)	78.0	87.63 (1.30)	0.6	2.72 (0.81)	8	75.50 (1.77)	1.78 (0.31)	8

*Excludes the first peak.

Note: Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

ATTACHMENT 11

INDIVIDUAL CRDOA SHIM SEQUENCE VARIATION ANALYSIS

DATE	REGION/(SN)	OUT SHIM					IN SHIM		
		FIRST PEAK (X2 WATT)	MEAN PEAK* (X2 WATT) (STANDARD DEVIATION)	FIRST DECAY TIME	MEAN DECAY TIME/ (STANDARD DEVIATION)	NO. OF DATA POINTS USED	MEAN PEAK* (X2 WATT) (STANDARD DEVIATION)	MEAN DECAY TIME/ (STANDARD DEVIATION)	NO. OF DATA POINTS USED
06/25/84	35/(21)	76.0	85.0 (1.0)	0.6	1.98 (0.32)	9	73.75 (1.67)	3.35 (0.58)	8
06/25/84	36/(8)	78.0	87.88 (0.83)	0.6	3.0 (0.15)	8	77.63 (0.74)	2.40 (0.21)	8

*Excludes the first peak.

Note: Wattage values were determined on a 0 - 500 scale where the maximum deflection corresponded to 1000 Watt, hence all values should be multiplied by 2.0.

EXPLANATION OF WATTAGE TEST EVALUATION SUPPORTING DATA

This data was collected on either of (2) Esterline Angus Model A 601C Graphic (recording) Wattmeters, rated at 100 volts and 1000 watts, full scale (3 phase, 3 wire, 60 Hz), serial numbers 182698, 182699, calibrated July 7, 1984, with a guaranteed accuracy of 1% full scale (10w). Precision, as indicated by peak and nominal values reached over many shims at approximately the same drum condition, appears to be about 1 watt. This means, provided voltage conditions are kept constant, the readings can be compared between shims on a given chart, so that very precise conditions can be achieved, which is important for the use of the wattage test done here (Note - variations in voltage over the time required to perform the test will generally not pose a problem, as these are typically slight). All wattage values are recorded assuming a precision of 1 watt. Also note that voltage variations have no effect on the watt recorder's ability to accurately determine wattage; rather, they change the motor operating point so that power consumption, for the same load, will be different. Finally, note that absolute determinations of power in watts, for comparison against FSAR, O&M, and other values, are admittedly a problem because the test did not include voltage data; the proposed procedure corrects this problem. Consequently, these comparisons and any conclusions should be very tentative. Remember the guaranteed accuracy is only ±10w, even if the precision is 1w.

All data values were recorded on a 0-500 scale where 500 corresponded to 1000w. Hence the reading in watts is that recorded times two. Also, the two wattmeters were adjusted for different chart speeds on the slow speed scale, as follows:

SN 182698 (East Rx) 5 sec/minor division
SN 182699 (West Rx) 2.5 sec/minor division

Because the speeds for various charts were different, evaluation of overall mean decay times for reference purposes was intentionally not done. This has no effect on the proposed test, as any given determination of position is done on a single wattrecorder.

Out Shims Data I, II

These list values for minimum wattage during the transient, peak wattage during the transient, and decay time (chart division units) for the two general transient types: (1) those starting at the in limit, and (2) subsequent transients with the drum wrapped. Note that with the drum wrapped, the nominal steady value is the minimum value, since no dip occurs.

Out Shims Analysis I, II

These compute differences, and express these in percent for comparison against test requirements. One observes that in a few instances, actual "in" conditions would not be met by the test requirements, even though limit switch behavior indicated that in fact, the rod pairs were "in".

In Shims Data/Analysis I, II

These list values for steady final wattage for in shims leaving the drum wrapped, and final peak wattage for shims that terminate at the "in" position, as well as the differences and percentage difference.

In Shims Transient Decay Time Data/Analysis II

This has no relevance to the test, but was included to show typical in shim decay time variation, for information.

Individual CRDOA Shim Sequence Variation Analysis

This is the summary of detailed evaluation of shim sequences on individual CRDOAs to determine the variation in nominal values for out peak (drum wrapped), out decay, in peak, and in decay. The purpose is to illustrate the mean and variation in these parameters, to allow comparison against the tested value, to examine the significance of the variation:

First Peak vs. Mean Peak
First Decay vs. Mean Decay

In shim data is again provided for information.

Note that 10 shim sequences from 10 different mechanisms tested on various dates were selected. Selection was random, with the exception that several charts could not be used due to incomplete or multiple shim activations during the transient periods, which required elimination because peak or other values could not be clearly defined. The proposed test also eliminates this possibility by requiring complete repition of the sequence, should this occur.