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ANALYSIS OF SNAP 10A/2 KINETIC BEHAVIOR USING PULSE REACTIVITY EXCITATIONS

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FOLDER Ref. File: Winter Mtg ANS 1965 Analysis of SNAP 10A/2 Kinetic Behavior Using Pulse Reactivity Excitations

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Partially self-limited reactor excursions excited by pulse reactivity insertions inherently yield reactor response which is far more rapid than that obtained from totally self-limited step-excited transients. Because of a need for reactivity feedback information under the conditions of the fast response found in SNAP 10A reactors, pulse reactivity insertion (i.e., reactivity which is rapidly inserted and withdrawn) is used to excite transient tests on the SNAPTRAN-1 reactor. The SNAPTRAN-1 reactor, a cross section of which is seen in the first slide, is a test version of the SNAP 10A reactor and has been modified to accommodate step and pulse reactivity insertions. Two of the four control drums seen here are used to provide step insertions of reactivity by rapid clockwise rotation to the full-in position followed by scram for reactor shutdown. The other two drums provide for pulse insertion by means of continuous rapid counterclockwise rotation of the pulse drums from the minimum reactivity worth position through the maximum worth position (full-in) and on around to the minimum reactivity worth position. It is through use of pulse transients that not only reactor response to large reactivity excitations but also the kinetic nature of the so-called "prompt" reactivity feedback can be studied.

The second slide shows the relative power and energy excursions associated with both a step reactivity insertion and a pulse reactivity insertion. The logarithm of power in watts, linear energy in megawatt-

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seconds, and reactivity in dollars are all plotted using the same time scale in units of milliseconds. The more narrow power excursion resulting from the pulse reactivity excitation can be seen to yield a much steeper slope for energy rise and thus a higher deposition rate than is achievable from the step reactivity excited power excursion. Thus, the pulse excited power excursion can be employed to investigate the time response characteristics of temperature manifested reactivity feedback. More specifically, any heat transfer rates which might influence the instantaneous thermal state of the reactor can best be observed with respect to a very short reactor period by use of pulse transients.

A major difficulty arises, however, when one attempts to analyze pulse excursion data for the presence of reactivity feedback. Instead of observing the inherent self-limiting deviation from the fixed amount of reactivity, as seen in the case of step excited reactor excursions, one must solve for the difference between the continuously changing excitation reactivity and the continuously changing resultant reactivity which is the sum total of both excitation as well as fedback reactivity. If the analyist is to define the input reactivity, he is faced with the formidable task of not only defining very accurately the drum motion as a function of time throughout the power excursion but also of defining very accurately the reactivity worth of the drum as a function of drum position.

The next slide depicts the reactivity as derived from the power excursion data plotted as a function of the concurrent drum position. The reactivity versus drum position plots seen here were normalized to a maximum value at the full-in drum position - that being 0°. Also seen in this slide is the effect of feedback on the deviation in reactivity from the standard no feedback case. The standard technique then for defining the reactivity coefficient of energy effective during a pulse transient relates this observed difference

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in reactivity to the concurrent change in nuclear energy as seen in the next slide.

In addition to this straightforward continuous method of reactivity feedback determination, two other methods are employed which use simple but accurate observations of transient nuclear power phenomena. The first of these two methods relates a change in the drum position at which peak power occurs from two transients having the same reactivity time histories, to the difference in energy that occurs between the two transients. The change in drum position at which peak power occurs represents some change in reactivity and can be related to the associated change or difference in the energy causing the drum position shift. When one plots the sum total of these changes, a well defined trend can be observed as seen in the next slide. If one performs a sufficient number of tests, a high degree of statistical certainty can be obtained.

The second of these two methods, while it yields only one point on the differential of reactivity with respect to energy curve, is very simple and highly accurate. This second method consists essentially of comparing the drum position at which peak power occurs for two transients in which a fixed difference in reactivity as a function of time exists. Since the reactivity swing is fixed, the transient reactivity for a given test, and thus the difference in reactivity for two tests, is adjusted by means of the reactivity level of the reactor at the time of the reactivity pulse insertion. Therefore delayed critical period measurements can be used to assess very accurately the difference between the initial reactivity states for two given tests and thus the fixed difference in reactivity throughout the transient excursion. For ease of control, a single drum was used for the pulse reactivity insertion. The total magnitude of the reactivity swing of a single pulse drum is 2.4 dollars which fortuitously allows insertion of this pulse from a delayed critical state of the reactor and thus simplifies the control

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of the initial power state of the reactor. With this control of the initial reactor power level, the energy release from any transient can easily be controlled. The energy release, in turn, determines the amount of feedback and thus causes the drum position at which peak power occurs to change by the amount appropriate for the fedback reactivity. Using a 20 cents subcritical state of the reactor from which to initiate the 2.4 dollar insertion, an excess reactivity pulse of 2.2 dollars can be impressed on the reactor. By using a very low starting power these tests yield no appreciable energy and are thus free of feedback. By performing many of these tests, the position at which peak power nominally occurs for a 2.2 dollar pulse insertion can be accurately determined. Then by performing several 2.4 dollar tests in which sufficient energy is manifested to feedback 20 cents of reactivity, peak power can be caused to occur at the same drum position as is determined for the 2.2 dollar pulse test.

The next figure shows the results of running several 2.4 dollar tests to determine the precise energy associated with causing peak power to occur at the same drum position as found for the 2.2 dollar pulse test. We now can assign the 20 cents difference in reactivity to that amount of energy found appropriate for this amount of compensation.

While only one value of differential reactivity was used for the tests we performed - that being the 20 cents difference between 2.4 and 2.2 dollars in reactivity - several values could be used to construct the continuous function of differential reactivity with respect to energy. Additionally, once having determined through delayed critical period measurements the precise difference in reactivity to be compensated for, the position at which peak power occurs for a given energy release can be determined very easily by recording both nuclear power and the drum displacement time-history on the

same recorded media as seen in the next slide. Reactivity calibration of the drum need not enter into the determination of feedback using this method. One needs only to find the voltage at which peak power occurs for one condition to know that a certain amount of energy is required to cause a coinciding of peak power occurrance at this same voltage for another reactivity.

The results of using these methods for analyzing pulse transients indicate that elaborate computer treatment and meticulous handling of time-history data is not necessary if one chooses to apply either of the last two methods of analysis and particularly the latter of these two methods. Both methods, while much simpler in operation, have been found to yield results which agree well with the results of step test analysis.

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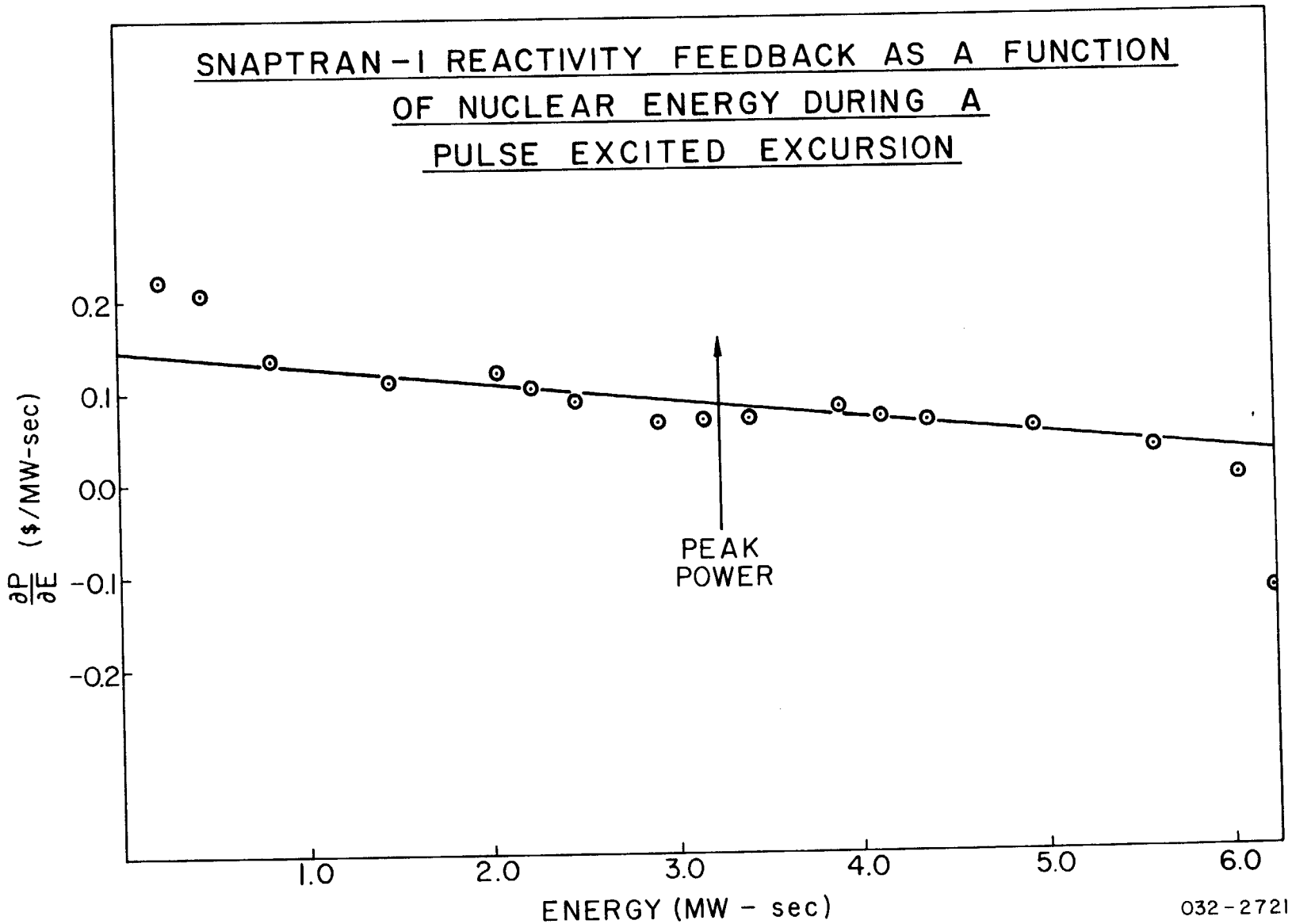
SNAPTRAN-I REACTIVITY FEEDBACK AS A FUNCTION OF NUCLEAR ENERGY DURING A PULSE EXCITED EXCURSION
0.2
0.1
0.0
-0.1
-0.2
∂P/∂E ($/MW-sec)
PEAK POWER
1.0
2.0
3.0
4.0
5.0
6.0
ENERGY (MW - sec)
032-2721

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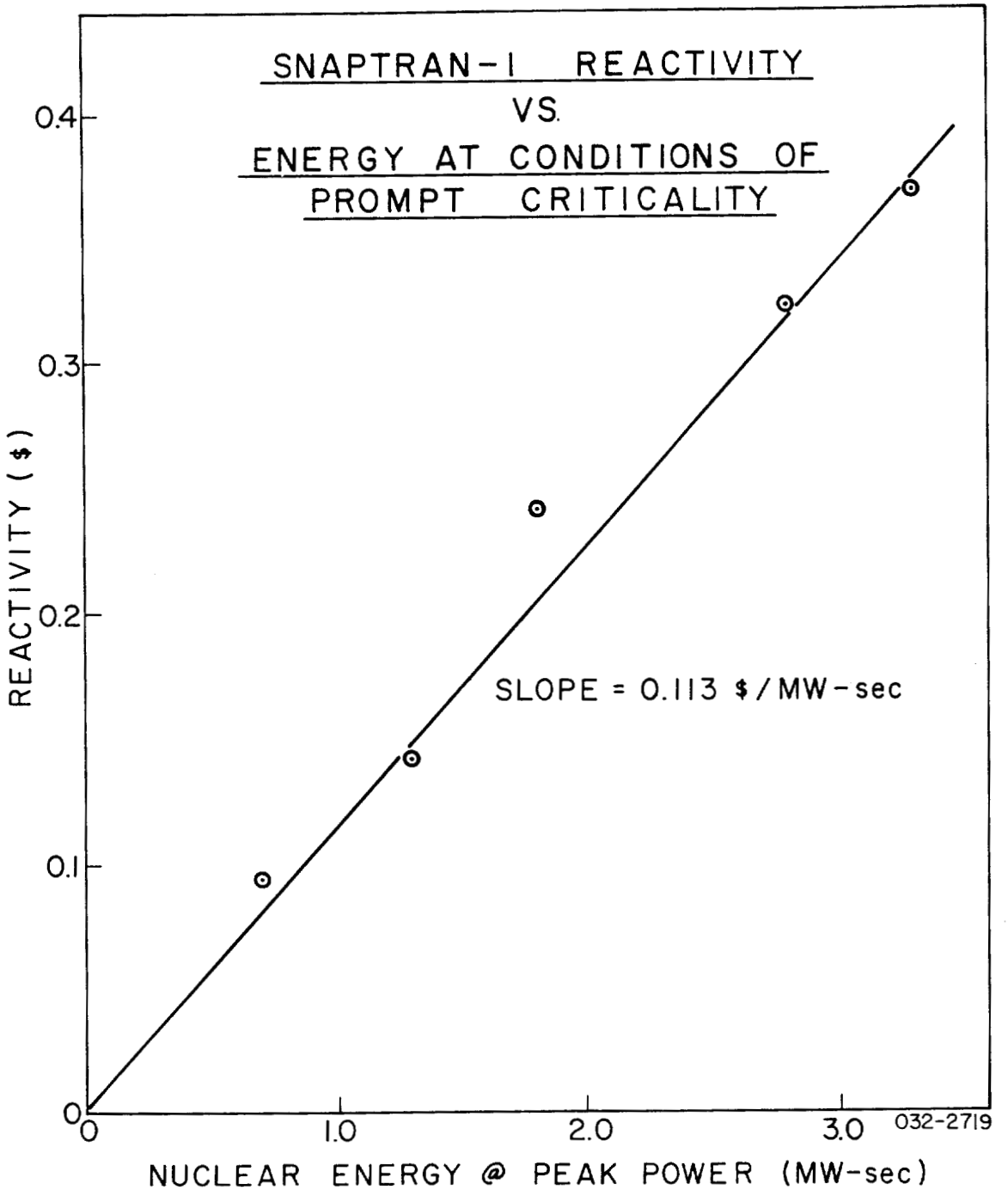
SNAPTRAN-1 REACTIVITY
VS.
ENERGY AT CONDITIONS OF
PROMPT CRITICALITY
SLOPE = 0.113 $/MW-sec
REACTIVITY ($)
0.4
0.3
0.2
0.1
0
0
1.0
2.0
3.0
032-2719
NUCLEAR ENERGY @ PEAK POWER (MW-sec)

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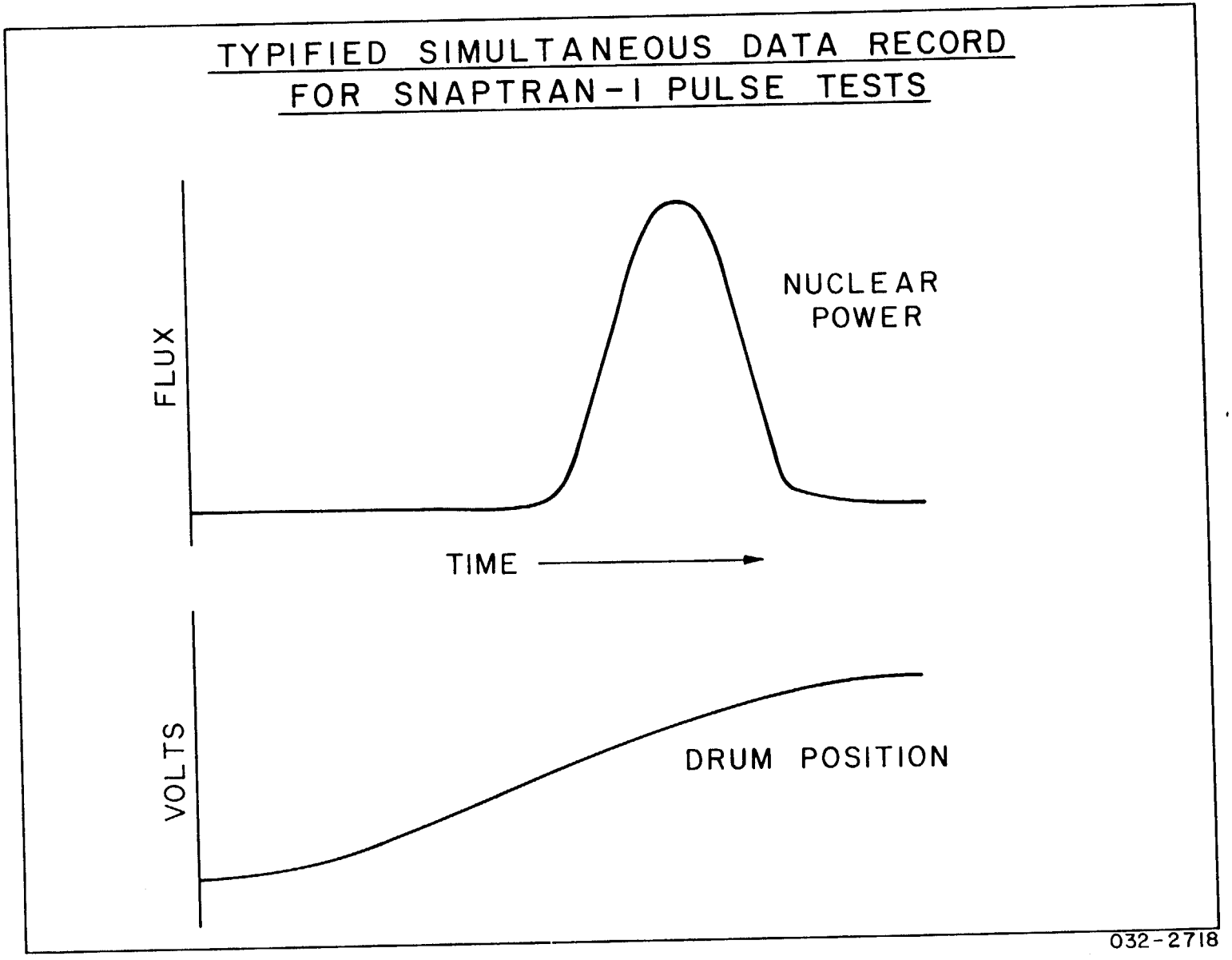
TYPIFIED SIMULTANEOUS DATA RECORD
FOR SNAPTRAN-I PULSE TESTS
FLUX
NUCLEAR
POWER
TIME
VOLTS
DRUM POSITION
032-2718

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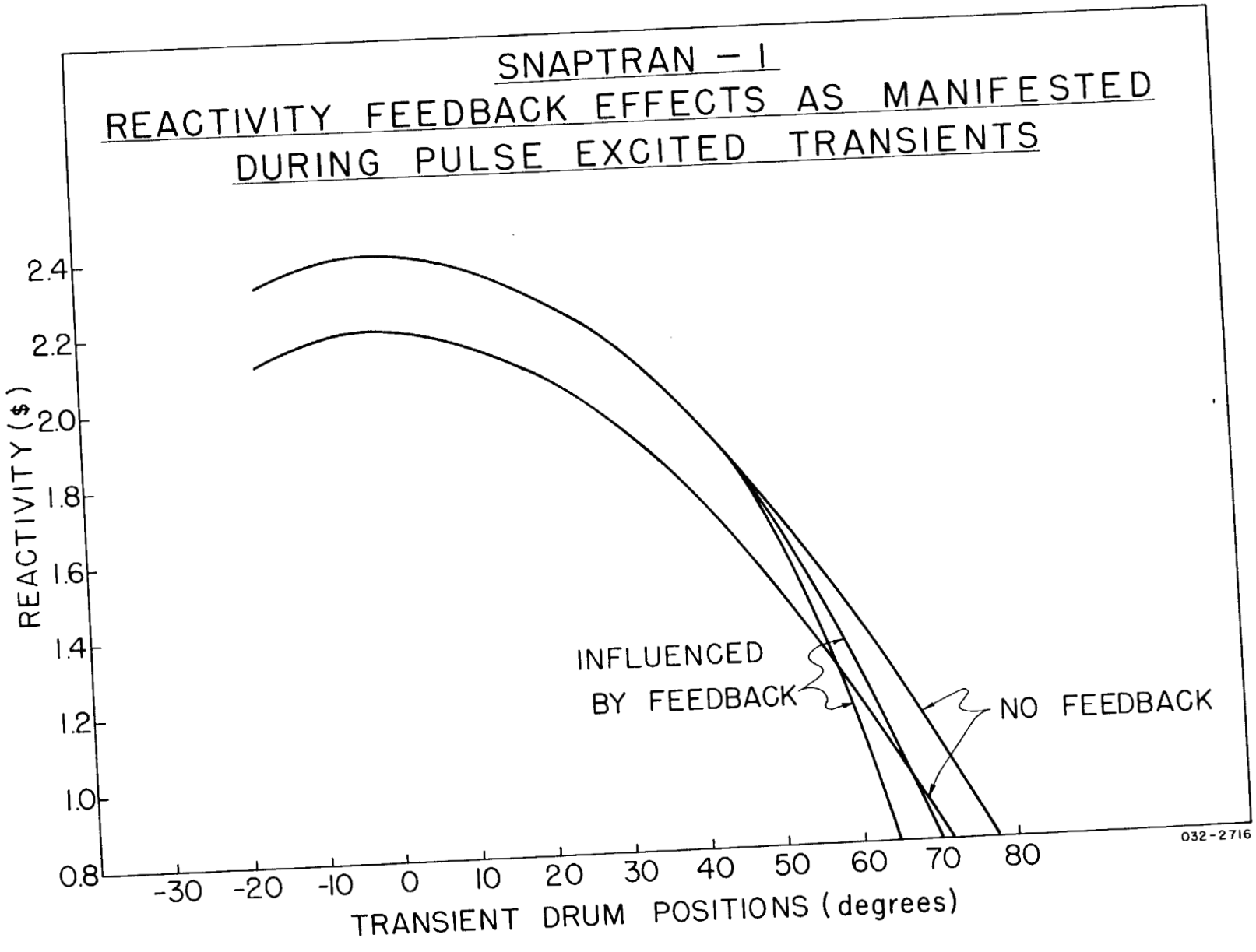
SNAPTRAN – I
REACTIVITY FEEDBACK EFFECTS AS MANIFESTED
DURING PULSE EXCITED TRANSIENTS
REACTIVITY ($)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
-30
-20
-10
0
10
20
30
40
50
60
70
80
TRANSIENT DRUM POSITIONS (degrees)
INFLUENCED
BY FEEDBACK
NO FEEDBACK
032-2716

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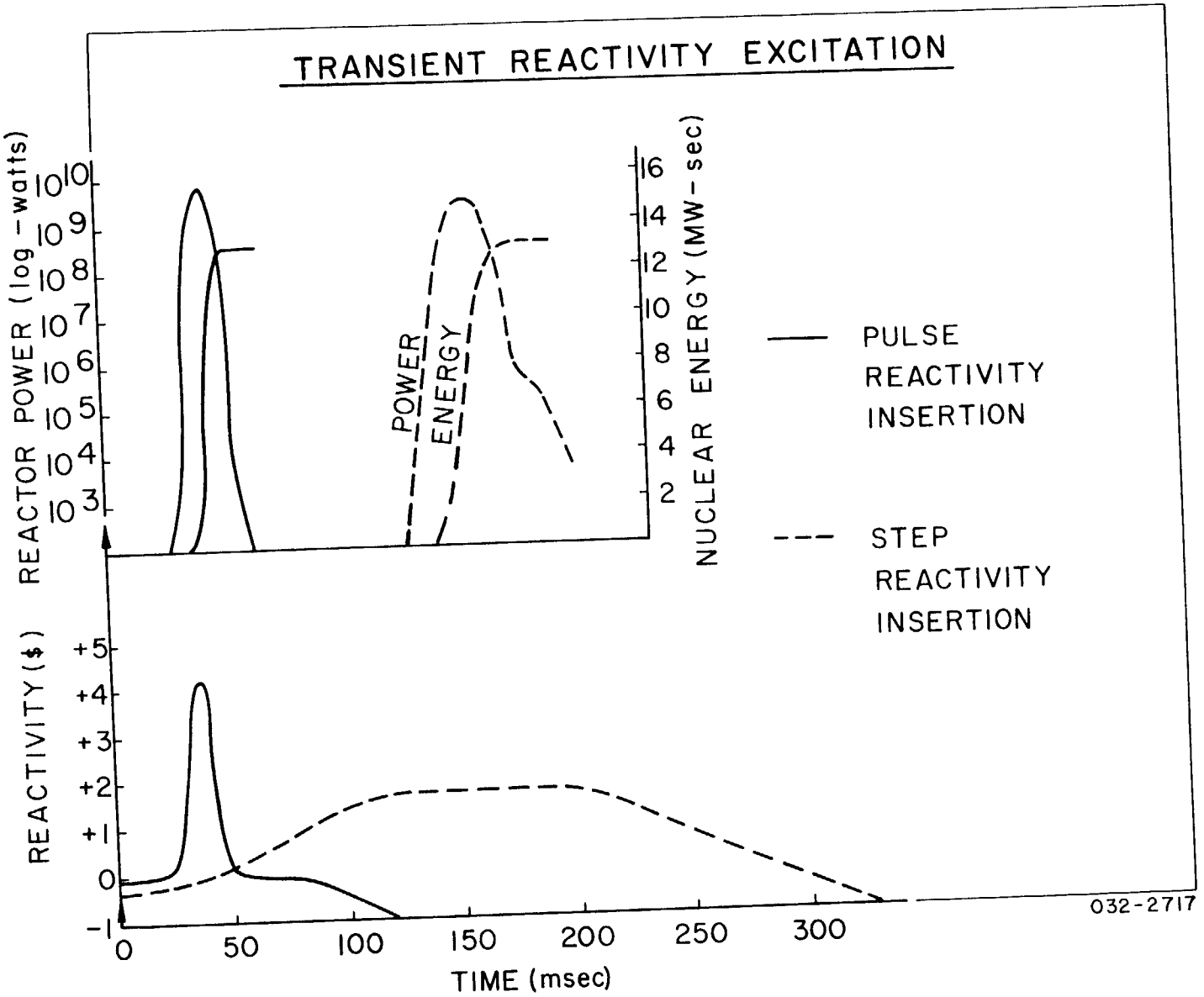
TRANSIENT REACTIVITY EXCITATION
REACTOR POWER (log-watts)
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
NUCLEAR ENERGY (MW-sec)
16
14
12
10
8
6
4
2
POWER
ENERGY
PULSE REACTIVITY INSERTION
STEP REACTIVITY INSERTION
REACTIVITY ($)
+5
+4
+3
+2
+1
0
-1
0
50
100
150
200
250
300
TIME (msec)
032-2717

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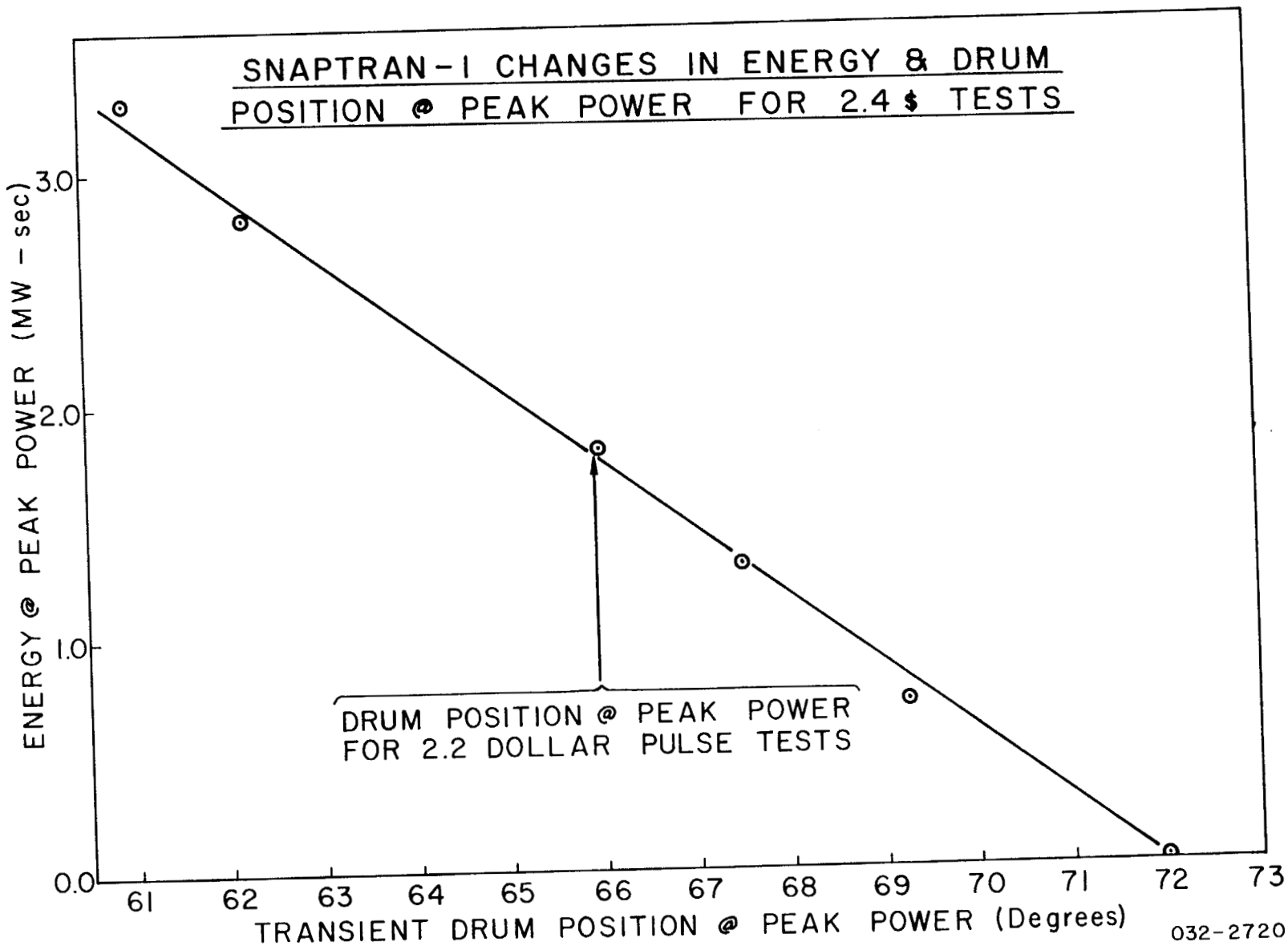
SNAPTRAN-1 CHANGES IN ENERGY & DRUM POSITION @ PEAK POWER FOR 2.4 $ TESTS
ENERGY @ PEAK POWER (MW - sec)
3.0
2.0
1.0
0.0
61
62
63
64
65
66
67
68
69
70
71
72
73
TRANSIENT DRUM POSITION @ PEAK POWER (Degrees)
DRUM POSITION @ PEAK POWER FOR 2.2 DOLLAR PULSE TESTS
032-2720

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